



Keynote Lecture



Pioneers and Founders of Coral Reef Studies in Japan and their International Cooperation

Kenji KONISHI

6-28-501, Tamagawacho, Kanazawa 920-0863, Japan

QWB02765@nifty.ne.jp

Coral reefs of Japan are developed on/around 3 active island arcs (Idzu-Ogasawara, SW Japan, and Ryukyu), 3 inactive remnant arcs (Daito, Okidaito and Kyushu-Palau), and 1 sea mount ridge (Marcus-Wake) in the subtropical NW Pacific. Except for the north, the borders of Japan are enacted with coral reef islands: Minami-tori (Marcus) on the east, Yonaguni on the west, and Okinotori (Parece Vela) on the south. Only Okinotori is located south of the tropic of Cancer.

The history of coral reef studies in Japan was influenced by her geopolitical situation in the NW Pacific. After the Meiji Restoration (1868), foreign scholars (e.g. Doederlein) were hired by the new government to catch-up and overtake western culture in academia. Their students, who studied abroad and succeeded them to become the first Japanese professors, produced the pioneers of coral reef biology; e.g. Okamura and Yendo in calcareous algae; Kinoshita in soft corals. Yoshiwara (Tokunaga) majoring in echinoids was converted to geology to study raised coral reefs in the Ryukyu

Islands (1901) and Taiwan, right after the Sino-Japan War. His collections of reef-forming fossils were sent to the overseas paleontologists for identification. Yabe broke new ground in describing Paleozoic corals, a subject elaborated beyond Japan by his first student, Hayasaka. Yabe also discovered the stromatoporoids in Late Mesozoic reefs.

In the wake of the World War I, foundation of the Pan-Pacific Science Congress facilitated the international cooperation to advance science of coral reefs in the Pacific. The League of Nations granted Japan the position to replace Germany, mandating the tropical islands north of the Equator: (Palau-Yap, Marshall-Gilbert, Caroline, and Mariana-except Guam-). In the final plenary session of the 3rd Pan-Pacific Science Congress held at Tokyo, a resolution (No. 7) to <institute the committee consisting of biologists, oceanographers and geologists to consider and draw up a plan for comprehensive investigation of the coral reefs of the Pacific Ocean>was passed. Notwithstanding the blow of world-wide economic depression, the 4th Pan-Pacific Congress was held at Batavia-Bandong, (immediately after the historic Low Isles Expedition led by Yonge), and the International Committee on the Coral Reefs of the Pacific, (that was chaired by Vaughn), became instrumental in building an international institute of marine biological science on the tropical Pacific. Hatai, the persuasive enthusiast for biology of coral reefs, was active in organizing a special committee in the Japanese Society for Promotion of Science, to invite such an institute at Palau, which was founded in the eve of 1933, the year of the 5th Pan-Pacific Science Congress at Vancouver.

Because so much is written about the Palau Tropical Marine Biological Station, it is only mentioned here that from 1932 to 1937 was the most productive period in coral reef research in Japan. Among numerous contributions, the symbolic one is confirmation of symbiotic dinoflagellates in the tissue of reef-forming corals by Kawaguti, the great grandfather of coral reef studies in Japan. Faunal analyses of reef-forming corals in Japan and the southern islands under the Japanese mandate were thoroughly carried out by Ma, Sugiyama and Eguchi under the supervision of Yabe. Additionally, deep drilling (1934 & 1936) at a raised atoll, Kitadaito, recovered cores of 431.67 m in the length, the deepest record at that time, that, though ambiguously, supported the Darwin's subsidence theory of atoll formation. Both geological and geomorphologic studies of the coral reefs in the southern islands and their surrounding ocean floors were comprehensively investigated by Tayama, which resulted in the classic bathymetric chart of the NW Pacific, a text to the post-war bloom of marine geoscience of the Pacific Basin. He proposed the fourth type of coral reefs, and named it "table reef". Pleistocene and Holocene raised reef complexes of the Ryukyu Islands were mapped by Hanzawa, who also examined biostratigraphy of reef-dwelling foraminifers in the Kitadaito cores.

Until Reversion of Okinawa (1972) after the end of the World War II, major parts of the Ryukyu Islands were under jurisdiction of U.S. Personnel of the U.S. Geological Survey achieved many excellent contributions on the reef geomorphology and geology, and, despite the title of military, their contents are academic. Ladd, Tracey, and others also of the U. S. Geological Survey drilled long cores at Bikini and Enewatak, and finally substantiated Darwin's subsidence hypothesis of atoll formation. It seems to be irony for coral reef scientists in Japan that the test of nuclear bombs similar to those dropped at Hiroshima and Nagasaki solved the long-standing problem of atoll formation coral reef scientists had struggled for or against at Funafuti, Michaelmas, Kitadaito and elsewhere for more than century.

Together with stable nuclides, radioactive isotope geochemistry has become the crucial "proxy" tool for dating, tracing water movements, estimating water temperature and chemistry and so forth.

Foundation of the University of the Ryukyus as well as similar ones (e.g. Yamagata, Kanazawa, Okayama, Kumamoto, Kagoshima) in 1950, which opened new departments and marine biological stations under the lead of experienced reef scientists, sprouted the post-war biological studies of coral reefs. Pre-war universities and their marine biological stations were also revived. International, though mostly bilateral, cooperative works resumed around 1960 to explore new targets in reef science with new insight, as earth science was at the dawn of plate tectonics, paleoclimatology and carbonate biogeochemistry, and molecular biology, new ecology and biogeography were emerging in the biological sciences. The International Coral Reef Symposia organized by Stoddart and his fellows, were initiated 35 years ago, and the second meeting was held on board the MARCO POLO cruising in the waters of the Great Barrier Reef province, a year after the Reversion of Okinawa.

Since then, coral reef studies have continued to rejuvenate steadily in the NW Pacific. Including more than 300 members of the Japanese Coral Reef Society, reef lovers in Japan are challenged by the current issues such as management (conservation and restoration) through research, and threats to reef ecosystems due to anthropogenic causes (coastal development, unchecked tourism, over-fishing, and others). With the help of international cooperation through ICRS/ISRS and ICRI, we hope that such problems can be overcome.

Biogeography, climate change and evolution of corals reefs

Terry P. HUGHES

Centre for Coral Reef Biodiversity, James Cook University, Townsville, QLD 4810, Australia.

terry.hughes@jcu.edu.au

Confronting the coral reef crises requires a major scaling-up of management efforts based on an improved understanding of the key ecological processes that underlie reef resilience. Managing for improved resilience, focusing on the role of human activity in shaping ecosystems, provides a basis for coping with climate change and uncertainty. Here I identify striking biogeographic differences in the species richness and composition of functional groups, which highlights the vulnerability of Caribbean reef ecosystems to phase-shifts from coral-dominance to less desirable states. Low diversity reefs, such as in the Caribbean Basin, the Eastern Pacific, and many high-latitude or remote locations in the Indo-Pacific have low functional redundancy, where functional groups may be represented by a single species. In these systems, minor changes in biodiversity can have a major impact on ecosystem processes. Although hotspots (areas of exceptional species richness) are one of the most frequently identified targets for the protection of marine ecosystems, “cool spots” (areas of low species richness) are arguably more vulnerable. Dispersal of larvae is a critical issue for understanding the response of coral reefs to climate change, yet current knowledge of this issue is minimal. The scale of reef decline indicates that even where local conditions for coral settlement get better (e.g. due to reduced overfishing of herbivores, improved water-quality, or a partial recovery of *Diadema antillarum*), it can no longer be assumed that recruitment will simply resume exactly as before. New studies show that the isolation and impoverished genetic diversity of oceanic reefs renders them particularly vulnerable. These findings have profound implications for restoration of degraded reefs, management of reefs and fisheries, and the focus on biodiversity hotspots as priorities for conservation.

Reef provinces and refugia: expansions, contractions and shocks to coral reefs throughout Quaternary climatic cycles

John CHAPPELL

Res School of Earth Science, Australian Natl Univ, Mills Rd, Canberra, ACT 0200, Australia

u6700013@adelong.anu.edu.au

Large shifts of climate and sea level occurred repeatedly through the last few million years. Regulated by slow variations of the earth's orbit, ice sheets advanced and retreated across the northern continents at time scales of tens to hundreds of thousands of years. Sea level has a fundamental influence on coral reef distribution and structure. Ice-age sea levels were up to 130 metres lower: during each ice advance, atolls became narrow fringing reefs and corals in shelf provinces such as Australia's Great Barrier Reef retreated to shelf-margin refugia. Every 100,000 years or so, during interglacial high sea levels, reefs built structures similar to those of today, at their present locations. These intervals were relatively short. Moreover, during each glacial cycle, sea level fluctuated dramatically, sometimes cycling up and down by 10-20 metres in a few thousand years. Tropical and sub-tropical climates changed in concert with these sea level changes, with interglacial-glacial shifts of sea surface temperature by up to several degrees.

These events forced corals to repeatedly migrate from shelf areas of high environmental diversity to topographically restricted habitats, with little species loss and no apparent change in their capacity to build coral-dominated reef framework. However, comparisons with a series of recent case studies, reviewed here, show that human impacts on the boundary factors of reef systems are different from those of their long, pulsating history, and that estimates of reef resilience based on the past are not an adequate guide for predicting the future of coral reefs.

Importance of Cyanobacteria in Coral Reef: Paleo (Stromatolites), Benthic (Microbialites) and Planktonic (*Trichodesmium* and other) with a special focus on Calcification and Nitrogen Cycle

Loic CHARPY

COM, rue de la batterie des Lions, 13007 Marseille, France

lcharpy@com.univ-mrs.fr

Cyanobacteria dominated marine environments during early geological history and were the only reef builders on Earth for more than three billion years. Thus although cyanobacteria have been supplanted on modern coral reefs by eukaryotic algae, they still play an essential role in their ecology. Cyanobacteria form a major component of the epilithic algal community and the benthic microalgae of soft bottom sediments and many cyanobacteria were found on the fish grazed plates. Furthermore, cyanobacteria are important in calcification and decalcification. Beach rock seems to be a notable example of such activities as well as the carbonate precipitation inside modern stromatolites. All limestone surfaces have a layer of boring algae in which cyanobacteria often play a dominant role. Cyanobacterial symbioses are abundant in coral reefs. The most common hosts are sponges and ascidians. However, their greatest role in the benthic communities is nitrogen fixation. In deep lagoons coccoid cyanobacteria are very abundant and their high production is grazed by ciliates and heteroflagellates, but also by benthic coral reef community. Recently, new unicellular cyanobacteria that are expressing nitrogenase were found in the open ocean and in coral reef lagoon. They are abundant enough to potentially have a significant role in N dynamics. *Trichodesmium*, a filamentous nitrogen fixing cyanobacteria can form very large blooms in the world tropical oceans and are a common feature in coral reefs waters. In addition, planktonic diatoms may contain the heterocystous, N₂-fixing cyanobacterial endosymbiont *Richelia intracellularis*. The importance of N₂ fixation is probably actually largely underestimated in coral reef. In the future, we can expect an increase of N₂ fixation in coral reef ecosystems as it has been observed in the Pacific Ocean where relative importance of N₂ vs. NO₃ as a source of new N has increased since 1995, probably due to global anthropogenic and climatic changes.

Priority Issues in Coral Reef Management: Key Outcomes of the Second International Tropical Marine Ecosystems Management Symposium (ITMEMS2)

Richard KENCHINGTON

Centre for Maritime Policy University of Wollongong NSW 2522, Australia

richard.kenchington@netspeed.com.au

The International Coral Reef Initiative (ICRI) established the quadrennial International Tropical Marine Environment Management Symposia (ITMEMS) to provide structured opportunities for managers to discuss the issues, priorities and lessons learned from management. The concept was that these should alternate with International Coral Reef Symposia (ICRS) so that there is a major coral reef symposium every second year but with different emphases to reflect the growing and different needs of science and management.

The practice of plenary reports has now been established as a means of reporting between the science and management symposia. Dr Terry Done reported to ITMEMS2 on key outcomes from ICRS9. This paper is the first plenary report from ITMEMS to ICRS.

ITMEMS2 was held in Manila, Philippines in March 2003. The Proceedings will have been published and will be available on ReefBase by April 2004. ITMEMS2 consisted of 20 workshops that considered priority issues or problems of management identified early in the Symposium planning process through a questionnaire to managers from all coral reef regions of the world. Each workshop considered reports or case studies designed to identify lessons learned from experience and to develop conclusions and recommendations for improvement of management effectiveness.

The paper provides an overview of ITMEMS2 and briefly discusses some of the outcomes of workshops addressing resource management, protected area strategies, monitoring, targeted research, performance evaluation, dissemination and accessibility of information for coastal and marine management. Issues that will be highlighted include the role of protected areas, mitigating the effects of bleaching, achieving sustainable fisheries and the roles and cost-effectiveness of habitat restoration protocols.

**Towards integrated coral reef science: A new challenge for conservation
and restoration of coral reefs**

Makoto TSUCHIYA

Faculty of Science, University of the Ryukyus, Nishihara, Okinawa 903-0213, Japan
tsuchiya@sci.u-ryukyu.ac.jp

For the conservation of beautiful coral reef ecosystems, it is absolutely true that sentimental discussions are no longer valid and that we need strong scientific and theoretical information to contribute to planning, implementation and evaluation of management. Important points for this discussion are; 1) Recognition of the ecosystem functions and resilience of coral reefs and their scientific backgrounds, 2) Biodiversity at scales from genetic, to species to ecosystem, 3) Ecological modeling considering the population size and resource capacity of a range of species characteristic of the ecosystem as a key input to design of management of coral reefs and the roles of MPAs within ecosystem management, 4) Environmental education for children, 5) Development of interdisciplinary science including natural and social sciences, and 6) Combined discussion for the management of forest, river and coral reef ecosystems.

All the topics described above are closely related each other and, here, I will propose several ideas for making clear their scientific importance and necessity of the comprehensive discussion among fishermen, people working on tourism, administrative officials, researchers and so on. Moreover, realistic, practical measurable and objectives and implementation costs for habitat and ecosystem restoration should be established, e.g. establishment of beautiful coral reefs in which big fishes are swimming among dense coral communities. In order to achieve the purpose, accumulation of scientific knowledge on carrying capacity or levels of sustainably acceptable impact of a reef for tourists and fisheries, medium and long-term biogeochemical cycles in reefs, linkages with other areas and habitats, ecological niche of key species for maintaining healthy reef dynamics are required. The effect of aquaculture on reef ecosystems should be discussed in cooperation with fishermen's understanding of these points

This paper also stresses the restoration of ecosystem function as an indicator of coral reef's rehabilitation.

The Diversity and Extent of Planet Earth's Modern Coral Reefs as View from Space

Serge ANDRÉFOUËT

University of South Florida, USA, and Institut de Recherche pour le Développement, New Caledonia
andrefou@noumea.ird.nc

Remote sensing of planet Earth, using both airplanes and satellites, has permitted numerous synoptic observations of coral reefs and their environment since the 1980s. Today, the oceanic and atmospheric environment of coral reefs is now routinely monitored at global scales. However, there weren't any consistent systematic global observations of the reefs themselves until the late 1990s. In 1999, the Landsat 7 mission established a new system for scheduling acquisitions which eventually made possible to assemble and process a database of images covering virtually all the reefs in the world. The Institute for Marine Remote Sensing at the University of South Florida has processed this database under the framework of the "Millenium Coral Reef Mapping Project." This communication presents the first outputs of this project. Included is a description of the entire continuum of reef geomorphological structures existing on the planet, and an explanation of the classification scheme used to establish consistent products worldwide for a variety of applications. Initially, fundamental scientific questions were targeted, such as reef evolution or influence of climate on reef growth patterns, but the products also appeared to be useful for regional planning and management. Detailed results for specific reef regions (e.g. Great Barrier Reef), and for main structures (e.g. atolls or barrier reefs), are presented. Specific applications are also discussed, such as exploratory genetic classification schemes, or investigation of biodiversity patterns. Additionally, although these products are image-based remotely sensed observations, integration with in situ techniques (e.g. geological coring or benthic surveys) will be discussed in the hope of strengthening the connections between traditional field work and remote sensing work in the next decade. Finally, conclusions will address the lessons learned from this project for future high resolution space-missions and prospective outputs beyond the current Millenium geomorphological products.

Coral taxonomy, biogeography and evolution: a tortuous pathway*J.E.N. VERON*

Australian Institute of Marine Science PMB 3, Townsville 4810, Australia

jveron@aims.gov.au

Systematics, taxonomy and identification are very different subjects, requiring different data and interpretations. Systematics is linked to the non-observable genetic organisation of life. Taxonomy is linked to observation and therefore underpins identification. Species in corals, along with most other forms of life, are human-created units which vary continuously in both space and time. Colonial corals also vary greatly with environment. Inevitably, coral systematics, taxonomy and identification are complex subjects and made all the more so if combined with each-other or when used in conjunction with other disciplines, notably biogeography and palaeontology.

Corals have been a central interest to marine taxonomists and biogeographers since the early twentieth century. However, until the advent of scuba diving, coral taxonomy was not closely linked to the realities of the reef. It was also regionally based, so that the taxonomy developed in one country was not generally applicable to the corals of another. For this reason, coral biogeography lagged well behind taxonomy and remained at generic level until recent times. This has now changed, largely because GIS technology has opened the gate for species-level biogeography just as scuba diving opened the gate for species-level taxonomy. Now, information technology provides pathways to the future by accommodating all the complexities of environmental and geographic variation for both taxonomy and biogeography.

These advances have only distantly been applied to palaeontology. Reconstruction of the Family Tree(s) of Scleractinia appears to be on the verge of rapid development, mostly through the application of molecular, computer and other technologies.

Evolutionary pathways at species level are not visible in the fossil record, nor can they be seen in any taxonomy that is based in a single geographic region. However, detailed taxonomic study in many regions has revealed the full extent of geographic variation, not only within species, but within species groups. These observations have led to the concept of reticulate evolution, a subject still in its infancy but one that greatly affects biological knowledge of all taxa, especially marine invertebrates.

The predicted onset of global warming on top of the deterioration of most of the world's reefs through human impact is now what matters most. The effective contribution of science to the future has limitations, foremost of which is information transfer to end-users. The combination of *Coral ID* and *Coral Geographic* are intended to address this need, specifically by making very large amounts of information readily available to specialists and non-specialists alike.



Oral Session
June 28 (Mon)



Macroalgal Blooms as Bioindicators of Anthropogenic Nutrient Enrichment on Coral Reefs near Green Turtle Cay, Bahamas: Taxonomic, Morphometric, Biochemical, and Physiological Evidence

*Peter J BARILE**, *Brian E LAPOINTE*

5600 US 1, Ft. Pierce, FL 34946 United States of America
pbarile@hboi.edu

Excessive macroalgal biomass has been identified as an indicator of change on human-dominated coral reefs throughout their distribution. Here we report on the spatial and temporal trends of several metrics of macroalgal communities along gradients of land-based sources of nutrients from watersheds adjacent to Green Turtle Cay, Abacos, Bahamas. At four sites along this gradient we measured community taxonomic composition and morphometrics, tissue nutrient ratios (C:N:P), stable nitrogen isotope ratios, productivity rates and alkaline phosphatase activity (APA). Inshore sites supported an elevated biomass of non-calcifying chlorophytes and higher productivity rates and stable nitrogen isotope values, with lower APA and tissue nutrient ratios. In contrast, at oligotrophic offshore sites macroalgal communities were dominated by a higher biomass of calcifiers and chemically-defended phaeophytes, with higher APA and tissue nutrient ratios, and lower productivity rates and stable nitrogen isotope ratios. Macroalgae at more remote locations showed biochemical and physiological characteristics of nutrient limited production, and diluted utilization of land-based nutrient sources. We believe that these distinct macroalgal communities and their inherent taxonomic, morphometric, biochemical, and physiological indices are reliable indicators of anthropogenic nutrient pollution that accompany coral decline and bioerosion in stressed reef systems.

Cnidarian-associated Community as Bioindicator of Anthropogenic Disturbance on Reef Environments

*Carlos D PEREZ**, *Daniele A VILA-NOVA*, *Andre M M SANTOS*, *Bruno G T SILVA*, *Barbara MOURA*

Av. Prof. Moraes Rego 1235, Cidade Universitaria, CEP: 50670-420
 Federative Republic of Brazil
gpa@ufpe.br

An environmental indicator is defined as one species which performs the biotical or abiotical conditions from a specific environment. However, if it is possible to have a group of organisms rather than only one, you would be able to evaluate more ecological parameters. This project evaluates the possible indirect uses of cnidarians through their associated community study. This community could be used as a microphotograph of the reef status, and represent its habitat conditions. Two colonial cnidarians were studied on the reefs of Pernambuco, Brazil: the zoanthid *Palythoa caribaeorum* and the octocoral *Carijoa riisei*. These species were chosen because their architecture offer different micro-environments to the symbiotic organisms. For this study, two beaches were selected: Porto de Galinhas, which presents a great human pressure, and Guadalupe, which has less tourism impact. The human pressure was quantified through numbers of reef walkers, rafts and tourists per raft. Seasonal collections (dry and rainy seasons) throughout two years were made. A greater richness, abundance, diversity and evenness was found at Guadalupe. Porto de Galinhas presented a greater seasonal difference while Guadalupe was more constant throughout the year. Dry season is characterized by an higher number of tourism at Porto de Galinhas and coincidentally the associated community was the poorest among the ecological parameters. These beaches are subjected to the same abiotical factors, which does not explain the differences between them and indicates the presence of an external factor that could be making this difference. This study suggests that the human impact during the dry season on the reefs of Porto de Galinhas could be this factor, that is affecting the environment and indirectly the associated community. In the future, it is necessary to establish a direct relation among the anthropogenic disturbances and the ecological parameters of these cnidarians-associated community.

Distribution of N-Alkane in Reef Sediment as the Signal of Run-off Loading to Coral Reef

*Yutaka TATEDA**, *Nao MUKAE*, *Mitsunori OHNO*, *Kenji IWAO*, *Kazuyuki SHIMOIKE*, *Hiroki TANIGUCHI*

1646 Abiko Chiba Japan
tateda@criepi.denken.or.jp

Normal alkanes from C₁₂ to C₃₆ were identified in the coral reef sediments of Aka island and Miyako island, Okinawa, Japan. These natural organic compounds in reef sediments were categorized to marine originated *n*-alkanes (C₁₅ to C₁₇; coral/plankton origin) and to terrestrial originated *n*-alkanes (C₂₇ to C₃₁; land vegetation origin). Some *n*-alkanes of intermediate numbers were likely to be originated from algae and *Zostera* in reef lagoon. The longer chain *n*-alkanes detected in reef sediments at reef lagoon of Aka island and Miyako island were estimated to reflect substantial input of terrestrial *n*-alkanes by eventual run-off to these areas in coral reefs. The result indicated that terrestrial *n*-alkanes concentrations with ratio to marine *n*-alkanes are regarded as a good signal to estimate run-off event memory to coral reefs, suggesting its usefulness for predicting possible land-derived stress to reef area in future land use.

Histopathological Indices as Indicators for Sedimentation Stress on Scleractinian Corals

*Bernardo VARGAS-ANGEL**, *Heather A HALTER*, *Erin C HODEL*

8000 N Ocean Drive, Dania Beach, Florida United States of America
vargasb@nova.edu

Aimed at developing a provisional tissue stress index to assess coral tissue responses to increased sedimentation, colonies of *Montastrea cavernosa*, *Solenastrea bournoni*, and *Siderastrea siderea* were exposed to heavy loads of sediments in laboratory conditions. Experimental specimens were sanded at a rate of approx. 1.4 g cm⁻², once per day, during a five-week period. Experimental effects were histologically assessed based on the relative condition/integrity of tissues and selected cellular elements, including: epidermis, gastrodermis, mucous secretory cells, amount and color of mucoid secretions, zooxanthellae, and nuclei. Two histological stains were used to evaluate tissue condition and damage: Movat's Modified Pentachrome and Harris Hematoxylin. Slight adverse effects were noted as early as week one for all species; these included swelling of the outer epidermis, changes in size and appearance of mucous secretory cells, and color of mucus secretions. In weeks 2 and 3, sanded corals exhibited mild to moderate atrophy of the outer epidermis, and further inflammation of mucous secretory cells. Changes in zooxanthella densities and staining properties were evident at this time in sanded specimens for all species. Several of the above symptoms were also present in some control colonies, probably due to tank effects. Severe to acute effects were noted in weeks 4 and 5, including increased debris in gastrodermal cells of the lower polyp region, advanced atrophy of epidermis and mesenteries, and tissue erosion and necrosis; albeit some colonies of *S. siderea* developed liquefactive necrosis as early as week 3. Interestingly, gametogenesis progressed throughout the duration of the experiment, and mature spermaries were observed in week 4, for both sediment-exposed and control corals. Our results indicate that histopathological techniques are successful in detecting subtle tissue changes in moderately to severely stressed corals. Thus, the use of these indices offers potential application for coral reef health assessment and monitoring.

Effects of Suspended Red Solids on Stress in the Nile Tilapia *Oreochromis niloticus*

*Miriam DOMINGUEZ**, Makoto TSUCHIYA, Akihiro TAKEMURA

Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, 3422 Sesoko, Motobu, Okinawa 905-0227, Japan.
miriamquis@hotmail.com

Approximately 55% of the total land area of Okinawa, southern Japan, is covered with red soils, which are discharged into rivers and carried to the coastal areas during a rainfall. It is believed that the red soils suspended in water cause severe damages to aquatic organisms. However, few studies have been conducted exactly how the red soils affect aquatic organisms. The present study addressed questions of effects of suspended red soils on stress and immune related parameters in the blood circulation of tilapia, *Oreochromis niloticus*. When the fish were exposed to suspended red soils at concentrations of 20, 200 and 2000 mg/ml for 6, 24, 48 and 144 h, plasma levels of cortisol and glucose did not change at concentrations of 20 and 200 mg/ml. However, these parameters increased significantly from 6 to 48 h, when the fish were exposed to the highest concentration of the suspended red soils. No changes in plasma levels of lysozyme and immunoglobulin occurred during the experiment period. The results suggest that the suspended red soil during a heavy rainfall becomes an acute stressor against organisms inhabiting rivers and coastal areas.

Three-isotopic Composition of the Dissolved Oxygen in the Coral Reef

*Osamu ABE**, Sarma VVSS, Hiroya YAMANO, Atsushi WATANABE, Naohiro YOSHIDA, Toshiro SAINO

Hydrospheric Atmospheric Research Center, Nagoya University, 464-8601, Nagoya, Japan
oabe@ihas.nagoya-u.ac.jp

To estimate gross productivity at coastal aquatic ecosystem, diurnal variations in three-isotopic composition of the dissolved oxygen were determined in Kabira Reef, Japan. Kabira Reef is a well-developed fringing reef located on the western coast of Ishigaki Island, southwest of Japan, and has a characteristic current pattern, when north to northeast winds prevail, East China Sea water enter over the reef crest and leave through a prominent channel. Therefore, the influence of the metabolic activity with respect to primary production and respiration over the entire reef can be quantified by monitoring water property at offshore and prominent channel as initial and final values respectively. Water samples for three-isotopic compositions were collected at every 2-hour interval at the point close to the prominent channel from March 6 to March 8, 2003. Hydrographic (water temperature, salinity, dissolved oxygen concentration, tide) and meteorological (wind, air temperature, air pressure, solar radiation) parameters were monitored continuously throughout study periods. Two water samples were collected from offshore during study periods. Electromagnetic current meters were set at three locations in the reef and measured at every 5 minutes to determine residence time of reef water. Both O-18/O-16 and O-17/O-16 were decreased during daytime due to production of oxygen and they are equal to isotopic composition of seawater. During nighttime, both isotopic compositions were increased due to respiratory isotope fractionation. O-17 anomaly, which reflects both gross productivity and gas exchange between atmosphere and ocean, show a cyclic variation in accordance with tidal change.

Invertebrates, Communities, and Reef Health in Airai, Palau

*Ann KITALONG**

Box 1696, Koror, Palau 96940 Republic of Palau
kitalong@palaunet.com

An invertebrate survey was conducted in Airai, the Republic of Palau, through assistance from the Marine Resources Pacific Consortium-Palau. The goal of this study was to promote sustainable use of coastal resources through capacity building and community participation. The objectives were to train young community members on simple survey techniques, obtain baseline data on key invertebrates and provide resource management recommendations. Two community members and The Environment Inc. team surveyed 4 to 8 sites of known "hot spots" for targeted species, covering an area of 6,000-m² to 12,000-m² for each species. Selected species were weighed to the nearest 0.1 kg. A total area of 24,500-m² was surveyed. Estimated total habitat areas were derived using Arcview. Densities and estimated standing stock in numbers or tonnage were as follows: *Stichopus variegatus*: 0.18/m², 44-mt. *Tridacna crocea* and *T. maxima*: 0.057/m²; 607,000 embedded clams; *Lambis lambis*: 0.0026/m², 5.8-mt; *Actinopyga miliaris*: 0.014/m², 2.3-mt; *Holothuria scabra*: 0.004/m², 0.64-mt. *Hippopus hippopus*: 0.0017/m², 22,706 clams. *Tripneustes gratilla*: 0.001/m², 0.2-mt. *Stichopus variegatus* and embedded clams were common at several sites. Eight invertebrates targeted for this survey were not found. Overall, invertebrates numbers were low and not found at several or all previously known hot spots. Less accessible and healthy areas tended to have more invertebrates. Fisherfolk attributed over harvesting and pollution to low invertebrates numbers at previously known "hot spots." The team recommended to develop and implement an Airai Management Plan for key marine resources and their habitats that included: community participation and awareness; annual monitoring; employment of two conservation officers; set asides for critical habitat as part of the nation-wide protected areas network; harvesting regulations, and to stop sources of pollution.

Distribution and Abundance of Giant Sea Anemones in the Ryukyu Archipelago, Japan

*Michael ARVEDLUND**, Kenji IWAO, Akihiro TAKEMURA, Tyge D HERMANSEN

Sesoko 3422, Motobu, Okinawa 905-0227, Japan
michaelarvedlund@hotmail.com

Of the ten giant host sea anemone species of the three different families: The Actiniidae, the Stichodactylidae, and the Thalassianthidae, hosts worldwide to 28 species of anemonefishes (family: Pomacentridae), at least six have been observed in the coastal waters in the Ryukyu Archipelago, Japan. These are *Entacmaea quadricolor*, *Heteractis crista*, *H. magnifica*, *H. aurora*, *Stichodactyla gigantea* and *S. mertensii*. However, most studies of the abundance and distribution of these symbiotic sea anemones in this region have been conducted on the reefs of Sesoko Island, Okinawa (Lat. 26.640 Long. 127.867) only. We examined the distribution and abundance at three shallow southeastern sheltered reef sites of Akajima Island, in the Kerama Islands (Lat. 26.180 Long. 127.283), about 40 km west of southern Okinawa, and three similar sites of Sesoko Island. We found a significant difference in the abundance and distribution of the giant sea anemones between coral reefs of these two islands. In Sesoko, only three host anemone species were observed: *H. aurora*, *E. quadricolor* and *S. gigantea*, in relatively low abundance, contrary to Akajima. In Akajima, all six host anemone species, which has been observed in the past in the Ryukyu Archipelago, were observed. We discuss possible biotic, abiotic and anthropogenic factors contributing to this difference and the likely value of including these relatively easy identifiable fish symbiotic actinarians in future surveys of coral reefs, for the use as a potential bioindicator of the general condition of a coral reef.

A Preliminary Assessment of the Abundance and Distribution of *Acanthaster planci* in the Remote US Pacific Islands from Towed-diver Surveys

*Molly A TIMMERS**, *Stehani R HOLZWARTH*, *Russell E BRAINARD*

1125B Ala Moana Blvd, Honolulu, HI 96814 United States of America

molly.timmers@noaa.gov

The Coral Reef Ecosystem Division of NOAA Fisheries Pacific Islands Fisheries Science Center has conducted ecosystem-based research at all of the remote U.S. Pacific Islands, except Wake Island. Survey regions include the Northwestern Hawaiian Islands, Guam and the Commonwealth of the Northern Mariana Islands, American Samoa, and the U.S. Pacific Remote Island Areas (Johnston, Palmyra, and Kingman Atolls, and Howland, Baker, and Jarvis Islands). Abundance and distribution of crown-of-thorns starfish, *Acanthaster planci*, were assessed within these regions using benthic towed-diver surveys. Divers were towed behind a small boat on a 60-m line at depths ranging from 1 to 30 m. All visible *A. planci* were recorded in addition to habitat type, benthic substrate, temperature, and depth along transects which were approximately 2 km long. Each tow was georeferenced, providing a way to link *A. planci* abundance and distribution to localized areas and habitats. The ability to use towed-diver surveys to record *A. planci* over large spatial areas is an effective technique to assess population levels and identify areas of potential concern. As an example of the utility of these surveys, high levels of *A. planci* were observed around Kingman Atoll in 2002 but not in 2001. Repeated surveys provide a valuable means for temporal and spatial monitoring of *A. planci* and evaluating their impacts on benthic community structure in remote U.S. Pacific Islands.

Risk Assessment of Oil and Gas Operations in Abrolhos, the Largest South Atlantic Reef Complex

*Guilherme F DUTRA**, *Gabriel B MARCHIORO*, *Marcelo A NUNES*, *Paulo G P PEREIRA*, *Rodrigo L MOURA*

Rua das Palmeiras, 451 Caravelas BA 45900-000 BRAZIL

g.dutra@conservation.org.br

Southwestern Atlantic reefs are priority areas for biodiversity conservation due to their small size, significant endemism, and high rates of habitat loss. Abrolhos (56,000km²) represents the largest coral reef and the most biodiverse area in the South Atlantic, with about 9% of its area within MPAs. With the exception of MPAs, oil operations at sea were not subjected to environmental licensing till the late 1990's. Only recently (1999) the Federal Environmental Agency improved the standards for oil operations at sea, but its main phases (seismic, perforation and production) remain to be integrated in terms of licensing. Despite this incipient system of licensing and monitoring, offshore development represents 84% of the National production. In 2003, a major portion of Abrolhos was offered in an international auction for concessions. In order to contribute with the development of standards and to evaluate allocation of blocks in sensible areas, Conservation International Brasil and partners developed an impact assessment. GIS tools were used to integrate all phases of oil operations and consolidate a marine biodiversity database compiled by the Brazilian Government, resulting in matrices of sensibility for each coastal and marine ecosystem to oil operations. The baseline study was reviewed during a workshop with National experts, resulting in great public awareness and an exclusion proposal for 243 blocks located among coral reefs, calcareous algae beds, seagrasses, and mangroves. This initiative motivated the Brazilian Government to exclude 162 blocks, and a legal charge resulted in the exclusion of additional 81 blocks. The complex ecological, social and economic implications of oil development near coral reefs still need major attention from governments, environmentalists, scientists and the private sector. While technologies to minimize impacts of oil production near coral reefs remain tentative, the exclusion of the most fragile areas is a sensate and economic alternative for several areas.

The Search for Integrated Coastal Management Sustainability: Results from a Multidisciplinary Examination in the Philippines and Indonesia

*Patrick CHRISTIE, Richard POLLNAC, Robert POMEROY, Kem LOWRY**
3707 Brooklyn Avenue NE, Seattle, WA, 98105-6715, USA
patrickc@u.washington.edu

Integrated coastal management (ICM) is the center of considerable attention from government, non-government and donor agencies. At least hundreds of millions of dollars are spent annually on ICM in the tropics. However, few ICM planning processes are continued after external financial and technical support is terminated. A three-year research project has been investigating, from a multidisciplinary perspective, the factors influencing the sustainability of ICM activities in the Philippines and Indonesia after formal project termination. This presentation will give an overview of the project's research design and findings. Research in nine sites has demonstrated that economic incentives, institutional design, legal frameworks, and social equity are important issues influencing ICM sustainability.

Coastal Management in the Philippines: Lessons of 20 Years

Alan T WHITE, William JATULAN*

5th Floor, CIFIC Tower, North Area, Cebu City, Republic of the Philippines
awhite@mozcom.com

The Philippines has one of the richest experiences of integrated coastal management (ICM) of any country in the world beginning in the late 1970s. Yet, its coastal areas and resources are still beset with ever increasing degradation and destruction given the context of high population growth, poverty and the increasing demand for food from the sea. In spite of the problems, many lessons and successes are evident that offer much hope for coastal management in the country. Emerging trends are realigning the requirements for national institutional and policy frameworks in support of coastal management. The first is that ICM is replacing the emphasis on fisheries development and narrowly based habitat management of past projects thus emphasizing the need for improved integration and collaboration. A second trend is that local government units are assuming more responsibility for and allocating resources to manage municipal waters and coastal resources compared to their past dependence on national government. Thus, national agencies are redefining their roles to provide technical assistance to local government as opposed to taking the lead in resources management. This trend also means that the assisting organizations such as universities, non-government organizations, and donors must work effectively with local government. Finally, multi-sector collaboration is becoming essential to solve the complex and deeply embedded coastal resource management problems that exist because of population, poverty, scarce resources and a lack of accessible alternatives. Economic development will need to become more sensitive about how to employ people to enhance natural resources and reduce pollution.

Initiating Integrated Coastal Management in Fiji

*Bill AALBERSBERG, Batiri THAMAN**

Director, Institute of Applied Science, University of the South Pacific, Suva, FIJI
aalbersberg@usp.ac.fj, thaman_b@usp.ac.fj

Fiji, like most Pacific Island nations, has a local tenurial control system embedded in the cultural tradition of its indigenous people. This provides both opportunities and challenges for the implementation of integrated coastal management (ICM). In this situation approaches that depend mainly on national-level efforts such as development of coastal commissions or departments may not be effective. Experience in Fiji has shown that a participatory approach which works with communities and districts that control inshore fishing rights to help them develop, implement and monitor marine resource management plans is very effective in addressing many coastal issues at a local level. We suggest that for the Pacific Islands having this locally-managed marine area approach as a basis for ICM is optimal. In Fiji the ICM program has developed by: 1) initial meetings with key national figures, 2) a national workshop to endorse ICM and agree to a pilot region which exemplifies conflicts in resource use in Fiji, 3) work with the communities in this area to develop localised coastal management plans, 4) involvement of all stakeholders in the area (private sector, communities, government departments, NGOs) to develop a joint coastal management plan, 5) implementation of this plan and meetings every two months by a local steering committee to review progress and identify areas in which national input is needed, 6) meetings by a parallel national committee in alternate months to discuss issues raised at the local level and national policy changes that may be required. (This group often also clarifies policies that the local group is not clear about), 7) an annual meeting of leaders of relevant government departments to discuss lessons learned from the project. This approach seems to be working well and helps assure that the need for ICM grows naturally from actual practical needs of coastal dwellers.

A Blueprint for Maximizing Sustainable Benefits of Coral Resources: The American Samoa Case Study

James P G SPURGEON, Toby ROXBURGH*

Jacobs House, London Road, Reading, RG6 1BL United Kingdom of Great Britain and Northern Ireland
james.spurgeon@jacobs.com

The true environmental, social and economic values of global coral reefs are rarely fully appreciated nor managed appropriately in a sustainable and equitable manner. There is often insufficient funding available, inadequate and ineffective management, and the wrong incentives in place. These factors contribute significantly to the ongoing degradation of coral resources worldwide. What is needed is readily available, simple and fully integrated guidance to help unlock the full value of corals and to facilitate more effective and sustainable management. Such guidance must be multi-disciplinary with appropriate outputs targeted at all levels, from the general public through to government decision makers. This paper outlines some steps currently being made to do exactly this. We are currently initiating a study to develop a framework, set of principles and methodology to assist with maximization of sustainable coastal resource benefits, capture of monetary values and optimization of management costs. The approach will be applicable for both marine protected area management and coastal zone management. Initially, the study focuses on the islands of American Samoa as a case study. This is the main emphasis of this paper. Here the Government has taken the bold step of pursuing coastal zone management based on first understanding the full range of existing and potential coastal resource values. Such values relate to fisheries, cultural values, tourism, ecological services and coastal protection etc. Results of the valuation exercise will be provided. The overall study will complement existing guidelines and integrate latest research and principles from disciplines such as: ecology, environmental economics, sociology, philosophy, law, operations management, marketing, business strategy, information management and organizational behavior. Potential study outputs ultimately include: (a) an outline of coastal values; (b) an overview of valuation techniques including benefit transfers; and (c) an integrated multidisciplinary approach to maximizing benefits, optimizing costs and capturing monetary values.

Nature Restoration Project in Sekisei Lagoon

*Kei OSADA**, *Keisuke TAKAHASHI*, *Takahiro OKANO*, *Mitsunori SAGARA*

4-21 Okinawa-Tsukansha Bldg., Naha-city, Okinawa, Japan

KEI_OSADA@env.go.jp

In 2002, the new “National Biodiversity Strategy of Japan” was approved. The Strategy basically aimed at creating a balance between people and nature in Japan. In addition, “the Law for Promotion of nature restoration” is enacted in 2003 to promote the nature restoration project to actively rehabilitate degraded environments, such as rivers, tidal flats and forest. “Restoration of Nature” becomes the important challenges in the field of biodiversity conservation in Japan. Sekisei Lagoon, the largest coral reef area in Japan spread out between Ishigaki Island and Iriomote Island, is designated as the Iriomote National Park and includes 4 Marine Protected Areas. More than 300 species of hard corals sustain its biodiversities and also speculated that the coral communities supply the coral juveniles to such northerly areas as around Okinawa Island. Furthermore, the area deeply concerns the economy and community of the region through diving, underwater-observing boat, fishery and other human activities. Coral communities in Sekisei Lagoon are deeply damaged through several severe impacts such as outbreak of Crown of Thorns Starfish from 1970's to 80's, event of coral bleaching in 1998 and constant soil erosion and sedimentation from land like sugar cane field. In 2002, Ministry of the Environment, Government of Japan started the survey to form the management and rehabilitation plan for recovering the sound ecosystems of this significant sea area. The Plan, which include the plan for conservation, management, wise-use, rehabilitation program, education; thought to be the first Integrated Coastal Zone Management Plan for coral reef areas in Japan. The plan will be formed based on the scientific data such as annual coral reef monitoring data over 20 years, demonstrative experiment for propagating coral with participation and understanding of various stakeholders such as diving agent, fishermen, local citizens, farmer, and related national and local governments.

Watershed Planning as an Approach to Integrated Resource Management and it's Application in the Caribbean Region

*Annie I HILLARY**

1315 East-West Highway, Silver Spring, MD 20910 United States of America

Annie.Hillary@noaa.gov

This presentation will describe how watershed planning can serve as an approach for integrated coastal management for small islands and contribute to sustaining the health of coral ecosystems. The paper will explore lessons learned from watershed based approaches in small island national planning with emphasis on work underway in the Caribbean region through the Global Environmental Fund project, “Mainstreaming Adaptation to Climate Change” (MACC) and the National Plans of Actions under the UNEP Global Program of Action (GPA) program. These programs provide insight into approaches to utilize watershed planning as a vehicle for integrated coastal management and have application to other small island states.

The objectives of MACC are to mainstream adaptation to climate change in national development planning and private investment decisions by working with key sectors (water supply, agriculture and land use planning) with the aim of incorporating climate change monitoring, impact and risk assessment into their ongoing programs and long-term planning. Similarly, the GPA seeks to assist countries in developing National Programs of Action. Both the MACC and the GPA projects focus on watershed planning, public education and outreach, and on the enhancement of policy and regulatory controls (policies, regulations, and their enforcement) to address the impacts of climate change and land base sources of pollution, and can contribute to coral ecosystem management.

The Phylogeography of *Symbiodinium* Diversity

*Todd C LAJEUNESSE**, *Daniel J THORNHILL*, *Gregory W SCHMIDT*,
William K FITT

Institute of Ecology and Department of Plant Biology, University of Georgia,
Athens, Georgia 30602 United States of America
fitt@sparrow.ecology.uga.edu

The evolutionary patterns and processes of endosymbionts in the genus *Symbiodinium* may be deduced from existing phylogenetic relationships and their geographic and ecological distributions. Ecological surveys incorporating species level genetic markers have unveiled a wide diversity of types within the major divergent lineages or clades that inhabit corals and their relatives. Each of these assemblages contains a small proportion of forms or species that demonstrate a broad capacity to inhabit numerous diverse host taxa under various physical-environmental reef conditions. However, the majority of *Symbiodinium* diversity comprises of types that are ecologically specialized and geographically restricted, in that they reside in specific host taxa, and/or hosts from a limited depth range and possess more narrow biogeographic distributions. Paradoxically, symbiont diversity in a coral reef community is, with few exceptions, inversely related to host diversity and may depend on changing selection pressures for generalist versus specialist symbionts. Nonetheless, host-symbiont specificity is relatively high, even with hosts that associate with multiple symbionts. These fine-scale ecological and phylogenetic patterns point to the importance of host specialization in driving most symbiont speciation during times of relatively stable environmental conditions. In response to times of major physical-environmental change, these symbiont communities appear to undergo dramatic turnover and loss of diversity. Major bottleneck/expansion episodes appear to have occurred during the Miocene-Pliocene transition and Pliocene-Pleistocene transition corresponding with the major environmental changes taking place during these periods. Regional differences in the magnitude of these transition events appear to explain the present dissimilarity in symbiont communities from the Caribbean, Indo-Pacific and Red Sea.

Symbiodinium, Retrotransposons and the Biological Species Concept

*Scott R SANTOS**

1007 E. Lowell St. Rm. 208 United States of America
srsantos@email.arizona.edu

Mobile genetic elements (MGEs), or “jumping genes”, are entities ubiquitous to nearly all organisms. MGEs may constitute over half of a eukaryotic genome and contribute to genomic organization and architecture while playing a significant evolutionary role in events ranging from modulating the long-term adaptive potential of the host population to host extinction. Here I describe the isolation, characterization and phylogenetic analyses of a MGE from symbiotic dinoflagellates belonging to the genus *Symbiodinium*. Using polymerase chain reaction (PCR) techniques, an approximately 600 bp DNA fragment was recovered and sequenced from *Symbiodinium* clade A isolates. Translation of this DNA fragment and BLAST searches of the protein product resulted in matches to a family of reverse transcriptases specific to retrotransposons (MGEs which translocate via an RNA intermediate). Phylogenetic analyses place this element, which has been termed *kendo*, as a novel lineage within the widely distributed *RTE* clade of non-long terminal repeat (non-LTR) retrotransposons with strong statistical support. MGEs such as *kendo* are absent from the genomes of strictly asexual organisms; the fact that *Symbiodinium* harbors retrotransposons is additional evidence for the occurrence of recombination in the life cycle of these dinoflagellates. Furthermore, the strict vertical transmission of non-LTR retrotransposons coupled with the apparent confinement of *kendo* to a single lineage of *Symbiodinium* clade A (as defined by chloroplast large subunit ribosomal gene [cp23S-rDNA] phylogenies) suggests that the distribution of unique retrotransposons among the symbiotic dinoflagellates can serve as a marker for delineating recombining populations and determining “species” boundaries in *Symbiodinium* according to the biological species concept, something that has previously eluded investigators interested in these enigmatic organisms.

Morphological and Molecular Insights into the Taxonomy and Systematics of Symbiotic Dinoflagellates (Zooxanthellae) from the Southern Great Barrier Reef

*Katherine M FERGUSON**, *Dee A CARTER*, *Anya SALIH*, *Andrew J HOLMES*
Bld G08, University of Sydney, NSW Australia
kfergus@mail.usyd.edu.au

Coral reef communities owe their existence to the long established, mutualistic relationship between scleractinian corals and their symbiotic dinoflagellates (genus *Symbiodinium*). Molecular analysis based on rRNA has found corals on the Great Barrier Reef (GBR) predominantly contain clade C symbionts and that substantial diversity exists within this clade. Separate Previous morphological studies, using confocal laser scanning microscopy and three dimensional (3D) reconstruction, also found a relatively high degree of polymorphism of clade C zooxanthellae in GBR corals, identifying four distinct morphological ‘types’ based on their chloroplast size and structure. The aim of the present study was to integrate the molecular and morphological data and provide a more holistic picture of *Symbiodinium* taxonomy and systematics. Seven coral species, known to harbour different clade C dinoflagellate morphotypes, either singly or in various combinations, were collected from One Tree Island lagoon, Southern GBR. Molecular analysis was performed using two markers -28S rRNA and the non coding region of the psbA minicircle in order to place the studied dinoflagellates into phylogenetically distinct groups and to assess whether these groups correlated to the identified morphotypes. We also used the DNA-specific fluorophore, 4',6-Diamidino-2-phenylindole (DAPI), to image and compare the nuclear chromatid numbers of dinoflagellates as an additional form of their morphological classification. By combining phylogenetic and morphological analyses, this study provides a powerful tool to define the systematics of this poorly understood group of organisms and will shed light on the level of diversity of zooxanthellae from the southern GBR.

Biogeographic Partitioning and Host Specificity among Foraminiferan Dinoflagellate Symbionts

*Xavier POCHON**, *Todd C LAJEUNESSE*, *Jan PAWLOWSKI*

30 Quai Ernest Ansermet, 1211 Geneva 4, Switzerland Swiss Confederation
xavier.pochon@zoo.unige.ch

Soritids, large calcareous foraminiferans abundant in coral reef ecosystems, depend on symbioses with *Symbiodinium* dinoflagellates for their growth and survival. Molecular phylogenetic studies have shown that the *Symbiodinium* inhabiting soritids evolved in several distinct lineages of which only one, referred to as clade C *Symbiodinium* is common in foraminiferans and other invertebrates. Clade C is extremely common in symbioses with numerous corals, soft corals and anemones throughout the Indo-Pacific tropics, but it shares dominance with clades A and B in Caribbean cnidarians. To explore the possibility that a similar biogeographic break exists in the symbionts harbored by soritids, we surveyed the *Symbiodinium* spp. from soritid genus *Sorites* collected from the eastern Pacific and Caribbean by using conventional restriction fragment length polymorphism (RFLP) and phylogenetic analyses of nuclear ribosomal genes. A distinctive biogeographic break between the kinds of symbionts found in forams from each ocean was clearly evident. Caribbean soritids harbored symbionts previously described as phylotypes Fr1 and Fr4, while *Sorites* from the eastern Pacific was dominated by a single *Symbiodinium* haplotype belonging to a distinctive sub-lineage of clade C specialists that associate primarily with Pacific corals in the genus *Porites*. All other clade C types recovered from soritids across the Indo-Pacific are also members of this sub-lineage, which provides further evidence for specificity of foraminiferan symbionts. Differences in the symbioses between Caribbean and eastern Pacific *Sorites* probably resulted from environmental pressures believed responsible for the differences in cnidarian symbioses from each ocean.

Acoel Flatworms-Coral Interactions in Eilat (Red Sea): A Study of Zooxanthellae Diversity in Worms and their Coral Hosts*Orit BARNEAH**, Itzik BRICKNER, Todd C LAJUNESSE, Yehuda BENAYAHURamat Aviv, Tel Aviv 69978, Israel
oritbar@post.tau.ac.il

Acoel flatworms were found on 12 species of corals including branching and massive stony corals as well as a soft coral, at a depth range of 4-40 meters, at different locations along the northern Gulf of Eilat (Red Sea). Both worms and their coral hosts contain algal symbionts in their tissues. We used histology, scanning and transmission electron microscopy to study the worms symbionts and molecular techniques to test the hypothesis that algal symbionts from the coral are consumed by the worms and translocated to their bodies. Two algal symbiont types differing in size were observed in the worms, which were collected from the stony corals *Turbinaria* sp., *Stylophora pistillata*, *Acropora hemprichii*, *Favia fava* and from the soft coral *Stereonephthya cundabuluensis*. The smaller symbiont, *Symbiodinium* sp. measured 8-11 μ m in diameter and the larger one, *Amphidinium*-like, measured 18-20 μ m. The *Symbiodinium* algae were scattered around the peripheral parenchyma of the worm while the *Amphidinium*-like symbionts occupied more central positions. Both types of symbionts were observed within a symbiosome membrane. The *Amphidinium*-like symbiont retained its flagellum inside the worm. Restriction fragment length polymorphism (RFLP) analysis of the 18S rRNA gene of the *Symbiodinium* symbionts was employed in order to compare the symbionts clade in worms vs. in their coral host. Three coral species and their worms showed consistency in the clade level while one coral-worm pair differed. Preliminary analysis using denaturing gradient gel electrophoresis (DGGE) and sequencing of the internal transcribed spacer 2 (ITS2) region indicates that the *Symbiodinium* symbionts from the corals and from their symbiotic acoel worms belong to different sub-clades. Possible scenarios for algal symbiont acquisition by the worms will be discussed.

Physiological Specificity in *Symbiodinium* Symbioses*William K FITT**, Todd C LAJUNESSE, Dan J THORNHILL, Gregory W SCHMIDTInstitute of Ecology and Department of Plant Biology, University of Georgia, Athens, Georgia 30602 United States of America
fitt@sparrow.ecology.uga.edu

Physiological performance of various types of the symbiotic dinoflagellate *Symbiodinium* sp. are compared in culture and in the host. Data support the hypothesis that uptake of *Symbiodinium* vs. algae from other genera is very specific, but that uptake of different types of *Symbiodinium* is non-specific. Specificity appears to reside in post-infection biology, including normal physiological processes of photosynthesis, translocation of photosynthates to the host, growth in situ, and competition.

Chemical Selection of Zooxanthellae by an Octocoral*Kazuhiko KOIKE**, Mitsuru JIMBO, Ryuichi SAKAI, Masami KAERIYAMA, Kenji IWAI, Koji MURAMOTO, Takehiko OGATA, Tadashi MARUYAMA, Hisao KAMIYAOkirai, Sanriku, Ofunato, Iwate 022-0101 Japan
k.koike@kitasato-u.ac.jp

In animal-algal endosymbioses, algal symbionts (zooxanthellae) contribute to the host by translocating photosynthetic products, thus the acquisition and maintenance of the zooxanthellae are crucial for the host to survive. Invertebrate larvae, non-symbiotic initially, must acquire most appropriate symbiotic algae from the environmental sources. However, no experimental evidences have been provided to explain the process of the selective acquisition. Recently, however, some host factors such as macerated animal tissue was reported to involve in an initial infection of zooxanthella in some cnidarians. We previously found that lectin (SLL-2) isolated from an octocoral *Sinularia lochmodes* localized densely on the surface of the *Symbiodinium* cells harboured in the host tissues. In the present study, we acquired some evidences that the lectin play functional roles in the symbiotic relationship between *S. lochmodes* and the *Symbiodinium* sp. In the cell culture experiments using four different ribotypes of *Symbiodinium*, the purified lectin (SLL-2) promoted the transformation from the free-swimming stage (motile form) to the symbiotic stage (coccoid form) at the concentration of 10-300 μ g ml⁻¹. Interestingly, though the growth of the coccoid cells was hardly affected, no further cell stage alteration occurred in the presence of the lectin for one week. Because concentration of the lectin in the coelmic fluid of the coral was determined to be about 300 μ g ml⁻¹, the physiological concentration of SLL-2 in the coral is possible to alter the behaviours of the symbiotic algae. On the other hand, SLL-2 significantly inhibited growth of other non-symbiotic microalgae, and some cells are even burst after the lectin treatment. These results clearly demonstrated that SLL-2 differentially affect the physiology of *Symbiodinium* and non-symbiotic microalgae and suggest that it is the host factor in this octocoral. Some other lectin-mediated symbiotic mechanism in other invertebrates will also be discussed.

Dynamics of Infection and Specificity of Host/Endosymbiont Associations: Evidence that Fine-scale ITS Diversity of *Symbiodinium* Confers Functionality in Symbiosis*Mauricio RODRIGUEZ-LANETTY**, Virginia M WEIS3029 Cordley Hall, Corvallis, Oregon 97331 United States of America
rodrigm@science.oregonstate.edu

This study was aimed at determining whether fine-scale molecular diversity of *Symbiodinium* corresponds to functional differences in host/symbiont specificity and dynamics of symbiosis onset in cnidarian/algal mutualisms. Infection experiments were conducted in aposymbiotic larvae of the scleractinian *Fungia scutaria* using known algal ITS-2 phylotypes within clade C. Our results show that algal phylotype is directly related to specificity during symbiosis onset in *F. scutaria* larvae. The three ITS symbiont types, C1, C15 and C31, within the major *Symbiodinium* Clade C engaged differentially in symbiosis with coral larvae. The homologous symbiont (C1), found in adult *F. scutaria* from the field, showed a significantly better and more stable association with the host larvae than the other two heterologous symbionts (C15 and C31). Confocal microscopic examination of the spatial distribution of symbionts in the host gastrodermal cells during the first 24 hours after infection revealed that both homologous C1 and heterologous C31 symbionts were phagocytized chiefly into gastrodermal cells lining the mid-region of the gastric cavity compared to the oral and aboral regions. After 24 hours, however, the C31 symbionts were absent from virtually all larval hosts, suggesting that they were either digested or somehow expelled. This is the first evidence that fine-scale ITS diversity of *Symbiodinium* confers functionality in the symbiosis.

The Source and Acquisition Processes of Symbiotic Dinoflagellates by Newly Settled Corals

*Selina WARD**, *Ove HOEGH-GULDBERG*

Centre for Marine Studies, The University of Queensland, St Lucia, Queensland, 4072 Australia
s.ward@marine.uq.edu.au

For the majority of broadcast spawning coral species, symbiotic dinoflagellates are not present in the eggs or larvae and mortality rates in the larvae and newly settled spat are generally very high. The dinoflagellates are acquired by the newly settled corals 7-14 days after settlement, but to date the source of these dinoflagellates has not been determined. Experiments have been run over three spawning seasons to determine the source of symbiotic dinoflagellates taken up by newly settled corals. Four species of acroporids have been used in separate experiments. Larvae were reared for a few days then settled onto conditioned tiles. The tiles were placed in aquaria containing either only filtered seawater, only unfiltered seawater, adult colonies of the same species as the larvae or sediments from the reef flat. Only the spat in the sediment treatments acquired symbiotic dinoflagellates, suggesting that the symbiotic dinoflagellates were coming from the sediments. Larvae from treatments with seawater, filtered seawater or adult colonies settled but the spat did not acquire symbiotic dinoflagellates by the end of the experimental period. In separate experiments, newly settled corals were offered different types of symbiotic dinoflagellates and other algae to determine whether the spat are selective in their uptake. Newly settled corals were maintained in the field and sampled to determine whether the clade of the symbionts changed over time.

The Dynamics of Ontogenetic Change Following Initial Acquisition of Symbiotic Dinoflagellates

*Mary-Alice COFFROTH**, *Sandra J CONNELLY*, *Tonya L SHEARER*, *Scott R SANTOS*

190 Burbank Dr. Amherst NY 14226 United States of America
coffroth@buffalo.edu

Symbiosis of marine invertebrates and dinoflagellates within the genus *Symbiodinium* are wide spread and are especially important in reef ecosystems. Many cnidarians initially acquire symbionts as larvae or newly settled polyps. In many taxa the initial acquisition is non-selective and does not reflect the specificity found in the adult host. However, it is unclear how this mixture of algal types is narrowed to the algal taxa observed in the adult host. In this study newly settled polyps of *Briareum* sp., which typically harbor *Symbiodinium* clade B as adults, were infected with either clade A or one of several distinct genotypes of clade B algae, placed in the field and the ontogenetic change in algal complement followed over time. Analysis of algal genotype in the polyps after one month in the field revealed a shuffling of algal types with polyps harboring a variety of algal taxa regardless of the source of the initial infection. A similar outcome was seen in polyps that were initially infected with *Symbiodinium* clade B algae that contained a rare chloroplast 23S rDNA genotype, demonstrating that this shuffling also occurred within a clade. However, after four months, all polyps harbored only clade B algae typical of the adult host. Survival of polyps initially infected with either clade A or B did not differ; suggesting that differential mortality of polyps does not explain the final dominance of clade B within the adult host. These results suggest a tight specificity between host and symbiont at a within clade level.

Changing by Degrees: Algal Symbiont Communities in Reef Corals from High Temperature Environments, Latitudinal Limits and Seasonal Extremes

*Andrew C BAKER**

CERC, MC 5557, Columbia University, 1200 Amsterdam Avenue, New York, NY 10027 United States of America
abaker@wcs.org

Reef coral symbioses worldwide are increasingly threatened by acute exposure to high temperature stress, leading to recurrent episodes of mass coral bleaching and mortality. However, many coral communities around the world experience chronic exposure to extreme temperatures without apparent harmful effect. Conventional explanations for these unusually tolerant corals assume localized acclimation or adaptation, but the mechanisms underlying this capability are under-investigated. One potential mechanism by which reef corals might acclimate or adapt to temperature extremes is the ability to host genetically distinct algal symbiont communities that differ in their thermal optima and resistance to bleaching. To test this hypothesis, molecular surveys were undertaken of algal symbionts from reef corals in extreme high temperature environments (Saudi Arabia) and from the latitudinal limits of coral distribution in three oceans (Japan, Madagascar, Israel, Brazil, Bermuda). Results showed that reef corals from high temperature environments were dominated by an unusual *Symbiodinium* in clade D, while corals at high latitudes (that experience cooler mean temperatures and higher seasonal variability) were dominated by a diversity of symbionts in clades A and B. These data indicate that: (1) the ability of reef coral species to associate with a diversity of algal symbionts may be important in understanding how they acclimate and/or adapt to chronic temperature stress; and (2) flexibility in coral-algal symbiosis may help mitigate the detrimental effects of climate change by elevating bleaching thresholds and buffering coral species from extinction. This adaptive response may already be occurring: the clade D symbiont found in chronic high temperature environments appears to be increasing in abundance on other reefs worldwide, particularly those devastated by the 1997-98 El Niño. Consequently, while reefs may continue to experience mass bleaching and mortality as their symbiont communities are slowly replaced, the long-term prospects for their ultimate survival may be better than assumed.

Flexibility of the Coral-Algal Symbiosis as a Mechanism to Cope with Environmental Change: Thermal Tolerance

*Ray BERKELMANS**, *Madeleine JH VAN OPPEN*

PMB 3, Townsville Q4810, Australia
r.berkelmans@aims.gov.au

Since the discovery of multiple clades of zooxanthellae (*Symbiodinium* spp.) in reef corals, much debate has taken place on the functional significance of a variable association between corals and their algal partners, and how flexible this association really is. The idea that corals may use this flexibility of symbiosis to increase their thermal tolerance, and that coral bleaching may be a mechanism of symbiont change, was first postulated in 1993. In the decade since, this hypothesis has been the subject of much research, but been found difficult to prove or disprove. Through a large-scale coral transplant experiment, we show for the first time that sub-lethal thermal stress can bring about a change in the dominant strain of zooxanthellae in a coral. Moreover, subsequent controlled-temperature experiments showed that the population that changed from Clade C to D (Keppel Islands, southern inshore GBR) increased its thermal tolerance to the equivalent of a warm-adapted population that always harbors clade D zooxanthellae (Magnetic Island, central inshore GBR). Significantly, a second population from a cool offshore reef (Davies Reef, central GBR) that also underwent bleaching did not change zooxanthellae clade and failed to change its thermal tolerance. We conclude that flexibility of symbiosis is possible in at least some coral populations and that this flexibility can increase their thermal resistance. Whilst these findings confirm that corals are capable of rapid physiological and functional adjustment to a changed thermal environment, our results require careful interpretation with respect to the climate change debate because: 1. The magnitude of increased tolerance was approximately 1-2°C, equal to or less than the predicted rate of climate warming over the next century under optimistic IPCC scenarios, and 2. Not all coral populations have the ability to change zooxanthellae clade. Indeed, those that can, may well be in the minority.

Flexibility of the Coral-Algal Symbiosis as a Mechanism to Cope with Environmental Change: Succession and Growth

*Madeleine J H VAN OPPEN**, Angela LITTLE, Bette L WILLIS

PMB No. 3, Townsville MC, Queensland 4810 Australia

m.vanoppen@aims.gov.au

The relationship between corals and their algal endosymbionts (*Symbiodinium*, also called zooxanthellae) has been a key factor in the success of scleractinian (stony) corals as modern reef-builders. The genus *Symbiodinium* comprises an extraordinarily heterogeneous group of dinoflagellates. So far, seven phylogenetic clades have been identified based on nuclear ribosomal DNA (A-G), and within each clade sub-clades (strains or species) are present. In many cases, the juvenile coral takes up zooxanthellae from the environment to establish the symbiosis, and can associate with a wide range of algal strains. Multiple strains can co-exist within a single host. The role of symbiont identity and diversity in terms of fitness of the coral colony has only been poorly studied. Previous studies have shown that cultured zooxanthella strains can differ considerably in physiological characteristics, such as photoacclimation responses to changes in irradiance and responses to high temperatures. However, it is unclear how these data from zooxanthella cultures relate to the natural, symbiotic situation. Here we investigate the natural infection of juvenile corals by zooxanthellae and show that 1) the initial uptake is non-specific and 2) the association is flexible and characterized by succession of zooxanthella strains over time. In addition, we show for the first time (by experimental infection) that the growth of the coral holobiont is significantly affected by the zooxanthella strain harbored. We conclude that coral-zooxanthella associations are flexible, and that algal endosymbionts contribute significantly to physiological attributes of the scleractinian coral holobiont. Flexibility to form associations with multiple symbionts, or to form new associations that are physiologically distinct may be an important mechanism for corals to cope with environmental change, and may have contributed to the evolutionary success of corals as modern reef builders.

Change and Stability of Symbiotic Dinoflagellate Taxa in Reef Building Corals

*Daniel J THORNHILL**, Todd C LAJEUNESSE, Gregory W SCHMIDT, William K FITT

Institute of Ecology and Department of Plant Biology, University of Georgia, Athens, Georgia 30602 United States of America

fitt@sparrow.ecology.uga.edu

Algal-cnidarian symbioses demonstrate varying degrees of specificity. Most cnidarians associate with a single *Symbiodinium* type, while some have associations with different symbiont types depending on habitat. Change in *Symbiodinium* sp. composition within coral colonies was examined seasonally in the Bahamas and Florida Keys. Genetic classification of symbiont type was made using denaturing gradient gel electrophoresis (DGGE) of the internal transcribed spacer region 2 (ITS2). While most coral species examined showed no change in the symbiont type, our data show that certain coral species change symbiont communities over time. Change in symbiont associations did not follow a regular seasonal pattern. We found that symbiont makeup from corals in the Bahamas were considerably less variable than the Florida Keys, indicating that corals in the Keys experience wider environmental fluctuations than their counterparts in the Bahamas. Shallow sites showed a higher degree of variability in partner combination than deep sites. Presumably, this is due to the higher degree of fluctuation in temperature and light in these habitats. The data are discussed in the context of the adaptive bleaching hypothesis.

Symbiodinium Population Dynamics: Investigating the Adaptive Potential of Coral Reefs

*Michael STAT**, William K W LOH, Ove HOEGH-GULDBERG, Dee CARTER

Building G08, Maze Crescent, University of Sydney, Sydney, 2006 Australia

m.stat@mmb.usyd.edu.au

Coral bleaching (loss of symbiont/symbiont pigment) is caused by a variety of stressful conditions and is often a precursor to widespread coral mortality. The strain of *Symbiodinium* has been proposed to play an important role in determining the thermal stress tolerance of the holobiont (*Symbiodinium* + coral partnership). The present study set out to investigate 1) the diversity of *Symbiodinium* found at two locations in the Great Barrier Reef using sequence variation in the rDNA gene; 2) whether the mode of symbiont transmission affects the diversity, and how this relates to the potential of the host to adapt to bleaching stress, and 3) whether bleach resistant or sensitive *Symbiodinium* molecular types occur. Some investigators have hypothesized that bleaching may represent an opportunity to change the symbionts in a coral for more tolerant ones during a stressful episode (Adaptive Bleaching Hypothesis, ABH). Hence this study also investigated 4) whether symbionts change seasonally and after a bleaching event. Conspecific colonies located at Heron Island and One Tree Island were sampled during July 2001 (winter), February 2002 (summer, during bleaching event), and August 2002 (winter, post bleaching). Most corals had numerous different rDNA sequences, suggesting they either harbour multiple symbiont types or have a single type with heterogeneous copies of the rDNA repeat. Intracolony variation relating to levels of light intensity was detected in a colony of *Montipora digitata*. Changes over time or before and after bleaching were exceedingly rare and restricted to changes in the *Symbiodinium* population within a single colony of *Seriatopora hystrix*.

Some Aspects of the Physiology and Ecology of the *Acropora longicyathus* Multi-clade Symbiosis

*Maria Del C GOMEZ CABRERA**, Selina WARD, Ove HOEGH-GULDBERG

Centre for Marine Studies, The University of Queensland, St Lucia QLD 4072, Australia

klegomez@uq.edu.au

Large beds of *Acropora longicyathus* colonies can be found in the shallow waters surrounding One Tree Island lagoon (Great Barrier Reef, Australia). Colonies of *A. longicyathus* in this site can harbour one of two clades of symbiotic dinoflagellates (clade A or clade C) or a mix of these two clades. 75 colonies of *A. longicyathus* were tagged in the lagoons that surround One Tree Island and monitored every three months for a period of two years to verify the identity of the symbionts associated with them. 86% of the colonies surveyed had symbionts clade C, 5% had symbionts clade A, and 8% of the colonies had a mix of both symbiont clades. We found no change in the symbiotic dinoflagellate clades associated with this coral species during the term of the study. Also as part of this study we investigated several physiological characteristics of individual colonies of *A. longicyathus* and the symbiotic dinoflagellates associated with them. Preliminary results suggest that *A. longicyathus* colonies associated with different symbionts display different physiological responses to environmental conditions. Colonies harbouring dinoflagellates clade A presented a slower skeletal growth rate than colonies harbouring clade C or the mix of both clades, but these differences disappeared during summer. Samples of colonies harbouring clade A or clade C taken during Autumn contained more lipids than samples taken during other times of the year. These results may imply that the symbiont composition is playing a role in the structure of *A. longicyathus* population in One Tree Island and may influence the performance of this population under extreme conditions like increases in ocean temperature related to global warming.

Coral Reefs in 2050

*Terry DONE**, *Scott WOOLDRIDGE*

PMB #3, Townsville, Qld, 4810 Australia

t.done@aims.gov.au

Each reef has its particular pressures and prospects, depending on its location and its level of human use and impacts. Its quality - defined in terms of its capacity to maintain or accrete bulk reef framework, and the abundance and diversity of its total biota - will be a legacy of its chronology of disturbances, and a function of the strength of its local restorative processes of settlement, growth and survival of reef species. These in turn may depend on the efficacy of measures to address manageable impacts such as fishing, sedimentation, and water quality. Projections of increased rates and severity of bleaching impacts from warming seas to 2050 suggested that a high level of resilience combined with a low rate of warming will be necessary to prevent net declines in several indicators of reef health (% coral and algal cover; species diversity; trophic structure; bio-construction). Expected performance of key structural reef populations (such as corals) are conditional upon the abundance and effects of key facilitating species (such as herbivorous fishes and invertebrates) that fashion the reef surface into a patchy substratum of inhospitable and hospitable surfaces. The relative proportions of these different types of surfaces is in part a function of how that biomass is apportioned between territorial "farmers" (that maintain high algal biomass) and roving "scrapers" (that keep algal biomass low). This balance may be affected by the abundance and composition of predatory fishes in the area, which in their turn may be affected by the rate of fishing, both at that place, and at prospective sources for larvae. Networks of no-take zones that protect all types of herbivores and allow piscivore populations and biomass to return to more "pristine" levels may thus cascade through to the state of the substratum, and hence the recovery of complex reef architecture and communities.

Multi-scale Comparative Analyses of Recent (1997-2003) Reef Ecosystem Health Using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Regional Database

*Judith C LANG**, *Philip A KRAMER*, *Robert N GINSBURG*, *Patricia RICHARDS KRAMER*, *Stewart T SCHULTZ*, *The Agrra ASSESSMENT TEAMS*
125 Airstrip Lane, P.O. Box 539, Ophelia, VA, 22530 United States of America
jandl@rivnet.net

Specific norms for over 30 indicators of present reef ecosystem health, akin to those for humans or national economies, can now be calculated for several distinct reef habitats (e.g., elkhorn coral-dominated reef crests, intermediate-depth fore-reefs) at multiple spatial scales ranging from <1 km to >1000 km in the western Atlantic. To date, over 720 sites have been surveyed during 34 assessments in 17 nations. The AGRRA benthos and fish protocols collectively enable small, well-trained teams to rapidly quantify key elements of coral reef structure, function and regeneration potential throughout this region with the same methodology. Assessed parameters include: live stony coral cover; size, recent *versus* old partial colony mortality, signs of stress (e.g., bleaching) or disturbance (e.g., disease, overgrowth) in reef corals at least 10 cm in diameter; algal group relative abundances and macroalgal height (a proxy for macroalgal biomass); species richness of reef fishes; density and biomass of ecologically or commercially significant fishes; and *Diadema* density. In general, as much evidence of degradation is seen in the more remote reefs as in reefs that are more proximal to human coastal development; nonetheless, a few reefs near small human populations still retain an abundance of healthy coral and/or fish populations. The AGRRA dataset has captured bleaching- and disease-induced mortalities temporally associated with the 1998 ENSO event, provides spatially-explicit information for identifying "end member" reef types (e.g., those in serious decline, resilient to perturbations or good sources of larvae), demonstrates the importance of assessing directly-comparable reef habitats, and illustrates the value of regional generalizations that are based on region-wide, multitaxon sources of information.

Factors Influencing Alpha and Beta-Diversity of Caribbean Reef Seascapes

*Alastair R HARBORNE**, *Peter J MUMBY*, *Carrie V KAPPEL*, *Craig P DAHLGREN*, *Fiorenza MICHELI*, *Katherine E HOLMES*, *Daniel R BRUMBAUGH*

Hatherly Laboratory, Prince of Wales Road, Exeter, EX4 4PS United Kingdom of Great Britain and Northern Ireland

A.R.Harborne@ex.ac.uk

Conservation of alpha (species) diversity is often cited, along with protection of fisheries, as a key aim of networks of MPAs. However, there is currently limited understanding of how the composition of a community within a given habitat varies at a range of spatial scales. Despite limited empirical information, the concept of habitats as surrogates of species diversity is often invoked in reef conservation initiatives. Furthermore, alpha-diversity has recently been linked to spatially-explicit habitat maps to provide a measure of beta (habitat) diversity. For example, an area with a relatively large number of habitats characterised by very different communities has greater beta-diversity than an area with fewer and / or more similar communities. Beta-diversity is a poorly understood property of reefs but has intrinsic conservation value, lends itself to conservation planning and may prove to be an effective scale of diversity to represent ecosystem functions. Patterns of intra-habitat variation in benthic and fish community composition were examined in a range of habitats (e.g. *Montastraea* reef, seagrass and mangrove) across the Bahamas Archipelago. Using a nested sampling design, we examine significant discontinuities in community structure at scales of <1 km, 5-10 km and 100s of km. Changes in structure are then be linked to putative controlling factors such as oceanographic connectivity and species-area relationships. Similarly, inter-taxa comparisons are assessed in the context of key life history traits. The scale and relative influence of factors controlling beta-diversity was examined using maps from two islands in the US Virgin Islands. For one island we examined the role of factors such as exposure, reef physiography and disturbance history in controlling patterns of beta-diversity. The resulting explanatory model was then applied to the second island for validation. Finally, the scaling relationship between the size and shape of MPAs and the beta-diversity they encompass was assessed.

Perturbation and the Geographic-scale Homogenization of Reef Biotas

*Richard B ARONSON**, *William F PRECHT*, *Ian G MACINTYRE*

101 Bienville Boulevard, Dauphin Island, Alabama United States of America

aronson@disl.org

Intense, large-scale perturbations have the potential to reduce or eliminate historical differences between spatially disjunct coral reef communities. Paleontological records from the western Caribbean provide a dramatic illustration, in which two lagoonal reef systems with different biotic histories were recently perturbed to a single, novel state. Coring studies revealed that reefs in Bahia Almirante, a coastal lagoon in northwestern Panama, were persistently dissimilar from reefs of the central shelf lagoon of the Belizean barrier reef for at least 2,000-3,000 years prior to the last several decades. The Panamanian reefs were dominated continuously by the finger coral *Porites furcata*. Shifts from the *Porites*-dominated state to dominance by other coral species were rare, were restricted to small areas, and lasted for decades to centuries. The Belizean reefs were dominated continuously by the staghorn coral *Acropora cervicornis* in the same depth range during the same period. Excursions from the *Acropora*-dominated state were likewise rare and spatially localized. *Acropora* populations in the Belizean lagoon were nearly extirpated by an outbreak of white-band disease in the late 1980s, and changes in water quality were apparently detrimental to branching *Porites* in Bahia Almirante in recent decades. These large-scale perturbations caused the two reef systems to converge on a third, historically unprecedented state: dominance by the lettuce coral *Agaricia tenuifolia*. *Agaricia* possesses life-history attributes and environmental tolerances that enabled it to become dominant in both disturbed ecosystems. Although the two phase shifts to *Agaricia* differed in both their general mechanisms and specific causes, they had the effect of eliminating the salient difference in benthic composition between the Panamanian and Belizean reefs. The changes in species composition thus obliterated the influence of several thousand years of reef history. Other reef systems should be examined to test the hypothesis of faunal homogenization

Holocene Precedents for Mass Mortality on Coral Reefs

*John M PANDOLEFI**, *George S BURR*, *Alexander W TUDHOPE*, *Evan N EDINGER*, *Robert S STENECK*, *Melissa A FREY*, *Michael JENNIONS*, *Charu SHARMA*, *Hal LESCINSKY*
10th Street and Constitution Avenue, Washington D.C., 2-560-0121, U.S.A.
pandolfi.john@nmnh.si.edu

Evidence for past coral mass mortality events occurs along 35 km of the Holocene raised reef terrace (9000 - 6000 ybp) of the Huon Peninsula, Papua New Guinea. The events occur along discrete horizons that can be traced laterally along the coast for up to 20 km. Some events are associated with volcanic ash, indicating explosive volcanic eruptions as the agent, whereas others contain little evidence of their cause. Horizons are characterized by abundant, in place corals that cease growth collectively at a distinct horizon. The corals are characterized by heavier encrustations of calcareous algae, and less boring than colonies above and below. Recovery quickly follows all mass mortality events. In some cases, the coral community structure overlying the mass mortality horizon is the same as the previous community, but in other cases the new community is different. However, in both styles of recovery the coral (and foraminifera and snail) community structure is persistent until either the next mass mortality event or until the end of Holocene accretion. Thus, history plays a substantial role in determining post-disturbance community structure at a particular site through time. Documentation of these events is significant for three reasons: 1) disturbance and recovery is recognizable and measurable in uplifted Quaternary coral reefs; 2) even in coral reefs that have suffered large-scale disturbance, recovery occurs; and 3) such events were rare in the natural history of coral reefs of the Huon Peninsula during rapid sea level rise. Quaternary raised reef terraces show great promise for understanding the ecological dynamics associated with disturbance events of coral reefs over broad temporal and spatial scales.

The Ocean Thermostat and its Potential Role in Coral Reef Distribution

*Joan KLEYPAS**, *Janice LOUGH*
PO Box 3000, Boulder CO 80307-3000 United States of America
kleypas@ucar.edu

The future state of coral reefs will be strongly shaped by the nature of sea surface warming due to the enhanced Greenhouse effect. Coral reefs will be affected by the rate of sea surface temperature (SST) change, the absolute SST change, and whether either change exceeds the physiological limits of reef-building organisms. During this century, high latitude reefs are likely to experience large increases in SST, but these are unlikely to surpass the high temperature threshold for reefs. Low latitude reefs will probably experience less SST warming, but are at risk if that warming exceeds the ultimate thermal maximum for corals. Coral reef distribution today does not, however, appear to reflect an absolute upper thermal limit (coral reefs occur in the warmest, enclosed seas, where SSTs routinely exceed 31°C). Two important questions guiding predictions of which reefs will cope with future SST warming are (1) What is the upper thermal limit of the ocean? and, (2) Will thermal conditions optimum for reef growth be exceeded in significant parts of the ocean? Recent estimates of maximum sea surface temperatures during hot climates of the Cretaceous and Eocene indicate that maximum SSTs were 28-32°C, and perhaps 1-2°C higher. Maximum SSTs today are around 30-31°C. The "ocean thermostat hypothesis" postulates that several atmospheric and oceanic feedbacks prevent open ocean SSTs from exceeding 30-31°C. Three mechanisms for a thermostat include: (1) evaporative cooling or evaporation-wind-SST feedback; (2) cloud reflection or cloud shortwave radiative forcing; and (3) ocean dynamics and heat transport. In this talk we present analyses of long-term SST records and climate model data to evaluate whether a thermostat "signal" exists in the western Pacific warm pool, and what it means for the future of our warmest reefs.

Testing a Functional Group Approach for Predicting the Assemblage Structure of Caribbean Coral Reefs

*Thaddeus J T MURDOCH**
101 Bienville Blvd. Dauphin Island, Alabama United States of America
tmurdoch@disl.org

The need to understand how coral assemblages are structured across habitats is greater than ever. Disease, hurricanes, pollution, overfishing, introduced species and other factors have each been postulated to play the predominant role in determining the assemblage structure of reef corals. A single theoretical framework is required to consolidate the disparate theories developed for each environmental or biological factor. Ecologists studying a range of organisms have found that a functional group approach can accurately predict how communities will respond to changes in environment conditions. A functional group approach categorizes organisms, regardless of phylogeny, according to similarities and differences in life history or other ecologically relevant traits. One such model, the "CSR plant strategy theory" developed by Phillip Grime in 1973 for terrestrial plants, predicts the assemblage structure of biota over gradients of stress and disturbance. To test the CSR model, coral assemblages on reefs in Bermuda were assessed at the hierarchical level of species and at the hierarchical level of functional groups. The data were used to address the question of whether the functional-level approach provides information about community structure that species-level analysis fails to provide. Additionally, the predictions of the CSR model were tested regarding how coral cover, species diversity and assemblage structure should vary in habitats characterized by differing levels of disturbance and resource-limitation.

Hierarchical Analysis of Coral Community Structure across an Oceanic Biodiversity Gradient

*Ronald H KARLSON**, *Howard V CORNELL*, *Terry P HUGHES*
Department of Biological Sciences, University of Delaware, Wolf Hall,
Newark, Delaware 19716 USA
rkarlson@udel.edu

Although much of ecological theory is devoted exclusively to local processes, we know that local communities can also be profoundly influenced by processes operating across broader spatial scales. Thus an emerging focus in community ecology is directed at how processes operating at different scales interact to influence community structure. Here we examine coral communities across an oceanic biodiversity gradient extending 10,000 km from the world's richest coral biodiversity hotspot in the central Indo-Pacific to French Polynesia. We used a hierarchical sampling design to partition variation in the species diversity of corals among three adjacent habitats (reef flats, crests, and slopes), multiple sites per island, three islands per region, and five regions. Our results indicate highly significant variation due to habitat and regional differences. Local coral diversity and habitat-specific regional pool sizes increase from reef flats to crests and slopes and towards the biodiversity hotspot. Strong regional enrichment (enhancement of local diversity) and linkage between local and regional scales is supported by a highly consistent linear relationship between local and regional species richness. Regional enrichment is pervasive as it influences local assemblages across the entire regional diversity gradient. We conclude that local diversity patterns are influenced by more than local environmental factors and a broader regional perspective is required to understand them. Local assemblages of organisms are embedded in regions with different histories, geographies, and human influences and they are affected jointly by local and regional factors. Understanding these influences is essential for the management and preservation of these endangered communities.

Mid-domain Effects and Environmental Gradients on Indo-Pacific Coral Reefs: New Theory for Analyzing Species Richness Gradients

Sean R CONNOLLY*, Terry P HUGHES, David R BELLWOOD

Department of Marine Biology, James Cook University, Townsville, QLD 4811, Australia

sean.connolly@jcu.edu.au

The boundaries of geographical domains constrain the locations and sizes of species ranges and potentially influence the shape of species richness gradients. However, rigorously incorporating this 'mid-domain effect' (MDE) into assessments of the environmental causes of species richness gradients has proved problematic. I present a stochastic, explicitly biological theory for the encounter of suitable environmental conditions within a bounded domain in which the distribution of suitable environmental conditions may depend upon geographical variation in environmental conditions. For a null model without gradients in environmental conditions, the theory predicts a mid-domain peak in species richness, and it predicts left-skewed lognormal distributions of range size, consistent with empirical data. Within this framework, alternative models representing different hypotheses about the causes of species richness gradients can be formulated and fit to empirical data, and their relative performance quantified. I illustrate this approach using Indo-Pacific coral and reef fish data by comparing the fit of a MDE-only model with one that incorporates enhanced environmental conditions at latitudes where reef accretion occurs. Although the MDE-only model explains most of the latitudinal variation in species richness, the alternative model provides better fit with over 99% confidence, capturing nearly all of the variation among species in range size, and nearly all of the variation in species richness across the domain. This theory provides theoretical support for a mid-domain effect. It also provides a statistically powerful framework for assessing the plausibility of alternative hypotheses about the causes of species richness gradients in a way that rigorously accounts for the effects of geometric boundary constraints.

Spatially Synchronous Changes in Abundance of Coral Reef Damselfishes Are Linked to Global Climate Fluctuations

Alistair J CHEAL*, Steven DELEAN, Hugh SWEATMAN, Angus THOMPSON

PMB No.3, Townsville MC, Townsville, Queensland Australia

a.cheal@aims.gov.au

The spatial scale of synchrony in the dynamics of separate populations has important implications for the understanding of population regulation and the conservation of habitat islands. The nature of the relationship between regionally correlated climatic forces and population synchrony is increasingly relevant in the context of global climate change. We analysed 8 years of annual data for 9 damselfish species (genus *Pomacentrus*) from 42 coral reefs at nested spatial scales, on the Great Barrier Reef, Australia. We investigated the spatial scale and extent of synchrony in changes in abundance among reefs and assessed whether these patterns correlated with climatic and environmental variables. Synchrony was high among damselfish assemblages within distinct geographic regions (reefs separated by up to tens of kms). However, damselfish numbers were often highly correlated with the same index of the El Nino Southern Oscillation across four regions (separated by hundreds of kms), suggesting that global climate fluctuations influenced the base level of damselfish population structure over very broad scales. Within a number of regions it appears that damselfish recruitment success was enhanced during El Nino conditions. We discuss water temperature, ocean currents and dispersal as potential agents influencing patterns of damselfish population synchrony.

The Role of Herbivory in Coral Reef Ecosystem Function and Resilience

David R BELLWOOD*

Centre for Coral Reef Biodiversity, James Cook University, Townsville, Q 4811, Australia

david.bellwood@jcu.edu.au

For over 50 million years coral reefs have evolved in the presence of fish herbivores. Since their appearance on reefs after the K/T boundary, herbivorous fishes have been a constant factor in the development of benthic communities. The interaction between fishes and corals has now reached the stage where modern coral reefs appear to be dependent on the presence of a significant biomass of herbivorous fishes. This relationship is exhibited at numerous spatial scales, with examples from the Atlantic and Indo-Pacific regions, and from small experimental plots to the scale of reef systems. However, there are significant differences in the regional and local composition of key functional groups within the herbivorous group or guild, which have profound implications for the future of coral reefs, and the management of coral reef systems. This presentation will look at the nature of herbivory on coral reefs at a range of spatial scales, evaluating our ability to identify herbivorous fishes, assessing the extent of functional redundancy and, in particular, identifying the key functional components in the reef fish/coral reef interaction. The future health of coral reefs is dependent on our ability to identify and manage ecosystem function to maintain resilience. This presentation will examine the central role of herbivory in this endeavour.

Habitat Selection of Settlement Substrata Determines Post-settlement Survival in Corals

Lindsay M HARRINGTON*, Katharina FABRICIUS, Glenn DE'ATH, Andrew NEGRI

PMB No.3, Townsville, QLD 4810 Australia

l.harrington@aims.gov.au

Habitat recognition and selective settlement by dispersive larvae increases the post-settlement survival chances of benthic organisms. This study describes an intriguing example of a finely-tuned system of species interactions, in which crustose coralline algae (CCA) species use physical, biological and chemical means to inhibit coral settlement, while the settling corals in turn chemically and physically recognize a hierarchy of CCA that maximize survival chances. We examine the interactions between settling larvae of two common reef building coral species (*Acropora tenuis* and *A. millepora*) and five species of CCA (*Neogoniolithon fosliei*, *Porolithon onkodes*, *Hydrolithon reinboldii*, *Titanoderma prototypum* and *Lithoporella melobesiodes*) that co-occur on reef crests and slopes of the Great Barrier Reef. Rates of larval settlement, post-settlement survival, and the sensitivity of larvae to chemical extracts of the CCA were all positively correlated across the five species of CCA. This indicates that early pre-settlement cues determine the choice of settlement substrata which, in turn, enhances post-settlement survival. In particular, rates of settlement and survival of corals were greatest on the CCA species *Titanoderma prototypum*, and the larvae responded to lowest concentrations of chemical extracts from this species. The rate of post-settlement survival of the corals varied greatly between CCA species due to the various defense strategies (shedding of surface cell layers, overgrowth and potentially chemical deterrents) employed by each species. Non-living settlement substratum on coral reefs is sparse, consequently the fact that only a few CCA species (notably *T. prototypum*) appear to facilitate coral recruitment could have potentially large implications for structuring reef ecosystems.

Population Dynamics of Stony Coral Species across Habitats in Bank Systems of the Bahamian Archipelago: Maximizing Survival and Growth Potential through Space and Time

*Kathleen L SEMON**, Kathleen M SULLIVAN SEALEY, Vanessa L NERO

1301 Memorial Drive, Rm 25 Cox Science Center, University of Miami, Coral Gables, Florida 33146 United States of America

ksealey@miami.edu

Although stony corals are most frequently studied on high-relief reef structures, in fact, many coral species occur in a wide variety of nearshore tropical habitats, including mangrove creeks, seagrass beds and rocky platforms. In many habitats, coral colonies can occur at low densities, especially in nearshore or coastal habitats subject to more extremes of temperature, salinity and sedimentation stress. Some stony coral species are not habitat-specific and exhibit wide habitat and depth ranges, but little is known about the population dynamics of the species across habitats. Six coral species were identified as occurring on several types of reefs, hard-bottom and sand-bottom habitats: *Montastrea annularis*, *Porites asteroides*, *Siderastrea sidera*, *Siderastrea radians*, *Eusmilia fastigata* and *Agaricia agaracites*. These corals represent both brooding and broadcast reproductive modes, and exhibit a range of maximum colony sizes. The density of coral colonies, area of available habitat, and size distribution of colonies were recorded for several island bank systems in the central Bahamas. Observations of recruitment, growth and colony mortality were recorded to better understand the population dynamics of these coral species in different habitats. This ability to succeed in multiple habitat types likely plays a role in shaping population biology and structure of corals, including variable resistance to environmental stressors. This study estimated overall population size, potential reproductive output, and population structure for several species in several habitats as a mechanism for both increasing localized recruitment, and maintaining a sufficient population to both recover from disturbance as well as take advantage of stochastic opportunities for recruitment and reef development. Conclusions on ecology and evolution of coral life history traits in these six species are contrasted to fossil as well as modern distributions of colonies.

Constancy and Change in Deep Reef Coral Communities

*Rolf P M BAK**, Gerard NIEUWLAND

PO Box 59, 1790 AB Den Burg, Texel, The Netherlands Kingdom of the Netherlands

rbak@nioz.nl

Coral reefs are thought to be worldwide in decline but the data are practically limited to reefs shallower than 25m. Coral communities in deep reefs (> 30m) can show high coral cover but they are relatively unstudied. Our question is: what is happening in deep reefs in terms of coral cover and coral mortality? We collected data from permanent photo quadrats and video transects at deep Caribbean reefs (30-40m). We have analyzed biotic variables such as species composition, coral mortality, long term (1973 to present) change in coral cover, and we have recorded the impacts of storms and bleaching. At least 20 zooxanthellate coral species are common in these communities with coral cover being up to 70%. Communities are dominated by species such as *Agaricia lamarcki* and *Montastraea faveolata*. Over 30 years the dominant species increased in cover through extension of the skeletons, monopolizing space, until the process was disrupted by catastrophic mortality. We found that causes of catastrophic mortality, such as deep coral bleaching and storms, reduced coral cover by up to 76%. Such events reduced the dominance of agaricid species by up to 50% of pre-catastrophic cover. Abiotic data recorded, temperature and light, show temperature to be an extremely fluctuating variable in the deep reef environment.

Depth Limit for Reef Building Set by Vertical Darwin Point in Hawaii

*Richard W GRIGG**

1000 Pope R, Dept. of Oceanography, University of Hawaii, Honolulu, Hawaii 96822 USA

rgrigg@soest.hawaii.edu

In this paper, the relation between reef building (accretion) and depth in optimal environments in Hawaii is analyzed. For accretion, the growth rate of *Porites lobata* is used because it is by far the most abundant and dominant species of reef building coral in Hawaii. Therefore, it can be considered representative of the total reef community. Optimal growth of *P. lobata* occurs at a depth of 10 m below which both growth rate and abundance decrease linearly with increasing depth. A lower depth limit for this species is found at about 70 to 80 m, yet reef accretion ceases at 50 m depth, where the growth rate is 25% of what it is at 10 m. At 50 m, colonies rarely exceed 15 cm in height or an age of ~40 years. Colony growth-form is platy; most colonies being broader than tall, presumably to maximize horizontal surfaces to light. At this stage, rates of bio-erosion of colony holdfasts exceed attachment rates, causing colonies to detach from the bottom. Continued bio-erosion further erodes and dislodges colonies leading to their break-down and ultimate formation of coralline rubble and sand. Hence, within optimal environments in Hawaii, a threshold for reef building exists at ~50 m depth where reduced rates of growth are exceeded by increasing rates of bio-erosion. Conceptually viewed, this depth horizon represents a vertical Darwin Point. It also explains the history of reef morphology in such environments where the carbonate substratum shallower than 50 m is primarily modern (~100 years or less) while below 50 m, it is late Pleistocene or early Holocene in age.

Holocene Development of Belize Barrier and Atoll Reefs, Central America, Caribbean Sea

*Eberhard GISCHLER**, J Harold HUDSON

Senckenberganlage 32, 60054 Frankfurt am Main Federal Republic of Germany

gischler@em.uni-frankfurt.de

The Belize barrier and atoll reef system is the largest in the Atlantic Ocean. Subsurface data from 25 rotary drill cores, 31 vibracores, and 82 radiometric ages indicate that the Belize barrier reef was established from >8.26-6.68 kyrs BP, and the Belize atoll reefs from 7.78-5.03 kyrs BP on Pleistocene reef limestones deposited during oxygen isotope stage 5. Reef anatomy is characterized by three facies. In order of decreasing abundance, these facies are represented by corals (mainly *A. palmata* and members of the *M. annularis* group), by unconsolidated sand and rubble, and by well-cemented coral grainstones-rudstones. Holocene reef accumulation-rates average 3.25 m/kyr along the barrier reef and 4.83 m/kyr on the atolls. The degree of reef consolidation is negatively correlated with Holocene thicknesses, indicating that slowly growing reefs are better cemented than fast growing ones. In atoll lagoons, basal mangrove peats -which indicate initial marine flooding- formed between 8.77-6.84 kyrs BP. Mangrove peat lies on top of late Pleistocene soil and is superimposed by restricted-marine carbonate sediments rich in *Halimeda* and open-marine carbonates rich in mollusks. Holocene lagoonal accumulation-rates average 0.6 m/kyrs. The Belize shelf lagoon behind the barrier reef was inundated between 10-5.6 kyrs BP based on data from other workers. The non-synchronous start of Holocene reef and lagoonal development was a consequence of variation in elevation of antecedent topography, largely controlled by underlying NNE-trending structures. From N to S, Pleistocene elevation decreases along these structural trends, probably reflecting differential subsidence and variations in karst topography.

Wave-induced Water Motion over Space and Time: The Functional Implications for Coral Reef Fish Assemblages

*Christopher J FULTON**, *David R BELLWOOD*

Department of Marine Biology, James Cook University, Townsville, Queensland, 4811, Australia
christopher.fulton@jcu.edu.au

Wave energy has been identified as one of the key physical factors shaping the structure of shallow aquatic communities. Recent studies on a group of coral reef fishes, the wrasses (F. Labridae), have revealed a functional link between the swimming abilities of these fishes and their distribution patterns in relation to wave energy. The present study explored the utility of this concept for several other reef fish families that span a broad range of swimming modes and performances. Levels of wave-induced water motion were quantified over spatial scales ranging from around reefs (1-4 km apart) and among habitats (10-100 m), to within the water-column of a single habitat (30-120 cm), and over temporal scales incorporating changes in sea conditions. Direct comparisons were then made between levels of water motion and the distribution patterns of fishes (156 species from 7 families) according to their swimming mode and sustained swimming speeds. Marked changes in wave-induced water motion, from less than 14 cm s^{-1} in sheltered habitats to more than 65 cm s^{-1} in exposed habitats, were correlated with shifts in the prevalence of swimming modes. Pectoral-swimming species increased in prevalence with increased levels of water motion, whilst pectoral-caudal and caudal-swimming species decreased with increased water motion. Consequently, wave-exposed habitats were characterised by pectoral-swimming fishes, with up to 84% of species and 97% of individuals in exposed crest and flat habitats using this mode. Furthermore, fishes from exposed habitats often displayed markedly higher sustained swimming speeds than fishes from sheltered locations. Water motion appears to be an important physical factor for shaping the distribution patterns of coral reef fishes through interactions with their swimming abilities. Whilst these functional relationships are manifest at a local scale in the present study, available evidence suggests that the implications may extend over global biogeographical scales.

Phenotypic Plasticity of Coral Reef Fishes on Geographic Range Margins

*Karin BUECHLER**, *M Julian CALEY*

Townsville 4811, Australia
Karin.Buchler@jcu.edu.au

Theory predicts that the edges of geographic ranges are determined by complex interactions between demography, population genetics and selection. Compared to populations at the centre of a species distribution, populations at geographic margins are expected to inhabit less optimal, spatially or temporally heterogeneous habitats. In such boundary habitats, natural selection should favour a high degree of phenotypic plasticity if it has a genetic component and provides a fitness advantage in variable environments. In this research we investigated growth plasticity in central and marginal populations of three species of anemonefishes using a common-garden experiment. Adult pairs of *Amphiprion akindynos*, *A. melanopus* and *Premnas biaculeatus* from central and marginal populations were bred, their larvae reared to settlement, and the resulting juveniles divided among two temperature and feeding treatments. Growth, survival and body condition of the offspring were recorded to estimate genotype - environment interactions for each species. These norms-of-reaction were used to estimate genetic variation in phenotypic plasticity. Preliminary results indicate that offspring from marginal populations exhibited greater growth rates and mortality in all experimental environments. Differences in levels of phenotypic plasticity and the extent to which they support our predictions will be demonstrated and discussed in the context of global climatic change, where local conditions may vary too rapidly for the evolution of new local life-history optima. In such scenarios the evolution of phenotypic plasticity and the resultant ability of species to promptly respond to environmental change may be of critical importance not only to marginal populations, but may have increasing adaptive significance for central populations also.

Coral Reef Classification Using Acoustic Backscatter

*Paul SEEKINGS**, *Tse-Lynn LOH*, *John R POTTER*

14 Kent Ridge Road Singapore 119223 Republic of Singapore

paul@arl.nus.edu.sg

Quick and cost-effective surveys of coral reefs are becoming increasingly important as the extent and rapidity of global coral reef degradation becomes obvious. Remote survey methods based on satellite images and aerial photography can cover broad areas rapidly, but they are difficult to ground-truth, are adversely affected by atmospheric and water opacity and can be prohibitively expensive for many of the developing countries with the most pressing need for basic surveying. In-situ surveying by divers provides excellent quality discrimination, but requires well-trained divers, is resource intensive and too slow to meet global needs of rapidly mapping large areas. We present research aimed to develop methods to classify coral based on the acoustic backscatter from an active high-frequency interrogating signal. The principle is to use a hybrid of acoustic imaging (instead of photographic) with the additional feature of acoustics to penetrate the coral and give information about density and other parameters not apparent from a surface optical image. A prototype system has been developed that can be moved over the coral reef at a few metres altitude, simultaneously taking photographs for ground-truthing comparison. A spread spectrum signal is used to insonify the coral to gain the advantages of increased bandwidth. The signal processing methods are based on wavelet decomposition and bi-spectrum analysis applied to beamformed data from a compact array of hydrophones. We are working on neural network classification and recognition of the each coral type signature. Initial field trials have concentrated on classifying major morphological coral forms both dead and alive. A prototype system would be compact enough to fit on an AUV or inflatable boat, thus bridging the gap between rapid but superficial satellite/areal photographic methods and resource-intensive diver methods. The method has the potential to identify both coral types and the health of each coral type.

Evaluation of Coral Reef Distribution by Means of Acoustic and Optical Apparatus

*Wen-Miin TIAN**

70, Lien-Hai Road, Ku-Shan Distract, Kaohsiung City, Taiwan

tiwemi@mail.nsysu.edu.tw

An integrated procedure which incorporated a high-resolution side-scan sonar, an underwater video camera and a global positioning system (GPS) was used to conduct seafloor mapping around a small island, Liu-Chiu Yu, off Southwestern coast of Taiwan. The purpose of this investigation was intended to delineate the compositions of the seafloor with emphasis to define the area which was covered by live coral reefs. The geocoded, high-resolution sonograph collected by the side-scan sonar illustrated the morphology of the seafloor with an averaged resolution of 5 cm per pixel. Five different types of seafloor were recognized, which include muddy seafloor, sandy seafloor, sandy seafloor with gravel, rocky seafloor and rocky seafloor with coral reefs. By the cross correlation of images collected by side-scan sonar and underwater video camera, it was concluded that rocky seafloor with the outer appearance of a bush (ex. staghorn coral, bush coral, or table coral etc.) is much easier and more precisely to be identified. However, for those with the outer appearance of a sphere, there are very limited identification phenomena can be recognized. It was estimated that about 40% of the surveyed area (2.6 km²) was covered by coral reefs. The detailed information of coral reef distribution was then incorporated into an GIS system for display and further investigations. This procedure which can conduct seafloor mapping effectively, offered good opportunities and a new method for the estimation of live coral reefs.

NASA EAARL Airborne Lidar Sensing of Morphologic Habitat Complexity in the Northern Florida Reef Tract

*John BROCK**, *Ilsa KUFFNER*, *Wayne WRIGHT*, *Linda DUNSMORE*, *Victor BONITO*, *Donald HICKEY*, *Melanie HARRIS*, *Philip THOMPSON*, *Bernhard RIEGL*

600 4th Street South United States of America

jbrock@usgs.gov

The topographic variability of reef substrates and the composite three-dimensional thicket structure of their variable benthic communities both contribute to habitat complexity, a primary ecological factor on reefs. The NASA Experimental Advanced Airborne Research Lidar (EAARL), a temporal waveform-resolving, airborne green wavelength lidar, is designed to simultaneously survey these two separate components of habitat complexity at high horizontal (~ 1 m) and vertical spatial resolution (~ 0.2 m). In early August 2002, an intensive USGS - NASA EAARL survey was conducted over a broad swath of the northern Florida reef tract, extending from north of Triumph Reef to south of Carysfort Reef. Algorithms were developed to analyze the one-nanosecond temporal resolution laser reflections that are provided at rates up to 5000 Hz by the NASA EAARL. Two highly complementary types of information about benthic morphologic complexity were extracted from the EAARL active optical soundings acquired over the northern Florida reef tract, 1) substrate optical rugosity and the 2) range-amplitude characteristics of the laser bottom reflections that quantify the instantaneous vertical thicket structure of the benthic community. Optical rugosity was determined by converting each across-track lidar raster scan into a submarine topographic transect, followed by computing the ratio of surface contour length to direct geometric length along each transect. The time-amplitude reflection profile of each laser pulse bottom reflection was converted to a range-backscatter record and normalized for attenuation using water-column thickness derived from the full laser reflection. Bottom reflection metrics, including total reflection length, integrated backscatter, and weighted mean backscatter, were calculated for each optical sounding. The validity of these novel metrics as proxies of habitat complexity, height of branching organisms, and other ecologically important variables is being evaluated through the detailed in situ measurement of patch reef communities surveyed by the EAARL.

A Method for Extracting Flow Lines in Coral Reef Area Using Aerial Photographs

*Mari YOSHIDA**, *Hiroshi HANAIZUMI*, *Hiroya YAMANO*

3-7-2 Kajino-cho, Koganei, Tokyo 184-8584, Japan

i04h0021@k.hosei.ac.jp

It is very important to monitor water exchange in a coral reef area for keeping the coral reef healthy. We propose an automated method to extract flow lines from aerial photographs in the coral reef area. The proposed method is based on the fact that water flow in the coral reef area gives some effects such as growing speed of coral reefs. In this method, we detect flow line patterns in the image digitized from the aerial photograph. The flow line patterns are approximated by linear parallel patterns in a local area. The line integrations are calculated for 12 directions from 0 to 180 degrees. When the direction of the linear parallel patterns and that of the line integration are not identical the shape of the line integration is just like blurred because high and low density areas which are not on a linear parallel pattern are cancelled out. This means we can get the direction of the linear parallel pattern from the clearest line integration among all 12 directions. The clearness is evaluated by accumulated difference between neighboring top and bottom of the line integration. As calculating line integration for 12 direction for all local area requires huge processing time, we use a FFT method based on the projection theorem for reduction of the processing time. The direction of the flow line is indicated small line segment for every local area. We also use Bezier curves to provide global flow lines. The proposed method was successfully applied to actual aerial photograph images.

Biooptical Modeling of Pigments in Coral

*Eric J HOCHBERG**, Amy APPRILL, Marlin J ATKINSON, Robert R BIDIGARE

46-007 Lilipuna Rd., P.O. Box 1346, Kaneohe, Hawaii, 96744 United States of America

hochberg@hawaii.edu

Photosynthetic pigments within zooxanthellae are inherently related to the shape and magnitude of optical spectral reflectance in corals, but there are currently few data available to develop biooptical models. In this study, we measured cm-scale spectral reflectance for several massive colonies of *Porites* sp. growing *in situ* on the reef in Kaneohe Bay, Oahu, Hawaii. For each reflectance spectrum, we collected a tissue sample and utilized high-performance liquid chromatography to quantify six major photosynthetic pigments. Multivariate multiple regression analysis showed that a linear model accurately predicts pigment concentrations from spectral reflectance, with squared multiple correlation values of 0.94, 0.94, 0.99, 0.82, 0.99 and 0.99 for chlorophyll *a*, chlorophyll *c*₂, peridinin, β -carotene, diadinoxanthin and diatoxanthin, respectively. Simple empirical models such as this afford the immediate opportunity for routine non-invasive monitoring of coral-zooxanthellae status, and ultimately for remote sensing of reef biogeochemical processes.

Effects of Sedimentation by Contrasting Sediment Types on the Photophysiology of Corals

*Miriam WEBER**, Katharina FABRICIUS, Christian LOTT, Dirk DE BEER

Bothmerstr. 21, 80634 Muenchen Federal Republic of Germany

m.weber@hydra-institute.com

Terrestrial runoff increases nutrification and siltation on coastal coral reefs worldwide. While moderate levels of sedimentation are a natural environmental factor for many coastal reefs, few studies have addressed the synergistic effects of nutrients and sediments on corals. We exposed corals to different sediment types at environmentally relevant concentrations and exposure durations. Photophysiological stress-responses, measured as the photosynthetic yield of zooxanthellae, were determined with PAM (Pulse-Amplitude Modulated) chlorophyll Fluorometry. Photophysiological stress varied greatly between sediment types, and was related to a number of different nutrient-related, physical and geochemical sediment characteristics. Stress responses from sediments with low nutrient concentrations contrasted strongly from those with high nutrient concentrations, and also in response to a number of geochemical parameters. Photosynthetic yield was reduced by nutrient-rich sediment from an Australian river estuary > 2.5 times compared with yield reduction by nutrient-poor sediment from another Australian river estuary and almost 5.5 times compared with yield reduction by nutrient-poor calcareous coral dust. Processes within the sediment layer on corals need to be investigated in detail to explain such relationships between stress-responses and sediment properties. We present first data on the microenvironment of nutrient-rich versus nutrient-poor sediments on corals using oxygen-microsensors.

Evaluation of Benthic Survey Techniques for Validating Remotely Sensed Images of Coral Reefs

*Chris M ROELFSEMA**, Karen JOYCE, Stuart PHINN

University of Queensland, St.Lucia, 4072 Queensland Australia

c.roelfsema@uq.edu.au

Field validation of maps derived from airborne or satellite imagery is essential to enable their use for mapping seagrass and coral reef habitats. Methods of benthic survey in seagrass and coral reef ecosystems have been documented elsewhere, yet a comparative evaluation to identify optimal methods for integrating field data with remote sensing has not been completed. This study compares the cost effectiveness of six different field survey techniques for determining substrate cover in seagrass and coral reef environments. Ultimately, our goal is to use the survey data for validating maps of seagrasses and coral reefs derived from remotely sensed imagery at various scales, from airborne hyperspectral (CASI) to satellite multispectral (Ikonos and Landsat ETM+). The study was conducted at Heron Reef, in the Capricorn Bunker group, southern Great Barrier Reef, Australia. Six types of field survey techniques were applied to the same section of reef, under similar environmental conditions (water depth, tidal stage, currents, sun-light), to measure substrate characteristics. The techniques tested were: line intersect, point intersect, 0.5x0.5m quadrat with ten points, 0.5x0.5m quadrat estimates, digital camera transect and 5x5m grid surveys. Survey and processing techniques were conducted by the same researchers. The length of time required to collect and process the data was recorded for comparative purposes. The final comparison covered both field survey and data processing techniques, in terms of: the accuracy of the final result; equipment needs; time taken, skill and knowledge requirements; safety; and cost. The results obtained demonstrate actual costs and benefits for each of six different field methods, along with their data processing requirements for benthic surveys and validating airborne and satellite image data. Based on these findings, scientists or managers should be able to make an informed selection of field survey techniques to suit their scale/s of mapping and validating remotely sensed data.

Extracting Information on Water Properties, Bathymetry and Habitat Composition from Hyperspectral Remote Sensing of Coral Ecosystems

*James A GOODMAN**, Susan L USTIN

UC Davis, 113 Veihmeyer Hall, Davis, California 95616 United States of America

jagoodman@ucdavis.edu

Remote sensing is increasingly being employed as a significant component in the evaluation and management of coral ecosystems. Advantages of this technology include both the qualitative benefits derived from a visual overview, and more importantly, the quantitative abilities for systematic assessment and monitoring. Advancements in instrument capabilities and analysis methods, particularly with respect to hyperspectral remote sensing, are continuing to expand the accuracy and level of effectiveness of the resulting data products. Not only do hyperspectral instruments offer the spatial and temporal capabilities of traditional remote sensing, but also the spectral detail necessary to extract multiple layers of information from an optically complex environment. This spectral resolution is especially relevant for the analysis of coral ecosystems, which are spatially heterogeneous and include the confounding effects of the overlying water column and atmosphere. We demonstrate a successful application of hyperspectral analysis of coral ecosystems in the Hawaiian Islands using representative data acquired from NASA's Airborne Visible Infrared Imaging Spectrometer. As a first level of analysis, the process employs a semi-analytical inversion model to derive bathymetry and water properties on a pixel-by-pixel basis. Linear spectral unmixing is then used to extract information on the coral, algae and sand composition of each pixel. The unmixing model is based on the spectral characteristics of the dominant species and substrate types, and uses an optimization routine to mathematically invert the relationship of how each component spectrally interacts and mixes. The functional result is the ability to quantitatively classify individual pixel composition according to the percent contribution from each of the different components. Thus, the overall analysis illustrates the capacity to derive valuable information on water properties, bathymetry and habitat composition from hyperspectral remote sensing data, thereby establishing a spatially explicit quantitative method for assessing and monitoring coral ecosystems.

Extracting Coverage of Specific Coral-Reef Benthos from *in Situ* and Airborne Hyperspectral Data

*Hiroya YAMANO**, Naoto OHKAWA, Tsuneo MATSUNAGA, Takeharu IKEMA, Kazuo OKI, Yasuhiro SUZUKI

16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan
hyamano@nies.go.jp

Extracting coverage of coral-reef benthic components from a remote sensing imagery by unmixing method is a challenge, as reflectance characteristics of coral-reef benthic organisms (e.g., corals and algae) are similar. In addition, high diversity of spectral characteristics of coral-reef organisms makes it difficult to determine the end member spectra and to extract coverage of the benthic component. Here, brown corals have relatively stable reflectance characteristics caused by zooxanthellae absorption, which could be distinguishable from other benthic components. In the present study, we used a matched filter method for extracting cover of brown corals from mixed spectra. The unmixing experiment was conducted both *in situ* and airborne hyperspectral data. Extracting brown coral coverage from mixed spectra based on *in situ* data showed favorable results. Applicability of this method to *in situ* imagery is also discussed.

Scale-invariant Fractal Patterns of Coral Communities: Evidence from Remote Sensing (Arabian Gulf, Dubai, U.A.E.)

*Samuel J PURKIS**, Bernhard M RIEGL, Richard E DODGE

8000 N. Ocean Drive, Dania FL 33004, USA
purs@geo.vu.nl

The occurrence of power-law relationships between frequency and size of facies patches has been identified in both modern and ancient carbonate depositional bodies. However, quantification of the lateral extent of facies distribution in such systems, which vary on scales of centimetres to tens of kilometres, is notoriously difficult and remote sensing methods are increasingly becoming the tool of choice. In this study, facies patterns and their spatial relationships were quantitatively investigated in an Arabian Gulf shallow subtidal carbonate ramp setting in Dubai using a synergy of IKONOS satellite imagery and vessel-based acoustic bathymetry survey. The spatially detailed bathymetry was used as input into an empirical correction for the effect of the water column on the satellite imagery, facilitating classification of eight dominant facies types, using a classifier trained exclusively by hyperspectral *in situ* optical measurements of substrate reflectance. Secondly, the bathymetry was interpolated to represent a model of seafloor topography, which, when combined with the classified IKONOS imagery, yielded a three-dimensional model of facies distribution on the seabed. Both ground-verification and the predictive map derived from the IKONOS imagery confirm the fragmented nature of carbonate benthos in the study area, with patch sizes found to vary between 16 m² (the spatial resolution of the imagery) and 900 m². The patchy distribution of three assemblages of live and dead corals on extensive (but also fragmented) hardground pavements was investigated using a variety of spatial statistics and it was found that the relationship between patch size and frequency approximate to a power-law relationship (linear in the log-log domain) over several orders of magnitude. The area is known to be subjected to recurrent and cyclic thermal induced mass mortality events on a decadal time scale, inhibiting reef framework development and likely to be a controlling mechanism in the patchiness of the coral communities.

Crossing Boundaries to Develop Communication Strategies: Extracting Ethnographic Information for Integration to Remotely Sensed Images of Coral Reef Environments

*Candace M NEWMAN**, Ellsworth F LEDREW

200 University Avenue West, Waterloo, Ontario, N2L 3G1, Canada
cmnewman@fes.uwaterloo.ca

It is becoming increasingly evident that successful communication of the location and spatial extent of coral reef features, processes, and change identified within satellite imagery improves management decisions. It is these managers whose interpretations of remotely sensed information will guide the design of coral reef management plans. Thus, it is imperative that information acquired remotely is communicated within the appropriate socio-cultural context. Successful communication with someone from another cultural involves understanding the cultural landscape and knowing how to decipher relevant information for the study. In this study, we propose a method for extracting appropriate ethnographic information to integrate with remotely sensed imagery. We examine factors that control communication, these include perceptions, attitudes, traditions, and taboos, and we present a technique for finding a common ground. We report here results from an experiential observation study conducted on Bunaken Island, Indonesia in 2001 and 2002. Using observation techniques we extracted ethnographic information surrounding cultural meanings and human environmental perceptions. During the 2001 field season we also acquired an IKONOS image and ancillary *in situ* radiometric data using an Analytical Spectral Device (ASD). *In situ* data and contextual editing were used to classify the satellite image and identify the location and extent of coral reef features. Understanding the extent to which environmental information could be extracted for Bunaken Island from the IKONOS imagery we investigated which features were of interest to local managers. Throughout this process, perceptions and taboos were significant controls of communication while with the image itself cultural landmarks were most useful in orienting managers to reef locations. Results from this study support the need to investigate communication strategies to improve the utilization of information acquired using remotely sensed technologies.

A Triple Threat and Damage Index for Coral Reefs Derived from Remotely-sensed Data Analysis

*Enrico C PARINGIT**, Kazuo NADAOKA

W207, Ookayama West 8 Building, 2-12-1 Ookayama, Meguro-ku, Tokyo Japan
ecp@wv.mei.titech.ac.jp

Mass bleaching, algal phase shift and sedimentation are three of the most pressing issues affecting the state of coral reefs. It has been demonstrated in previous remote sensing research how each of the following environmental disturbances manifest in satellite- or airborne images of reef areas albeit in separate treatment. A logical step therefore to advance application of remote sensing in coral health monitoring is to integrate the methods to detect presence of bleached corals, algal domination or sediment intrusion, into one cohesive processing framework. After all, these threats often take place in succession or co-occurrence. A method is proposed to simultaneously derive indices for algal coverage, sedimentation, and bleaching from multispectral and hyperspectral imagery. With application to time series remotely-sensed data, the approach not only provides a potential for assessing coral reef health but may describe observed trends and predict vulnerabilities in a given coral reef environment. A novel visualization scheme to infer patterns the indexes is likewise proposed. Keywords: mass bleaching, algal phase shift, remote sensing, coral reef, health, sedimentation

Long-term Monitoring of Coral Reef Condition in Thai Water by Using Remote Sensing Techniques

Makamas SUTTHACHEEP*, Thamasak YEEMIN, Supichai TANGJAITRONG
Ramkhamhaeng University, Huamark, Bangkapi, Bangkok 10240 Kingdom of Thailand
smakamas@hotmail.com

There are over 300 major reef groups, covering an estimated area of at least 150 km² in Thai waters. They can be divided into four district areas with different oceanographic conditions, i.e., the inner part of the Gulf of Thailand, the east coast of the Gulf of Thailand, the west coast of the Gulf of Thailand and along the coastline on the Andaman Sea. It is necessary to have monitoring programs for providing information on the diversity and condition of particular sites as well as environmental changes. Recently remote sensing is the important alternative technology that can supply the data necessary to monitor coral reefs on a large scale in a cost and time effective manner. The present study aims to use remote sensing and GIS techniques together with field observation to survey and monitor changes of coral reef conditions in Thai waters, especially the comparison between the Gulf of Thailand and the Andaman Sea. Remote sensing techniques of Landsat-5 TM and Landsat-7 ETM+ have potential to provide large-scale monitoring data in coral reefs. Time series of Landsat-5 TM and Landsat-7 ETM+ images were analyzed to detect changes in coral reef conditions. Several corrections were undertaken to gain more accuracy. The results were compared with direct field observations. The impacts of severe coral reef bleaching phenomena on coral reef conditions were remarkably observed. The present study highlights the feasibility and utility of combining Landsat-5 TM and Landsat-7 ETM+ images for detection of long-term coral community changes of certain areas in Thai waters. It also shows the possibility of a cost-effective way to study in a relatively large and remote coral reef area.

Remote Sensing of a Remote Coral Atoll: Karang Kapota, Indonesia

Qamar A SCHUYLER*, Phillip DUSTAN, Eric DOBSON, Mark A FINKBEINER
58 Coming Street, Charleston, South Carolina United States of America
qamarama@yahoo.com

Coral reefs are rich tropical marine ecosystems that provide numerous benefits, including shoreline protection, high species diversity, and a source of protein for much of the world's population. However, multiple anthropogenic stresses threaten coral reefs and those who depend on them. It is therefore important to develop methods to study reefs on a global scale. Analyzing satellite imagery offers a relatively low-cost alternative to traditional field studies, but most analysis techniques currently being used require extensive ground-truthing expeditions and *a priori* knowledge of the reef. This situation is the exception; for most reefs, little or no ecological information exists to guide managers and researchers. Using a time series of five Landsat TM and ETM+ images of Karang Kapota atoll, in Indonesia, this research explores the utility of temporal texture as a diagnostic tool to assess ecological change in coral reef communities. This technique uses the coefficient of variation to quantify the temporal variability of an image time series on a pixel-by-pixel basis. The temporal texture analysis was verified with expeditionary field work on Karang Kapota. Regions of the atoll with unhealthy coral communities were found to have higher temporal texture values than a region containing primarily healthy coral communities. In the absence of extensive information and field verification, this technique may be able to alert managers to potential problems on even the most remote reefs.

Oral 2-7

Atmospheric CO₂ Increase during Deglaciation: A Reassessment of the Effects on the Carbon Cycle and Timing of Coral Reef Growth*Adam VECSEI**, *Andy J RIDGWELL*, *Wolfgang H BERGER*

Talstrasse 35, 04103 Leipzig Federal Republic of Germany

vecsei@uni-leipzig.de

The coral reef hypothesis asserts that carbonate production on newly flooded shelves has contributed importantly to the rise of atmospheric carbon dioxide during deglaciation. We constrain the timing and strength of such carbon dioxide flux by re-assessing reef and platform distribution in the world ocean. The space and time patterns of reef growth suggest that the re-partitioning of CO₂ from the ocean to atmosphere resulting from carbonate production was important particularly during the late stages of deglaciation. The effect peaked during the early to mid Holocene, when it presumably contributed to the reversal of an early Holocene declining trend in CO₂ and to warming in the climatic optimum, and explains the occurrence of reduced Holocene carbonate preservation in deep-sea sediments. We discuss the strength and timing of the coral reef effect as compared to other processes affecting the oceanic carbon reservoirs and to the regrowth of the terrestrial biosphere.

A Study on Geographical Variation of Topography and Gradient of Reef Slope*Nobuyuki HORI**

1-1 Minami-ohsawa, Hachioji, Tokyo, 192-0397 Japan

nhori@comp.metro-u.ac.jp

It is very few discussions worldwide geographical variation of topography and gradient of reef slope. The author (Hori, 1977) proposed the coral reef formation model, and showed the core zone (oceanic zone of coral reef formation during glacial period) and the peripheral zone (oceanic zone of coral reef formation during interglacial period) in map. The author's model shows that the width of coral reef is controlled by the gradient of shelf, and the basal depth of reef slope (Rd or Daly Point defined by Hori) is decided by sea surface temperature and sea level. In order to know the geographical difference of topography and gradient of reef slope between the core zone and the peripheral zone, topographic profiles of reef slope are obtained by using a small-sized depth sounder at Amami-Ryukyu Islands, South Pacific Islands (Guam, Honoluli, Fiji, Oahu, New Caledonia, Tongatapu, Rarotonga and Borabora etc.), Indian Ocean (Kenyan coast) and Sudan Red Sea coast. As a preliminary results, reef slopes in the core zone are very steep, and reef slopes in peripheral zone are more gentle and show the step-like topography.

The Evolution of Coral Reefs on Kita-Daito-Jima for the Last 25 Million Years*Yuka SUZUKI**, *Yasufumi IRYU*, *Tsutomu YAMADA*, *Shizue INAGAKI*

Aobayama, Sendai 980-8578, Japan

y_suzuki@dges.tohoku.ac.jp

Kita-daito-jima is a carbonate island, ~350 km east of Okinawa-jima. Sedimentologic and geochemical investigations were conducted on carbonates on this island and from Kita-daito-jima Borehole that reached 431.7 m beneath grand surface (mbgs). The results, combined with known biostratigraphic and Sr-isotopic dates, enable to delineate the evolution of coral reefs on this island for the last 25 million years. Atoll grew keeping up with the relative sea-level rise caused by subsidence of the island for 24-19 Ma. Then, the atoll was drowned at 18.6 Ma. The rapid reef growth occurred around 16.1, 15.5, and 10.9 Ma due to sea-level falls allowing hermatypic organisms to re-colonize on the submerged island. Massive dolomitization masks exact nature of depositional history of upper 100-meter-thick carbonates from the borehole. It is probable that the lower half of the carbonates accumulated in early Late Miocene time. Then, the island was drowned, which was followed by uplift after it reached a lithospheric fore-bulge of the Philippine Sea at ~6 Ma and by episodic dolomitization at 5.5 Ma. The submerged islands rose to shallow environment, in which platform-like reefs formed in Late Pliocene time. These reef deposits occur down to ~50 mbgs and crop out in an interior basin of the island. Most of the deposits were dolomitized at 2 Ma. Thick atoll deposits, constructing main body of the present-day island, accumulated on the karstified platform. The atoll progressively degraded, with carbonate sedimentation being confined into the northwestern part. After subaerial exposure and subsequent karstification, shoal with coral patches extended on the eastern coast. These deposits were dolomitized at 1.6-2.0 Ma. Hermatypic organisms inhabited submarine cliffs to form localized, small-scaled, fringing reefs during the last interglacial periods.

Geomorphology of Continental Southeast Florida Reefs Based on High Resolution Bathymetric Data*Kenneth W BANKS**, *Richard DODGE*, *Werner PILLER*

608 SW 16th St, Fort Lauderdale, Florida United States of America

kbanks@broward.org

The northern portion of the Florida reef tract extends along the southeast Florida continental coast northward to latitude N26 °43.1' **acent**. The northern tract is a relict Holocene reef that ceased upward growth approximately 7000 BP. Presently the system represents a complex of shore-parallel lithified Pleistocene shoreline deposits upon which exists relict reef framework (outer two ridges) and living benthic communities dominated by Octocorals, stony corals, sponges, and macroalgae. Recent advances in bathymetric surveying techniques have resulted in the ability to collect high resolution data for large areas. Laser Airborne Depth Sounding (LADS) and multibeam sonar surveys were conducted along the northern Florida reef tract from 2000 to 2003 providing a bathymetric data set with 4 m horizontal and 0.3 m vertical resolutions. Shaded relief images of these data reveal a drowned reef morphologically analogous to the living reef of the southern Florida reef tract offshore of the Florida Keys. Common structural features include patch reef, reef flat, and spur and groove formation. These data will be used to describe the present reef structure and to examine the relationships among geomorphology and oceanographic forces to identify possible structuring processes. This provides a unique opportunity to examine reef morphology 7000 years post mortem in a time of rising sea level. In addition to exposed reef topographic data, sediment vibro-cores have been collected between the reef ridges and seismic sub-bottom profiles surveyed revealing reef talus rubble layers and buried patch reefs. Some of these patch reefs have been exposed by offshore dredging and will be cored and dated to develop a constructional sequence for reef development in continental southeast Florida during the Holocene transgression.

Submerged Coral Reefs around Hawaii and Papua New Guinea; Recorders of Catastrophic Sea-level Rise?

*Jody M WEBSTER**, David A CLAGUE, Kristin RIKER-COLEMAN, Juan Carlos BRAGA, Donald POTTS, Christina GALLUP, Eli SILVER
7700 Sandholdt Road, Moss Landing, California United States of America
jwebster@mbari.org

A series of well developed submerged reefs are preserved on the flanks of Hawaii and in the Huon Gulf, Papua New Guinea. A combination of rapid subsidence and eustatic sea-level changes are responsible for repeated reef drowning and backstepping over the last ca. 500 ka. Bathymetric, radiometric and sedimentary data indicate that these reefs are sensitive recorders of abrupt climate change and associated rapid sea-level rise. Prevailing theories of Quaternary reef drowning suggest that each reef drowned during the initial stages of the major deglaciations. However, we present new data from the -150 m reef around Hawaii indicating that this reef persisted for up to 4.3 ka following the end of the Last Glacial Maximum at 19 ka and that drowning was caused by catastrophic sea-level rise associated with meltwater pulse 1A. New U/Th and ¹⁴C AMS dates, combined with reinterpretation of existing radiometric dates, constrain the age of the coral reef to 15.2-14.7 ka (U/Th age). The drowning age of the reef is roughly synchronous with the onset of MWP-1A between 14.7 and 14.2 ka. Dates from coralline algal material range from 14-10 cal ka (calibrated radiocarbon age), 1-4 k.y. younger than the coral ages. The data indicate a dramatic rise in sea-level around Hawaii ca. 14.7 ka. Paleowater depths over the reef crest increased rapidly above a critical depth (30-40 m), drowning the shallow reef-building *Porites* corals and causing a shift to deep-water coralline algal growth, preserved as a crust and nodules on the drowned reef crest. Furthermore, we propose that the chronologic and paleobathymetric relationships recorded in the -150 m reef may serve as a model for interpreting the drowning history of other older and deeper submerged reefs, which may also have drowned during as-yet unidentified global meltwater pulses.

Narrow Window for Holocene Reef Accretion on Oahu, Hawaii due to High Wave Energy and Shallow Antecedent Topography

*Eric E GROSSMAN**, Charles H FLETCHER, Stewart J FALLON, Walter A BARNHARDT, Bruce M RICHMOND, Michael E FIELD
400 Natural Bridges Dr., Santa Cruz, CA 95060 United States of America
egrossman@usgs.gov

Analyses of 43 cores and >75 km of seismic reflection data from Oahu, Hawaii show that Holocene reef development along wave-exposed coasts is restricted to the period 9 to 5 ka and to areas of wave-energy dissipation. This is due to the influence of high wave scour and sea-level history over a shallow, uplifting Pleistocene substrate. The pre-Holocene erosion surface is exposed at the seafloor in settings impacted by annual long-period swell and is covered by a thin (<1-2 m) veneer of coral-algal bindstone where wave energy is reduced by sheltering or divergence. The only significant Holocene reefs observed occur in drowned stream valleys/channels and only between 9 and 5 ka where accommodation space existed below wave scour. Four long (6 to 22 m), continuous cores from windward and leeward sites preserve the entire transgressive sedimentation history and record the lithologic responses to rapid sea-level rise ca. ~8.2 ka and wave scour as sea-level rise flooded the complex stepped topography and slowed at 5 ka. In each core, the Holocene reef is offset 8-14 m below sea level since 9 ka (3-11 m below the Hanuama Bay reef) suggesting that persistent wave stress limited their development and maintained them in a futile "catch-up" accretion scenario. Reefs initiated with encrusting and massive framestone accretion, followed by branching coral framestone in water depths >14 m or rudstone in water depths <10 m (reef flat/platforms). Importantly, Holocene reef accretion at all sites studied on Oahu terminated between 5 and 3 ka, as the rate of sea-level rise and accommodation space decreased. Although the island-wide turn off can be most easily explained by the regional influence of wave scour at depth as sea level stabilized ca. 5 ka, changes in the oceanographic, climatic, and/or hydrologic regime in the middle Holocene may also be important.

Barrier Reef Formation at High Latitude Island Arc, Sekisei Reef, Southern Ryukyus, Japan

*Hironobu KAN**, Toshio KAWANA
3-1-1 Tsushima Naka, Okayama 700-8530 Japan
kan@cc.okayama-u.ac.jp

Sekisei Reef is a barrier reef rarely develops at high-latitude island arc, between Ishigaki and Iriomote Island, the southern Ryukyus. We discuss the barrier reef formation in the high-latitude island arc based on cores from three drill holes and five seismic refraction profiles. The Holocene thickness of the Sekisei Barrier Reef is mostly within 20 meters and around 25 meters at the maximum. The pre-Holocene relief lies between 15 to 30 meters, particularly around 20 meters below the present sea level. The large extent of antecedent platform around -20 meters is considered to be the major cause for the formation of Sekisei Barrier Reef. The Holocene reef started to grow around 8500 cal BP both on the rim and on the lagoon simultaneously. The lagoonal patch reef grew rapidly at an average rate of 9.2 m/ka with ramose corals and calcareous algae, then reached to the sea level at 6500 cal BP. The barrier reef rim composed of tabular corals grew to the sea level around 4000 cal BP which lags 2500 years behind the lagoonal patch reef. This back stepping reef growth in the early stage of reef development is presumably showing the accretion style of the high-latitude barrier reefs in contrast to those in the low latitude where reef rim grew to the sea level initially without back stepping.

Higher Sea Level or Storm Impacts? Resolving Funafuti's One Hundred Year Old Scientific Debate

*Roger F MCLEAN**
Australian Defence Force Academy, Northcott Drive, Canberra, ACT 2600 Australia
rmclean@adfa.edu.au

The Royal Society Coral Reef Boring Expedition (1896-98) to Funafuti atoll, provided three lines of evidence for a higher sea level: emergent *Heliopora* corals in mangroves on the main island; raised reef along the southwestern side of the atoll; and, corals in growth position on top of intertidal breccia buttresses. While most of the expeditioners supported a higher sea level, and used the subsequent fall to account for island formation, Halligan and Finckh, believed that the *Heliopora* corals were moated, and the 'raised reef' comprised storm emplaced reef blocks not *in situ* corals. Hedley also argued that the islands were formed through storm deposition, not sea level fall. This early version of the sea level versus storm debate continued over the next 70-80 years and reached its most acrimonious after the CARMARSEL Expedition in the late 1960's. Now, a mid-to late-Holocene sea level highstand is widely accepted throughout much of the Pacific, and present-day researchers wonder what the debate was all about. Given this situation, it is instructive to reconsider the Funafuti evidence of one hundred years ago, together with that of more recent studies in the mid-1970s by Schofield (1977) and late 1990s by Dickinson (1999), the latter indicating shoreline morphology of Funafuti 'reflects a relative mid-Holocene-sea-level high stand'. These data are examined following an extensive geomorphic survey, which included levelling and mapping of all 33 islands on Funafuti together with detailed examination of some of the critical Royal Society Expedition sites. These surveys, supported by radiometric dates, show no indisputable evidence for a mid-Holocene high stand on Funafuti, and generally endorse the views of Halligan, Finckh and Hedley. Indeed, the data provides good evidence of a storm history extending over the past 2000 years rather than a Holocene sea level history.

Island - Reef - Sea Level Interaction: Reef Island Formation as a Control on Reef Growth, South Maalhosmadulu Atoll, Maldives

*Paul S KENCH**

Private Bag 92019, Auckland New Zealand

p.kench@auckland.ac.nz

The critical association between sea level and reef growth underpins conventional theory of reef island development and stability. Existing models of reef island formation from the Indo-Pacific require reef growth and reef flat formation at sea level as a precondition for island development. This temporal sequence implies island construction post-dates vertical reef growth and that islands have a sensitive relationship to water depth across reefs, which is critical to assertions of island susceptibility to sea level change. This study presents results from detailed investigations of the formation of three reef islands in South Maalhosmadulu Atoll, Maldives. Topographic surveys of islands and adjacent reefs are combined with more than 102 cores to reconstruct island and reef stratigraphy. This is temporally constrained by radiocarbon dating to produce a chronology of reef and island development in the mid-to late Holocene. Results highlight a new mode of island evolution in which the presence of islands is found to influence latter stages of vertical reef growth in the late Holocene. This model differs markedly from the conventional Indo-Pacific model of island formation. Reef island initiation occurred 5,000-6,000 years ago on submerged reefs approximately 2.5 m below current sea level. Island building occurred rapidly and was effectively complete 4,000 years ago. Since then, the outer reef continued to grow vertically, effectively in catch-up mode, encasing the islands. Morphodynamic variability of island beaches prevented vertical reef growth on the inner reef producing a marked moat between the outer reef and island shoreline. Consequently, the interaction between island morphodynamics and reef growth controlled ultimate reef topography and stabilised the islands

Radiocarbon Ages and Isotope Fractionations of Beachrock Samples Collected from Okinawa Islands, Southwestern Part of Japan

*Kunio OMOTO**

25-40, 3Chome, Sakurajousui, Setagaya-ku, Tokyo 156-8550 Japan

omoto@chs.nihon-u.ac.jp

A total of 119 beach rock samples were collected from 42 sites of 6 islands consisting of the Okinawa Islands, in the southwestern part of Japan. Their radiocarbon ages and isotope fractionations were measured at Radiocarbon Laboratory of Nihon University. Judging from radiocarbon ages obtained, the beachrocks began to form ca. 6,800yrs BP and some of them are still under development at present in the islands. Values of isotope fractionations of different materials making up the beachrocks ranged between +6.0 per mil and -6.0 per mil, while the average value was 1.5 per mil. The difference of age between isotope correction and reservoir correction is ca.+40 years. The average correction ages for fossil coral, fossil shell and calcarenite samples were 412 years, 438 years and 436 years respectively. Isotope fractionations in excess of 2 per mil suggest that these beachrocks were strongly influenced by underground and fresh running water when they cemented. A late Holocene sea level change was reconstructed based on the radiocarbon ages and elevations of sampling sites obtained from the surveyed islands. It has remained at the same level as at present one for at least the past 5,000 years on the stable islands except for several uplifted coasts.

Sea Level Changes during the Last Interglacial in Southwest Bohol, Central Philippines

Cherry L RINGOR, Akio OMURA, Yasuo MAEDA*

920-1192 Kakuma-machi, Kanazawa City, Ishikawa Japan

clringor@earth.s.kanazawa-u.ac.jp

Regional sea level studies in the central region of the Philippines show that this area experienced minimal vertical displacement in contrast to other areas of the archipelago. Specifically, Panglao Island in southwest Bohol is considered relatively stable since the Last Interglacial and thus can be used as a reference site for sea level work. Using a highly accurate ^{230}Th -spectrometric U-series method, we dated some coral reef terraces along the coastal areas of Pamilacan Island, Panglao, and Punta Cruz in southwest Bohol, and reexamined the sea level history during the Last Interglacial. In Pamilacan Island, radiometric dating of successive terraces yielded age groups of 79-83 ky, 101-108 ky, and 122-131 ky, at elevations of 3-4 m, 9-13 m, and 20-27 m apmsl, respectively. Based on published mean sea level data of 3-6 m apmsl during MIS 5e, we estimated constant rate of tectonic uplift ranging from 0.18-0.21 m/ky for the past 125 ky. Using these estimates of local uplift rates, paleo-sea levels at 105 ky and 82 ky are calculated to be 9-11 m and 6-9 m below present, respectively. In contrast, elevations of reef terraces correlated with MIS 5e in Panglao and Punta Cruz are only about 3-13 m apmsl and 5c terraces if not absent, are poorly developed. In one of the sites surveyed in Panglao, heights of the 5c and 5e terraces are only 5 m and 7-8.1 m, respectively. Here, local uplift rates since MIS 5e are much lower, about 0.01-0.04 m/ky and estimate of 5c mean sea level is at least as high as present. Variation in the uplift rates and paleo-sea levels within these three neighboring islands is probably related to localized activity of tectonic structures that caused vertical displacements in the flight of terraces in Pamilacan.

U-series Ages of Carbonate Sediments Underlying the Lowest Pleistocene Marine Terrace in Kikai Island, Central Ryukyus, Southwestern Japan

Miyuki INAGAKI, Akio OMURA, Hiroe YAGI*

Kakuma-machi, Kanazawa, Ishikawa Japan

kikai@earth.s.kanazawa-u.ac.jp

Pleistocene marine terraces distributed in Kikai Island have generally three steps. They consist of mainly thick Middle Pleistocene and thin Upper Pleistocene sediments. The higher two terraces are composed of coral limestone and the lowest terrace, extensively developed southwest of this island, is underlain by carbonate sediments composed of well-preserved biogenic remains, such as foraminifers, brachiopods, molluscs, and fragments of bryozoa, calcareous algae, and reef-building corals. We applied ^{230}Th -spectrometric U-series dating to three species of solitary corals, *Trachyphyllia geoffroyi*, *Cycoloseris* sp., and *Flabellum rubrum*, collected from the lowest terrace sediments. They provided reliable dates ranging from 96.6 ± 2.8 to 56.7 ± 2.2 ky (2 statistical error), corresponding to MIS 5b to 3. These can be divided into four age groups of 93.6 ± 2.8 - 87.6 ± 2.8 ky, 77.2 ± 2.2 - 76.1 ± 2.0 ky, 70.4 ± 2.0 - 68.5 ± 2.4 ky, and 63.4 ± 1.8 - 56.7 ± 2.2 ky. The lithofacies and dates suggest that this sediment was deposited on the insular shelf during both relatively high and low sea stands. Correlation is also observed between the age and elevation of samples where older samples occurred at higher, and the younger samples at lower elevation. In addition, corals obtained from landward of this terrace tend to show older ages, corals from seaward showed younger. Coral limestone is also sporadically distributed on this terrace. The youngest date obtained from them was 40.2 ± 1.2 ky from a sample collected at the southwest end of the terrace, about 25m apsl. Dates of the other four samples from the same site are comparable within the error; the average was calculated to be 41.2 ± 0.4 ky. We infer that this terrace was formed in different depositional environment between MIS 5b and 3 with the fall of relative sea level: from the insular shelf where fore-reef sediments were deposited to shallow water environment where coral reefs were formed. Thus, no Pleistocene carbonate sediments, younger than about 40ka, are exposed on the surface of Kikai Island.

Responses of Coral Reefs to Increased Amplitude of Sea-level Changes at the Mid-Pleistocene Climate Transition

*Yasufumi IRYU**, Kazuyuki YAMAMOTO, Tokiyuki SATO, Shun CHIYONOBU, Kenichi SAGAE

Aobayama, Sendai 980-8578 Japan

iryu@dges.tohoku.ac.jp

We show responses of coral reefs to increased amplitude of sea-level changes at the Mid-Pleistocene Climate Transition (MPT), based on results of stratigraphic and sedimentologic investigations on the Ryukyu Group on the northern half of Motobu Peninsula and calcareous nannofossil biostratigraphy in 10 borehole cores drilled for the construction of underground dams. Our data shows that coral reef growth started in earliest Quaternary time (1.45-1.65 Ma) and that extensive reef formation dates back to ~0.9 Ma. The mode of Quaternary sedimentation changed at ~0.9 Ma in the study area. Before the time, thick siliciclastics and carbonate-siliciclastic mixture accumulated, which was followed by accumulation of bioclastic sediments (detrital limestone). No indications have been found of episodic subaerial exposures during the deposition of these sediments, or no calcareous nannofossil biozones are lacking. Examinations of benthic foraminiferal assemblages showed that the siliciclastics and carbonate-siliciclastic mixture were deposited in shelf and fore-reef environment. The detrital limestone includes components characterizing fore-reef environment. Therefore, the coastal areas of northern half of Motobu Peninsula were mostly in fore-reef to shelf environments before ~0.9 Ma, during which the sediments had not been subaerially exposed. Shallow-water counterparts of the shelf to fore-reef deposits, coral limestone and fluvial conglomerate, are very limited in its distribution at present and may have much more poorly developed than the deeper ones at the deposition. Whereas, coral limestone that accumulated at ~0.9 Ma extends over the study area, ranging in elevation from 0 to 70 m. This coral limestone is overlain by fore-reef to shelf carbonates (detrital, rhodolith, and *Cycloclypeus-Operculina* limestones) which, in turn, overlain by coral limestone. The succession of the Ryukyu Group in this area records changes in amplitude and frequency of sea-level fluctuations at the MPT.

Holocene-Modern Scleractinian Coral Microstructure and Diagenesis: Constraints on Spatial Resolution and Interpretation of Geochemical Data

Luke D NOTHDURFT*, Gregory E WEBB

2 George Street (GPO Box 2434), Brisbane, Queensland 4001 Australia
lnothdurft@qut.edu.au

Scleractinian coral skeletons do not accrete along a continuous front and may contain as many as three separate phases of skeletogenesis including; trabecular extension, subsequent infilling of septa, and thickening related to density bands. Therefore, closely adjacent structural elements of the coral skeleton may not reflect deposition at the same time. The use of fine scale geochemical sampling techniques such as laser ablation inductively-coupled plasma mass spectrometry and ion microprobe, which provide increasing levels of spatial resolution for studying paleoclimate, coastal run-off, pollution, and ocean upwelling are ultimately limited by our knowledge of skeletal microstructure. The skeletal microarchitecture of different coral genera varies. In acroporid corals an initial phase of growth involving radiating fibrous aragonite trabeculae is followed by filling of inter-trabecular spaces with bundles of aragonite fibres that occur at an oblique, low angle to the basal ectoderm resulting in "shingle" like microstructure. Trabecular and shingle aragonite are intimately mixed spatially, but represent temporarily disjunct skeletal deposition. *Porites* skeletal microstructure lacks distinct separate phases of skeletogenesis in septa, but septal thickening at the base of the calyx continues while trabecular tips grow in calices. Therefore the age of septa increases both downwards and inwards. Comparison of live-collected and Holocene (5-6 ky) scleractinian corals reveals that recrystallization of original skeletal fibres (<0.5 μ m in diameter) to coarser crystals (2-4 μ m in width) occurred in the marine phreatic environment. Such microstructural alterations have not previously been identified in seawater over such a short time span. Additionally, parts of corals less than 2-3 years old may contain microborings and magnesian calcite and aragonite cements. Changes in the distribution of elements such as strontium and carbon associated with diagenetic alterations (recrystallization and cementation) may introduce significant errors in the use of the coral skeleton for paleoclimate interpretation and dating of seawater curves.

Coral Ba/Ca Records of Mid-Holocene Upwelling Activity in New-Caledonia

Lucien F MONTAGGIONI*, Guy CABIOCH, Thierry CORREGÉ, Florence LECORNEC

3 Place Victor Hugo, 13331 Marseilles Cedex 3 France, Metropolitan
lmontag@up.univ-mrs.fr

A variety of inimical factors, i.e. sea surface temperature, nutrients, nature of substrates, were invoked for explaining the retardation in reef settlement in New-Caledonia. Sr/Ca ratios used as a thermometer and Ba/Ca ratios as a tracer of nutrient loads were analysed in modern and mid-Holocene *Porites* skeletons. From modern corals collected close to the outer reef barrier, higher Ba/Ca values correlate positively with higher Sr/Ca ones and uncorrelate with lower Sr/Ca ratios, thus indicating that the increase in barium amounts occurs mainly during the less hot and drier (winter) seasons and that Ba does not derive from weathering of barite-rich, phanites outcropping in the mainland. These higher Ba/Ca values therefore could express the influence of active upwelling along the outer shelf, partly driven by the south trade winds during the colder season. Furthermore, comparisons between Ba/Ca values measured in modern corals from inshore and outer shelf-reefs respectively indicate that Ba supplies are higher on the outer shelf settings than along the coast. Such differences give further evidence of an open-sea origin for barium. By contrast, Ba/Ca records from the fossil *Porites* reveal that, between 6 and 4 calendar kiloyears B.P., Ba levels inshore averaged those at present reported from the outer shelf areas and reached maximum values during winters. Contrary to the present times, the coastal environments are believed to have experienced nutrient-loaded plumes that crossed over the inner shelf during the mid-Holocene, as a result of stronger wind-generated currents. The timing and intensity of paleoupwelling during the Holocene have implications for the understanding of reef development in New-Caledonia.

Reading Coral Growth Histories

Janice M LOUGH*

PMB 3, Townsville MC, Queensland 4810 Australia
j.lough@aims.gov.au

Positive prints of X-radiographs of coral slices are common tools used to identify and date annual density bands and identify tracks and sample locations for subsequent growth and geochemical analyses. The latter are used to develop quantitative reconstructions of past climate and environmental conditions in tropical ocean regions. The X-ray prints also provide a visual representation of coral growth, changes in coral growth and growth hiatuses. Changes in growth and growth hiatuses often represent a response of the coral to an environmental or climatic stress. These events are, therefore, worth noting to date a given stress and thus assess the spatial extent and frequency of such stress events through time. Documenting the occurrence and appearance of such events also provides useful insights into the growth response of the coral to stress, the recovery of corals from stress and may, on occasions, contribute to interpreting anomalies in geochemical records. Several examples of coral growth changes observed in X-rays and their causes will be presented. "Reading" the X-rays of coral slices can contribute to understanding past climatic and environmental stresses and recovery on corals and coral reefs.

Optical Densitometry of Digitized Images: A Method for Measurement of Coral Skeletal Density from X-Radiographs

Juan P CARRICART-GANIVET*, David J BARNES

Av. Centenario km 5.5. Apdo. Postal 424. 77000. Chetumal, Q. Roo. MEXICO.
jpcarri@ecosur-qroo.mx

A method, based upon Chalker et al.'s (1985) photodensitometry method, is proposed for the measurement of coral skeletal density. In the technique described here, variations in exposure of the X-ray film are measured in digitized images rather than by photodensitometry. X-radiographs were made of slices from skeletons of *Montastraea annularis* collected in La Blanquilla Reef, Veracruz, Mexico. Included on the X-ray film with each coral slice were aluminium and aragonite step-wedges and two aluminium bars. The developed X-ray films were digitalized with an ArtixScan 1100, MICROTEK scanner at 75 dpi resolution. Optical density (the grey scale values of pixels) was measured in three tracks across the digital image of the coral slice and along images of the step-wedges and aluminium bars using Scion Image (Scion Co., USA) software for Windows (Microsoft Corp.). Semi-logarithmic plots of optical density vs. thickness of the aluminium and aragonite provided curves in which the initial slope was linear. These slopes are the relative absorption coefficients for aragonite and aluminium, and they allowed estimation density in tracks across and along digital images of the coral slice and aluminium bars, provided thickness was known. Measurements of density along the aluminium bars were used to correct for variations in the intensity of the X-ray beam along the anode-cathode axis (the heel effect), which could otherwise introduce considerable errors in measurements of density across skeletal slices. Relative absorption coefficients varied from one X-ray to another, most likely due to differences in the X-ray film cassettes. This further emphasized the need to include step-wedge standards and aluminium bars in each X-ray of a coral slice. Results obtained using this technique compared well with results obtained with direct gamma densitometry of skeletal slices.

Growth and Demography of Two Species of Reef Shark on the Great Barrier Reef, Australia

*William D ROBBINS**

School of Marine Biology and Aquaculture, James Cook University,
Townsville, 4811, Qld. Australia
Will.robbsins@jcu.edu.au

Reef sharks are a globally distributed group of fishes, characteristically associated with shallow water environments. They share with other elasmobranchs very low reproductive and population turnover rates, and limited capacities for short-term dispersal. This combination of characteristics makes them particularly vulnerable to line-based fisheries. This study assessed age and demographic parameters for two species of reef shark in order to assess risks associated with fishing pressures. Whitetip reef sharks (*Triaenodon obesus*) and Grey reef sharks (*Carcharhinus amblyrhynchos*) were sampled from the central and northern Great Barrier Reef, Australia. Ages were determined by counting periodic band formation on vertebral thin sections. Maximum life spans were estimated at 19 and 22 years for the Whitetip and Grey reef shark respectively. Reproductive data showed that both male and female reef sharks reach sexual maturity between one third to one half of their lifespan. The data also suggested that the oldest decade of the Grey reef shark population may have been removed through fishing mortality, markedly limiting their reproductive output. Natural mortality estimates for the two species were quite high, averaging over 0.19 for each species. This combination of late maturity, limited offspring production and prevailing natural mortality shows that reef sharks, like many other shark species, are highly vulnerable to population depletion. Preliminary examination of age-based demography suggests that these species may already be under unsustainable fishing pressure on the Australian Great Barrier Reef.

New Techniques to Assess the Abundance of Tropical Reef Sharks

Mark MEEKAN, Mike CAPPO*

PMB 3, Townsville MC, Qld Australia, 4810. Australia
m.meekan@ajms.gov.au

For centuries artisanal fishermen have been aware that sharks are attracted to underwater sounds and have used this behaviour to target and capture these animals throughout the Indo-Pacific. Here, I describe our attempts to develop, trial and compare techniques that combine underwater video with speakers emitting underwater sounds as new, non-destructive methods for estimating the abundance and distribution of sharks. The localities chosen for these trials were the coral reefs and banks of Rowley Shoals and Scott Reef in northern Australia. Both these reef systems are isolated oceanic atolls that are remote from coastal regions. At Scott Reef, fishermen from Indonesia are able to harvest sharks, while they (and all commercial shark fishers) are excluded from reefs in the Rowley Shoals. We found that acoustic and video techniques showed great promise as a means of assessing shark abundance, particularly in areas of reef inaccessible to divers. We were able to document striking differences in diversity and numbers of sharks among habitats within a reef, and between reefs subject to different fishing pressure. Future directions for research and development of these systems are identified.

Assessing the Risk to Coral Reef Organisms of Extinction: The Example of Groupers and Wrasses

Andrew S CORNISH, Yvonne J SADOVY*

Pokfulam Rd. Hong Kong
acornish@hkucc.hku.hk

Although living coral reef resources are often extensively utilized by man, very few coral reef taxa have been evaluated for their vulnerability to extinction. The IUCN Species Survival Commission Specialist Group for Groupers and Wrasses has been evaluating species of these two families for the IUCN Red List since 1998. Such global assessments have long provided a valuable benchmark in the conservation management of terrestrial flora and fauna, but are under-utilized in marine conservation. The potential benefits of the IUCN Red List programme are discussed in addition to the evaluation criteria for the assessments themselves, and "tricks of the trade" that can be used to overcome the paucity of data for most reef species. Various species of Groupers (Serranidae) and Wrasses (Labridae), notably the Humphead wrasse (*Cheilinus undulatus*), are used to illustrate the assessment procedure and techniques.

Sustaining Artisanal Fisheries: The Effects of NTZs on Gleaned Molluscs in South Sinai, Egypt

Francesca BENZONI, Jennifer S ASHWORTH, Anna M ADDAMO, Ayman MABROUK, Paolo GALLI*

Dipartimento di Biotecnologie e Bioscienze, Piazza dell Scienza, 2, I-20126 Milano Italian Republic
francesca.benzoni@unimib.it

The Nabq Managed Resource Protected Area (MRPA) is located on the southern part of the Gulf of Aqaba coast of South Sinai, Egypt. A network of four no-take zones (NTZs) was established in 1995 within the Nabq MRPA to promote sustainable management of finfish stocks exploited by artisanal Bedouin fishermen. Gathering of *Tridacna* spp. and of other edible invertebrates on the reef-top is also part of the traditional fishery practised by the local Bedouin population, mainly by women. To assess the effects of these NTZs on gleaned invertebrates a survey of *Tridacna* and other invertebrates, along with reef structure and coral community composition, was undertaken within NTZs boundaries, and in four adjacent fished areas. *Tridacna* population distribution and structure were assessed at different zones along the reef profile at sites within and outside NTZs, with a survey of discarded shells also conducted. While no significant differences were found between TZs and NTZs benthos composition, differences in *Tridacna* and *Tectus* populations were found at the same sites. The size-frequency distribution of gleaned *Tridacna* showed a smaller size range than live giant clams within NTZs, while the formers had a greater modal size than live clams. Within the TZs there was a positive relationship between density of giant clams and of *Diadema*, thought to be due to high densities of the urchins acting as a deterrent to collection. Although the establishment of NTZs was initially planned for finfish management, it has led to differences in *Tridacna* populations between TZs and NTZs. For these sessile bivalves, spillover from NTZs to fished areas, such as may be important with finfish, is negligible or absent. Enhancement of adjacent fisheries is likely to be due to increased larval export.

Can Ecosystem-based Management Be Applied to the Hawaiian Black Coral Fishery?

Anthony D MONTGOMERY*

1151 Punchbowl Street Room 330, Honolulu, Hawaii, 96813 United States of America

Tony.Montgomery@hawaii.gov

Hawaii has had an active fishery for black coral since 1958. This fishery primarily (90%) consists of *Antipathes dichotoma* with the remaining 10% consisting of *A. grandis* and *Myriopathes ulex*. Currently, the State of Hawaii and the U.S. National Marine Fisheries Service (NMFS) manage the harvest of black coral around the Hawaiian Islands for the jewelry trade. The two main threats facing this fishery is a reduction in black coral biomass from years of harvesting and an invasion of an alien soft coral, *Carijoa riisei*, into deepwater black coral habitat. These threats have raised concerns for the future of this fishery and warrant a re-evaluation of the management of this fishery. This fishery has been historically managed at a species level with a minimum size restriction. However, the criteria for future management may need to include more than a single-species model. A multi-species management approach may be difficult due to our limited knowledge of the ecology of black coral as well as the Hawaiian deep reef community. Black coral may serve as an important keystone species due to the amount of habitat it creates. Therefore, the criteria needed to evaluate this fishery from an ecosystem perspective includes an understanding of the role of black coral as a three dimensional structure on the deep reef community as well as the impacts of an ecological phase shift caused by the overgrowth of the alien soft coral *C. riisei*. An understanding of these criteria may give insight to the ecological resiliency of a Hawaiian black coral forest and the applicability of ecosystem-based management.

Indirect Links between Subsistence Fishing and Sea Urchin Density at Large Spatial Scales on Fijian Coral Reefs

Rebecca E MITCHELL*, Nicholas K DULVY, Nicholas V C POLUNIN

Ridley Building, University of Newcastle, Newcastle upon Tyne, NE1 7RU United Kingdom of Great Britain and Northern Ireland

R.E.Mitchell@ncl.ac.uk

High sea urchin densities on coral reefs in heavily populated regions of the Caribbean and East Africa have been attributed to removal of potential predatory fish by fisheries exploitation. These dense urchin populations cause substantial bioerosion and subsequent reductions in reef complexity and productivity have serious implications for reef resilience and future fisheries production. Here we further explored associations between fishing activities and sea urchin density on coral reefs in a region of Fiji where anthropogenic disturbance besides non-destructive fishing practices were minimal. Large spatial-scale surveys of urchin density, fish biomass and habitat variables were carried out on outer reef sites across a range of fishing intensity provided by thirteen islands in the remote Lau group, Fiji. Total urchin density was low (0.05 - 0.7 urchins m⁻²) and although significant differences were evident among island fishing grounds, they did not relate systematically to variations in fishing pressure. Only the density of small urchins illustrated a positive relationship with fishing intensity but there was little indication from fish biomass data that this resulted from fisheries-related depletion of potential predators. Although fishing influenced large piscivorous and herbivorous fish in Lau, large invertebrate-feeding fish did not relate straightforwardly to variations in fishing intensity, and biomass of small fish of all trophic groups appeared to be unaffected by exploitation. Striking differences in benthic community structure identified among islands were most likely related to recent outbreaks of *Acanthaster planci* at the islands in question. The possibility that greater densities of small urchins were linked to *A. planci* disturbances at the most exploited island and whether outbreaks of *A. planci* could be linked to fisheries exploitation are discussed.

Causes of Collapse of Holothurian Fishery in Mexico

Maria Dinorah HERRERO-PEREZUL*

Apartado postal 592. CP 23000. La Paz, Baja California Sur, United Mexican States

dainoper@hotmail.com

The holothurian *Isostichopus fuscus* is a common inhabitant of coral communities (specially *Pocillopora* spp) in the Gulf of California and in the Pacific coasts of Mexico. It was the basis of an artisanal fishery of relative importance in the early 1990s, although is currently protected by the Mexican Government since 1994. However, no regulation measures existed for the fishery due the lack of information. The objective of this work was to assess the status of the fishery in Mexico and analyse the possible causes of collapse. This study is the result of the analysis of all the biological information generated to this date, and also by the analysis of catch and effort data from 1989 to 2001. The results obtained indicate that this is a very vulnerable resource. First it is the largest aspidochirotid of the Mexican Pacific coasts, reaching maximum length and weight of 30 cm and 800 g respectively so it is easily spotted by fishermen. Second, the species shows an inverse relation between growth rate and longevity, having a life span of 17 years and attains sexual maturity at 5 years of age. Reproduction occurs once a year during summer, when sea-surface temperature reaches 27°. The age of first capture was 4 years old, so the fishery targeted immature specimens too. *I. fuscus* populations are scattered with low densities (about 0.7 ind/m²), a slight increase in effort results in a reduction in population size. By 1994, the number of boats practically doubled in one year and consequently, catch decreased drastically. In addition, the collapse of the *I. fuscus* fishery can be attributed to the strong levels of exploitation and the lack of information. But also to the biological characteristics of the resource, which should be considered of most importance for management and conservation purposes.

Long Term Assessment of MPA Success in Northern Bohol, Central Philippines

Brian T CABRERA*, Brian GILES, Melita SAMOILYS, Denise MCCORRY, Amanda C J VINCENT

Project Seahorse #222 1st St. Happy Valley Subdivision, Guadalupe Cebu City, Republic of the Philippines

btc_ps@mozcom.com

Our long-term monitoring program provides an unusually thorough study of seven marine protected areas (MPAs) in a small region of the central Philippines. Comparison of inside/outside MPA and distant control sites shows convincing increases in fish abundances, particularly in top predators and mid-trophic fish families, in well-enforced MPAs. Community support for marine protected areas is a key factor in the success and persistence of no take-marine sanctuaries operating in the central Philippines. Using seahorse conservation as a model initiative for coastal resource management in the Danajon Bank reef complex of northern Bohol, we have assisted communities to establish MPAs in the region. Analysis (1998-2002) yielded mixed results in terms of the effectiveness of monitoring ecosystem responses to MPA establishment through the parameters we selected. Results from the fish data are encouraging since higher densities of medium to large mid-trophic and top-level predator fish, as well as the putative indicators of coral health, were recorded inside the majority of the MPAs compared with outside MPAs and control sites. There was little difference in percentage live corals, dead coral or rubble inside as compared to outside the MPAs but cover was higher for both inside and outside MPAs as compared to the control sites over a three to five-year period. The higher fish abundance may reflect protection from fishing mortality (direct or indirect) rather than improved reef condition. Conversely, live coral may not accurately reflect reef condition, as it fails to account for type and/or diversity of coral species.

Coral Transplantation: An Additional Tourist Attraction in Polhena Reef of Southern Sri Lanka

Terney Pradeep KUMARA (FRANSISCU BDUGE), Olof LINDEN, David SOUTER, Ruchira CUMARANATHUNGA*

178/A, BANDARAMULLA, MIRISSA, SRI LANKA Democratic Socialist Republic of Sri Lanka

terney@fish.ruh.ac.lk

Polhena is a fringing reef situated on the southern coast of Sri Lanka. The reef area consists of patchy reefs (56 %), Sea grass beds (9 %), coral rubble (23 %) and sand bottom (12 %). During 98 El Nino event, about 90% of living corals died and the remaining amount is highly under stress as the area is a popular public beach both among local communities and tourists. This study was carried out from August 2002 to November 2003. Polhena was selected because of the availability of suitable protruded dead branching corals for the attachment of transplants. Broken live *Acropora formosa* fragments were collected from Weligama reef and transported to Polhena in water filled plastic baskets and live *Acropora subulata* was collected from broken and only existed colony in the centre of the reef. The natural substrate was first cleaned by scraping with a wire brush and the collected corals were attached to the substrate using commercially available rubber bands. The height and the width of 20 fragments of *A. subulata* and height of 12 fragments of *A. formosa* were measured in every three months intervals and the number of tourists visit to the site was calculated monthly, distributing the data sheets to the tour guide operators. *A. subulata* showed a significant increase in both height and width in each three months time. $F = 25.468$, $df = 59$, $P < 0.000$, one way ANOVA and $F = 330.494$, $df = 59$, $P < 0.000$, one way ANOVA for height and width respectively. The mean increase of height was 1.516 ± 0.858 mm/month and the width was 5.688 ± 1.467 mm/month. *A. formosa* also showed a significant growth rate 6.138 ± 1.312 mm/month. Tourist visits to this site were zero at the beginning of the study and at the end it came up to 36.533 tourists per month and the total visited number were 548 at the end.

NOAA Fisheries, US Military Partnering to Conserve and Sustain Coral Reef Ecosystems in the Pacific and Indian Ocean

*John NAUGHTON**

1601 Kapiolani Blve Suite 1110 Honolulu, HI 96815 United States of America
john.naughton@noaa.gov

During the last few years, NOAA Fisheries and the other resource agencies have been working closely with the US Military to aid them in assessing the marine resources and habitats under Department of Defense (DOD) control in island areas throughout the Pacific and Indian Ocean. This has been mandated under a number of US environmental laws, such as NEPA, CWA, BRAC, and the Installation Restoration Program. A number of unique Cooperating Agency Agreements and MOUs have also been established to accomplish coral reef protection work. Often coral reef areas off DOD facilities have been subjected to serious impacts in the past from military activities. Examples of partnering activities to protect and restore coral reef habitat and associated fishery resources are presented, and include work conducted in water off military facilities at Kwajalein Atoll, Midway Atoll, Wake Island, Johnston Island, Diego Garcia Atoll, and the target islands of Kahoolawe, Kaula, and Farallon de Medinilla. Coral reef and fisheries enhancement projects include establishing no-take fishing areas, protecting sea turtle feeding and nesting sites, utilizing non-destructive methods for removing unexploded ordnance, restoring reef habitat, creating artificial reefs, removing oil from World War II ship wrecks, and creating large marine protected areas. The Navy often requests NOAA Fisheries expertise for short-term projects, recently to identify a site devoid of coral cover for placement of the vessel F/V Ehime Maru for crewmember recovery off Oahu, Hawaii. Several DOD agencies are working with NOAA Fisheries and other resource agencies to conduct long term monitoring, including coral reef recovery at several military facilities in the Pacific Islands. Selected projects with quantitative data sets are discussed.

Fishery Management of a High Latitude West Australian Coral Reef

*Jill STJOHN**

PO Box 20, North Beach, Western Australia 6920 Australia

jstjohn@fish.wa.gov.au

West Australian coral reefs were recently identified by Roberts et al. (2002) as one of 18 hotspots for coral reef diversity worldwide, ranking highly in total diversity (7th) and endemic species (2nd), but least threatened environmentally (15th). The most southern coral reef in the Indian Ocean, the Houtman Abrolhos Islands (or Abrolhos system), has extensive coral reefs and three distinct features that make it unique. This high latitude (28-29°S) archipelago has a transitional coral reef environment where temperate species mix with a predominantly tropical biota. For example, tropical coral species coexist with temperate macroalgae. Compared to reefs worldwide, the Abrolhos system is relatively pristine as the area is remote from human population centres and major industrial activity and it has had a relatively short history of fishing. The entire Abrolhos System is managed by the Western Australian Department of Fisheries. Unlike most coral reefs that have low-value, multispecies, fisheries, the Abrolhos System supports a single species fishery for the endemic western rock lobster (*Panulirus cygnus*, AU\$ 50 million), with smaller finfish (\$ 1 million) and aquaculture industries. The western rock lobster fishery was the first in the world to be awarded Marine Stewardship Council certification as an ecologically sustainable fishery in 2000. Despite restrictions on the type of line fishing near reefs and the introduction of no-fishing areas in the early 1990s, commercial and recreational catches of coral reef fishes have increased due to improvements in fishing technology. Formal management of the commercial line fishery is underway. In the move towards ecosystem-based management the department has established a field station and initiated a large collaborative research project on the oceanography, biodiversity, processes and productivity of the Abrolhos system. Such knowledge will provide the baseline information required to manage and assess both the ongoing fisheries and future developments.

Managing in a Multiple Boundary Context: The Coral Coast MPA

Beatrice P FERREIRA, Mauro MAIDA*

Av. Arquitetura s/n, Campus Universitario, Recife, PE 29060-900, Brasil

beatrice.ferreira@ibama.gov.br

The Coral Coast MPA in the north-eastern coast of Brazil is a multiple use protected area of 413.563 ha, including the reef shelf that encompasses mangroves, sea grass beds, sandy bottoms, coral and algae until the break of the continental slope. Reef fishes are intensively exploited in the region. Subsistence fishery concentrates in the mangroves and shallow reefs while medium scale commercial fisheries using sailing or motorised boats reach deeper formations until the shelf break. Since 1998, the Coastal Reef Project has been gathering socio-economic and biological information and implementing several activities in the region, with a participatory and adaptive management approach. Management interventions applied to date include the establishment of no-take areas, effort limitation through licence restrictions, ban on capture of some species or activities, planning for the use of the coastal areas, seasonal closures, and development of alternative uses of resources. We here will present case studies which resulted from these efforts, including 4 year monitoring of a closed area of four sq km thorough UVC and fisheries surveys in the adjacent reefs. We will discuss effectiveness in relation to the biology and distribution of the various species, with emphasis on the relationship of biological and management boundaries, and what are the existing perspectives for the sustainability of coral reef fisheries and related ecosystems in the region.

Assessing the Impacts of a Community-based Network of Marine Protected Areas through Long Term Monitoring of Coral Reef Resources

*Eric VERHEIJ**, *Melita A SAMOILYS*, *Hassan J W KALOMBO*

P.O. Box 5036, Tanga, Tanzania United Republic of Tanzania
tangacoast@kaributanga.com

A long term integrated and participatory conservation programme in northern Tanzania has resulted in the establishment of six collaborative management areas (CMAs), which are zoned for multiple uses and include no-take zones. Monitoring of these areas was initiated bi-annually in 1996 and has continued to the present. Trained community members conduct the monitoring. The following parameters are measured: benthic substrate (live, dead, or bleached coral, macro-algae, soft coral, sponge, seagrass and various abiotic parameters including rubble); sedentary macro-invertebrates (sea-urchins, sea-cucumbers, starfish, giant clams, octopus, crayfish, crown-of-thorns) and fish (generally identified at the family level, covering 13 families). Analyses to date have shown increases in fish densities and live coral cover on the closed reefs since management and enforcement was implemented in 1996. However, the pattern of recovery in coral cover was complicated by an El Nino coral-bleaching event in 1998. In addition, coral cover was affected by an outbreak of a coral disease along the east African coast in 2003, which affected 4 genera, including *Montipora* and *Astreopora*. The results indicate that recovery in closed reefs from bleaching and the disease was greater, supporting improved resilience. Further, coral cover has increased through the CMAs since destructive fishing practices, primarily dynamite fishing, have been greatly curtailed. The results demonstrate the positive impacts of protected areas for managing coral reef resources, and the effectiveness of community participation in long term monitoring.

Tanga Coastal Zone Conservation and Development Programme: An Example of an Successful Collaborative Management of Coastal and Marine Resources in Northern Tanzania

*Hassan J W KALOMBO**, *Solomon J MAKOLWEKA*, *Eric VERHEIJ*

P.O. Box 5036, Tanga, United Republic of Tanzania
tangacoast@kaributanga.com

The Tanga Coastal Zone Conservation and Development Programme (TCZCDP) started in 1994, with the general goal of enhancing the well-being of the coastal communities in the Tanga Region by improving the health of the coastal and marine environment that they depend on. A collaborative management approach is being used to help fishing villages and local government authorities to improve management of coral reefs, mangroves and other coastal resources. Districts and village level institutions are being strengthened so that they can undertake integrated management in a sustainable way. The main objectives of the programme are: a/ Conservation and sustainable use of coastal resources, b/ Capacity building, c/ Establishment of appropriate institutional arrangements, and d/ Environmental education and awareness-raising. The Programme has been implemented in three phases, Phase 1 (1994-1997), Phase 2 (1997-2000), and Phase 3 (2001-2003), following the model developed by Piccotto and Weaving (1994), which has four distinct stages: listening, piloting, demonstrating and mainstreaming. Collaborative Management Area Plans (CMAPs) were developed using an 8 step process. Six CMAPs were formulated, managing all of the coastal waters of Tanga Region. They are covering a total area of 1,603 km². Successes CMAPs include: a/ High compliance rate by the communities because of ownership of the CMAPs, including a decline of dynamite fishing by 96%, b/ status of the coastal marine resources improved, including a 5% mangrove cover increase, rapid recovery of the coral cover after the El Nino event of 1998, and continuous decline in the initially very high sea-urchin densities, c/ fish stocks increased by 100% since the start of the interventions, d/ fish catches are increasing, and e/ high awareness among local communities due to participation in resource assessment.

Sustaining Coral Reef Ecosystems and their Fisheries in the Kiunga Marine National Reserve, Lamu Kenya

*Julie CHURCH**, *David O OBURA*

P.O. BOX 15551, Nairobi 00503 Republic of Kenya
juliec@africaonline.co.ke

Coral reefs in the Kiunga Marine National Reserve (40° 07'E, 2° 00'S) are located in a transition ecotone between the warmer East African coral reef bioregion to the south, and colder waters of the Somali Current to the north. The reefs have been monitored annually from 1998 to the present, documenting a range of ecosystem changes from large and small scale threats. Reefs in the area suffered >80% loss of coral cover due to mass bleaching in the 1998 El Nino event, and 25-40% loss of coral species at individual site levels. Recovery of coral community structure has been variable, with some reefs showing strong recovery, while others have declined further. A Harmful Algal Bloom and coral disease in early 2002 further impacted reefs in the region, causing mass mortalities of fish and coral, and failure of coral recruitment in that year. Fishing impacts to the reserve are high, with a strong north-south decline in fish density due to easier access to the migrant and large fishing communities to the south of the reserve. Responsibility for management of the reserve area falls under multiple institutions, including the Kenya Wildlife Service, Fisheries and Forestry Departments, and the local council. However overlapping mandates, unclear relationships, limited information and understanding, and lack of resources have hampered effective management. The monitoring programme reported here is one aspect of new collaborative approaches to coral reef and fisheries management, and has focused on improving the information and understanding of the biological and resource systems of the area. The ecosystem trends induced by larger scale threats and the north-south fish resource gradient caused by local use patterns will be analyzed in an attempt to develop sustainable management practices for the MPA.

Coral Reef Fisheries and Ecosystem Based Management in the US Caribbean

*Graciela E GARCIA-MOLINER**, *Miguel A ROLON*

268 Munoz Rivera Avenue, Suite 1108, San Juan, Puerto Rico
graciela@coqui.net

The Caribbean Fishery Management Council has responsibility under the Magnuson-Stevens Fishery Conservation and Management Act to manage fishery resources in the exclusive economic zone adjacent to Puerto Rico and the U.S. Virgin Islands. The Council was among the first, if not the first, of the Regional Councils to prepare an ecosystem-based fishery management plan. The Council was ahead of the times. Because many of the managed resources also depend on near shore habitats, the Council includes the state waters in developing management strategies, as recommendations or as cooperative efforts to protect the resources. Coral reefs represent the most visible resource managed by the Council and the fishery management plan developed in 1996 approaches management of corals from an ecosystem perspective. The marine conservation district, a no-take zone established in 1999, was an additional step taken by the Council to protect the habitat and functionality of the habitat as one. In 1983, the Council developed rationale to manage fisheries from an ecosystem perspective. The Council historical documents indicate the extent of the effort in preparing an ecosystem-based fishery management plan. The discussion of the FMP ended in 1988. Now, over twenty years later, the ecosystem-based management approach is in vogue. What has changed, what has made everyone look at the ecosystem based management approach again? How is the Council going to broach the mandate of the Law?

Reconstructing Historic Coral Reef Fisheries Catches for US-Associated Pacific Islands: Regional Application and Global Significance*Dirk ZELLER**, Paul DALZELL, Jarad MAKAIU, Daniel PAULY

2259 Lower Mall, Vancouver, V6T 1Z4 Canada

d.zeller@fisheries.ubc.ca

Coral reefs account for ~0.1% of the world's oceans, and while yield estimates vary, global annual catches are at least 1.4-4.2 million tonnes. While this represents less than 5% of total global catches, it provides millions of people with food and livelihood. Coral reef resources are of fundamental subsistence, social and cultural importance for shaping and maintaining communities. Yet catches are often not reported, and usually remain unaccounted for in national and global statistics. Reconstruction of catch series requires interpolation and bold assumptions, justified by the unacceptable nature of the alternative, i.e., zero catches. For example, the only global data set of fisheries catches, FAO-FISHSTAT, reports total catches for Guam as <200 tonnes prior to the mid 1980s. Clearly, this is not reflective of true catches for an island nation whose human population nearly doubled to over 100,000 between 1950 and 1980. Without accounting for coral reef catches, we cannot obtain any measure of the true value of these resources to communities; or of the risks overfishing may represent, in light of some of the highest human population growth rates in the world. Furthermore, reconstructing these catches is crucial for establishing baselines for fisheries management and conservation. While few time series data exist, many local studies report catches or catch rates for some periods and locations, thus forming anchor points of 'hard' data around which catch estimates can be built, using interpolations to 'fill in' data-limited periods. Of particular importance are catch rates, as these enable us to estimate total catches in conjunction with data on fisher- and population-demographics. We present data of coral reef fisheries catches for U.S. associated Pacific islands, and illustrate how this approach can serve as a template for other fisheries that are generally perceived to suffer from data-limitations.

Local Action Strategy Process for Coral Reef Management in the Pacific*Alan R EVERSON**

1601 Kapiolani Blvd., Honolulu, HI 96815 United States of America

alan.everson@noaa.gov

Coral reefs under U.S. jurisdiction are located in the Atlantic (Florida, Puerto Rico, U.S. Virgin Islands) and Pacific (Hawaii, Guam, Commonwealth of the Northern Marianas, American Samoa). The U.S. Coral Reef Task Force has recognized the need to more effectively manage threats to coral reefs at the local level. Each jurisdiction has its own unique threats and management needs. The CRTF has identified six broad threat areas common to all of the jurisdictions. These are: land based sources of pollution, recreational overuse, overfishing (fishery management), lack of public awareness, coral bleaching and disease. As a result of this process, 3-year action plans or local action strategies (LAS) are being drafted within each jurisdiction for each threat area. This presentation will describe the process in greater detail for the fishery management LAS in the Pacific. The process was a collaboration between Federal, State, and non-government agencies. Key to the success of this endeavor was the involvement of stakeholders throughout the process. Several stakeholder meetings were held in each jurisdiction to solicit initial input into the LAS. In addition, multi-day workshops were staged to bring together scientists, managers and stakeholders to share information and concerns on the status of the resource, as well as strategies for management. To date, the process has resulted in a fishery management LAS for each of the Pacific jurisdictions. Each LAS will be used as a guide to help focus resources, build capacity and coordinate funding in an effort to improve management of coral reef fisheries at the local level.

From "Seashells" to "Molluscs": The Fractal Dimension of Molluscan Biodiversity

*Philippe BOUCHET**, *Pierre LOZOUET*

55 rue Buffon, 75005 Paris France, Metropolitan
pbouchet@mnhn.fr

Because species richness in tropical ecosystems is daunting, inventories and monitoring focus on a few "indicator" taxa that are used as proxies for marine fauna and flora in general. Species of fishes, corals, seashells, and seagrasses are the more frequently used proxies. But what exactly do these proxies measure? In a massive collecting effort involving 1700 day-persons, we surveyed sites in New Caledonia (3 sites) and the Austral Islands (1 site), each covering 50-300 sq. km of a mosaic of coastal habitats. All three New Caledonia sites reveal a common pattern of species richness and fauna composition: 2,800-3,000 species of molluscs per site were actually observed, and extrapolations from the cumulation curve indicate a range of 3,200-4,000 species potentially present at each site. This reflects the inaccuracy of any other survey of small benthic invertebrates. With 550 species only, the Rapa site confirms the reality of the tropical Pacific biodiversity gradient. Habitat heterogeneity was found to be high at all spatial scales, with only 22% of the total species shared by all three New Caledonia sites. In terms of conservation, the consequence is that at regional level even a 30,000 hectares site cannot be considered "representative". Twenty per cent of the species are represented by single specimens and make up 0.4% of all catches. One-third of the species have adult sizes under 4 mm, while only 10% are larger than 40 mm and would rank as "seashells". Such a fractal composition of the species guild is shared by insects in the canopy of rainforests. "Keystone" species, "indicator" species, and other "flagship" species may be adequate for biodiversity studies that focus on ecosystem function and habitat conservation, but they do not address one apparently fundamental property of complex tropical ecosystems: most species are rare and small.

Preliminary Analyses of Macromolluscan Diversity in Central Great Barrier Reef Soft Sediments

*Matthew A KOSNIK**

Centre for Coral Reef Biodiversity, Department of Marine Biology, James Cook University, Townsville, QLD 4811 Australia
matthew.kosnik@jcu.edu.au

Although existing data for molluscs as well as better-known groups such as fishes and corals suggest the potential for important latitudinal and cross-shelf trends in community composition, spatial patterns in molluscan diversity on the Great Barrier Reef (GBR) are largely unquantified. This study begins to quantify cross-shelf differences in macromollusc community composition using two cross-shelf transects across the central GBR. Bulk samples from a southern transect running from the Whitsunday Islands to the outer Whitsunday reefs are compared to bulk samples from a northern transect running from the Palm Islands to the outer Townsville reefs. Sediment grabs were collected from reef associated soft-sediments at a series of inshore, midshelf and outershell reefs on each transect. Macromolluscs were sieved from grab samples. Species richness and abundance patterns are compared along cross-shelf transects as well as between the Townsville and Whitsunday transects using the molluscs from the >4 mm and >2 mm sieve fractions. Taxon and functional group abundance distributions are compared between samples using both fitted distributions and standard species diversity and evenness metrics.

Comparative Biodiversity and Taxon Composition of Octocorals in Indo-West Pacific, Panamic, and Tropical Western Atlantic Faunas

*Gary C WILLIAMS**

California Academy of Sciences (IZG), Golden Gate Park, San Francisco, California 94118 U.S.A.
gwilliams@calacademy.org

The Indo-West Pacific is considered a complex mosaic of biodiversity where great spatial heterogeneity and localized periodic disturbances promote diversification. Regarding coral reef faunas, the region of the world with the highest diversity and endemism is bounded by a geographic triangle covering the Philippines in the north, eastern Indonesia in the southwest, and New Guinea in the southeast. Regarding the faunistics of shallow water octocorals (soft corals, sea fans, and sea pens), although species composition differs from one locality to another in the Indo-Pacific, higher taxon diversity is relatively consistent throughout much of the region. The same holds true with the Panamic and tropical western Pacific faunas, which are related faunas and very different from Indo-Pacific diversity mosaic. Much of the diversity of octocorals at various Indo-West Pacific coral fauna sites is comprised of three families of soft corals (Alcyoniidae, Nephthiidae, and Xeniidae), while the Panamic and tropical western Atlantic sites are composed mainly of two gorgonian families (Gorgoniidae and Plexauridae). Pennatulaceans are significantly more common and exhibit the highest diversity at various Indo-West Pacific localities. Although the systematics of octocorals in the tropical western Atlantic is relatively well known, this is not the case for the Indo-Pacific and Panamic regions, which are less well known. However, this situation is currently changing as workers are making significant contributions to our knowledge of the Panamic and Indo-West Pacific faunas. In this paper, sites in the high diversity triangle of the western Pacific are studied and compared with those in southern Africa (a composite fauna of eastern Atlantic, endemic, and Indo-Pacific elements), as well as the Panamic region (eastern Pacific), and the tropical western Atlantic.

Diversity of Soft Corals (Octocorallia: Alcyonacea) from Southern Taiwan

*Yehuda BENAYAHU**, *Ming-Shiou JENG*, *Shimrit PERKOL-FINKEL*, *Chang-Feng DAI*

Ramat Aviv, Tel Aviv 69978 State of Israel
yehudab@tauex.tau.ac.il

The geographic setting of Taiwan, between the West Pacific Ocean and East China Sea and at the cross-roads of the Philippine-Japan Island Arc, makes its reefs of special biogeographical interest. It has been suggested that Taiwan may serve as a steppingstone for the dispersal of shallow reef organisms. Soft corals from Nanwan Bay and Lu-tao Island, southern Taiwan, were studied during 1994 and 1998. SCUBA collections were carried out to a depth of 33 m. Approximately 230 samples were collected, encompassing the full variety of species found on the reefs. Visual estimates were made of the underwater abundance of species. The collection yielded 68 species of the families Helioporidae, Clavulariidae, Tubiporidae, Alcyoniidae, Nephthiidae, Xeniidae and Briareidae. These included one new species and 43 new zoogeographical records from Taiwan. Among the 21 listed genera the survey records seven for the first time in the Taiwanese reefs. The findings confirm the high soft coral diversity of these reefs. The shallow reefs of Nanwan Bay are densely inhabited by species of the family Alcyoniidae. In contrast, the deep reefs are characterized only by sporadic colonies of Alcyoniidae, replaced by abundant assemblages of azooxanthellate species of the families Nephthiidae and Nidaliidae. Soft corals of the family Xeniidae are abundant on the reefs of Lu-tao Is. at a depth range of 3-10 m. Interestingly, species of the family Xeniidae were rarely observed at Nanwan Bay. The coral reefs of Taiwan and Japan are closely linked by the northward-flowing Kuroshio current, which brings water and larvae from the reefs of the South China Sea. Therefore, we compared the generic affiliation and abundance estimates of the Alcyoniidae between southern Taiwan and the Ryukyu Archipelago (Japan), and found a close resemblance between the two reef areas.

The Glorieuses Islands in the SW of the Indian Ocean: A "Paradise" for Hydroids (Cnidaria, Hydrozoa)

*Nicole GRAVIER-BONNET**, *Chloe A F BOURMAUD*

BP 7151, 97487 Saint-Denis Messag. cdx 9, La Reunion, France
nicole.gravier-bonnet@univ-reunion.fr

Preliminary investigations led us to consider the Glorieuses islands (SW Indian Ocean) as a "paradise" for hydroids for their abundance and large distribution in the protected coral reefs there, compared to other locations of the area. Samplings were done by walking at low tides on the reef flats or by snorkeling, and by scuba-diving on the outer slope. Large colonies and seaweeds, that could bear microscopic species, were collected by hand. Fresh material was sorted with a stereomicroscope soon after the sampling: 75 species belonging to 19 families were checked, with 17 athecates for 58 thecates. Most of the families were represented by one to six species except the Aglaopheniidae (12) and the Sertulariidae (16). Three macroscopic species were dominant in respect of their abundance and biomass and are considered as bioindicators. *Dynamena crisoidea* was a characteristic species for the intertidal and shallow waters of the reef flats where small colonies covered densely all hard substrata (like immersed fossil beach rocks, flat bottom covered by sand, or coral stones on the reef front). *Aglaophenia cupressina*, the well-known fireweed, developed large and bushy colonies characteristic of coral patches dispersed on sand bottom at low depths both on the reef flat and on the outer slope. It was common to find several clumps of 10 to 30 plumes of this species on a single meter quadrat, which represents thousands millions of polyps. *Lytocarpus spectabilis* was a characteristic species of the mixed cnidarian fauna settled on hard substrata on the outer slope. Besides, reef builders as *Millepora platyphylla* and *M. tenera* were also very abundant in shallow waters. Except for *D. crisoidea*, all were venomous for human. Among microscopic species, an unidentified halecid, settled on two *Turbinaria* species growing on both sides of the reef front, also formed very large populations.

Hydromedusan Fauna in Coasts of the Nansei Islands

*Shin KUBOTA**

459 Shirahama, Nishimuro, Wakayama 649-2211, Japan
shkubota@hotmail.com

Hydromedusan fauna in the Nansei Islands is clarified, studying in 50 harbors on 14 islands, towing a plankton net from 1992 to 2004. A total of 55 species of 40 genera, excluding Siphonophora, belonging to the 7 orders in Hydrozoa were collected, and some are new to Japan, finding out in only the Nansei Islands. The morphology, geographical distribution, and life historical traits kept in the laboratory after capture are reported according to each species, with illustrations and photographs.

Species Diversity on a Small Scale: Coral Size and Resident Fish Assemblage Structure in Indo-West Pacific Corals of the Genus *Pocillopora* (Cnidaria: Scleractinia: Pocilloporidae)

*Terry J DONALDSON**

UOG Station, Mangilao, Guam 96913 USA Guam
donaldsn@uog9.uog.edu

Individual shrub-like *Pocillopora eydouxi* and *P. elegans* corals provide obligate and facultative coral-dwelling fishes sites for shelter, reproduction and feeding. They provide also an example of species-area relationships at a very small scale. These corals are distributed discretely and may be sufficiently isolated from one another to influence strongly the diversity, assemblage structure and social organization of the fishes that inhabit them. I examined the relationship between the size of these corals and four components of fish assemblage structure: species diversity, species richness, the number of resident fishes, and body size of resident fishes. Emphasis was given to those corals supporting at least one individual of the obligate coral-dwelling hawkfish, *Neocirrhites armatus* (Cirrhitidae). At total of nine species of fishes, including two additional hawkfish species, were observed living within the interstices or on the branches of corals surveyed in the Mariana and Society Islands. Coral size was a predictor of resident fish species diversity and richness, and the number of fishes per coral; it was also a predictor of the number of hawkfish species per coral, the number of hawkfishes per coral, and the number of *N. armatus* per coral. In addition, coral size predicted the number of the hawkfish *Paracirrhites arcatus* for *P. elegans* corals, only. Coral size did not predict the number of *Paracirrhites forsteri*, the number of *Caracanthus maculatus* (Caracanthidae- another obligate coral-dwelling species), the number of other fish species, nor the number of other fishes per coral of either species. Differences in all of these measures between *P. eydouxi* and *P. elegans* were not significant. Coral size predicted body size in *N. armatus*, only.

Biodiversity of Reunion Island Coral Reefs

*Chloe A F BOURMAUD**, *Lucas LECLERE*, *Perrine MANGION*, *Gwenaelle PENNOBER*

BP 7151, 97715 Saint-Denis Messag. cdx 9, La Reunion, France
chloe.bourmaud@univ-reunion.fr

A comprehensive bibliographic study was carried out to give the state of knowledge of the marine biota at Reunion Island: an estimated about 3000 species of marine coral reef organisms live in Reunion Island, a French overseas department in the Mascarene archipelago, located between 21° 07' S and 55° 32' E. Coral reef surface are totals ca. 7.5 km². Species distribution data have been recorded in a new online interoperable database and integrated in the information system of the coastal zone network. Since logging began in June 2003, we have entered approximately 6621 distribution records and 2832 taxon records. The information sources are just over 30 mainly literature references and unpublished data provided by local taxonomists. Algae, scleractinia, hydrozoa, mollusca (except nudibranchs and cephalopods) and vertebrates are the better known phyla. Sponges, cnidarians (except hard corals and hydroids), crustaceans and echinoderms are zoological groups that need more investigations. Moreover, ctenophores, plathyhelminthes and others worms, lophophorates and tunicates are completely unknown. Coral reefs of Reunion Island support 167 species of hard corals, and 6 species of hydrocorals. These reef builders are distributed over 18 families, including more than 50 genera. Mollusca are well studied and the level of endemism is estimated at 10%. Coral reefs shelter 667 fish species belonging to 146 families. Nine species are known only from Reunion suggesting a level of endemism of about 1%. Comparing with MASDEA data-bank (Marine Species Database for Eastern Africa), Reunion coral reefs apparently harbour 33.3% and 40.8% of the marine species, according to well-studied group such as Fishes and Cnidarians, respectively. For Algae and Mollusca, this rate is 86.0% and 50.9% respectively. Therefore, in spite of the island small size and the relatively young age of the Mascarene archipelago, its marine environments are home to a high biodiversity.

Indo-Pacific Sponge Biodiversity, Phylogeography, and Diversification*Gert WORHEIDE**, John N A HOOPER, Laura S EPP

Goldschmidtstr. 3, 37077 Goettingen Federal Republic of Germany

gert.woerheide@geo.uni-goettingen.de

Patterns of biodiversity (taxonomic richness, endemism, taxonomic affinities between communities) at small (), medium () and larger () scales of diversity were examined for marine sponge populations throughout the tropical and subtropical western Pacific. 37 and 13 scale faunas from 1343 investigated localities using a pool of 2324 species could be distinguished. Latitudinal gradients in sponge diversity were not evident, whereas various environmental factors were prominent at scales and biogeographic factors were prominent at and scales of diversity. However, investigations based on morphometric data alone could not elucidate which biogeographic factors were responsible and phylogenetic relationships between investigated populations and diversification patterns remained enigmatic. Consequently, genetic methods were applied and we used the widely distributed Indo-Pacific coral reef sponge *Leucetta* 'chagosensis' (Calcarea: Leucettidae) as a model species to investigate phylogeographic relationships of sponge populations ranging from the northern Gulf of Aqaba (Red Sea, Egypt) to the Tuamotu Archipelago (Eastern Central Pacific). Phylogeographic analyses of ribosomal DNA (ITS and partial 28S rDNA sequence types) showed that populations throughout the Indo-Pacific were phylogeographically structured. Five main clades were detected and their relationships will be discussed. Nested Clade Phylogeographic Analysis inferred cycles of fragmentation and range expansion events in some Pacific clades, supporting the hypothesis that historical processes like glacial sea level low stands influence sequence type distributions and diversification of *Leucetta*. Interestingly, we detected two distinct clades on the Great Barrier Reef and Queensland Plateau (Coral Sea) that appear to be more closely related to the remaining three clades than to each other. Analyses of newly developed single-copy nuclear markers allowed further exploration of patterns and processes of diversification of this taxon throughout the Indo-Pacific.

Biogeography and Diversity of Eastern Pacific Reef Corals*Hector REYES-BONILLA**, Peter W GLYNN, R Andres LOPEZ-PEREZ

Apartado postal 19-B, CP 23080. La Paz, B.C.S., Mexico

hreyes@calafia.uabcs.mx

Biogeography is a discipline that has undergone remarkable changes in objectives and research approaches, and the topic has become of the foremost relevance for reef coral science. In this study I describe patterns of distribution and diversity of reef corals of the eastern tropical Pacific Ocean: from the northern Gulf of California, Mexico (29°N) to Ecuador (1°S), including all oceanic islands adjacent to the mainland. Using data from field work, literature and museum specimens I created a matrix of presence and absence of all species in 25 sites, and calculated alpha, beta and gamma diversity. In addition I run cluster analysis and non-metric dimensional scaling, and estimated the relevance of 20 oceanographic factors and of two dummy variables (representing regional influences) on richness, using multiple stepwise ridge regression. The eastern Pacific reef fauna is composed of 44 species: 10 regional endemics and 34 immigrants from the western Pacific. Species richness varies from 2 to 24 per locality, and shows a strong latitudinal attenuation gradient to the north. From the ordination, the region was divided into three subprovinces: southern Gulf of California to Nayarit (20°N); Oaxaca (15°N) to Ecuador; and two oceanic islands (Revillagigedos and Clipperton). The results also showed that the Pacific Central American Faunal Gap, the main biogeographic barrier in the study region, is an asymmetrical boundary that allows more migration to the south than to the north. Gamma diversity was highest in Central America, and at regional level about 80% is due to local richness (alpha), while the remainder represents species turnover (beta). The multiple regression was significant ($R^2=0.56$) and evidenced that alpha diversity can be modeled using a combination of one regional factor (representing species immigration from the west) and four local environmental conditions, of which maximum surface temperature was the most important.

Diversification of Nudibranch Mollusk Biotas in the Indo-Pacific Tropics*Terrence M GOSLINER**

Golden Gate Park, San Francisco, CA 94118 United States of America

tgosliner@calacademy.org

Nudibranch mollusks have undergone considerable diversification within the Indo-Pacific tropics. Diversification varies considerably in different clades of nudibranchs that have been studied. Examination of a wide variety of these clades provides primary data that illustrate where basal lineages have speciated and contrasts these patterns with lineages from more highly derived taxa. Similar comparisons of these different lines of evolution on a regional basis demonstrate similar differences in amounts of speciation that has occurred and document at least one case of true adaptive radiation in geographically isolated portions of the Indo-Pacific tropics. Deeper clades of nudibranchs exhibit patterns of sister group relationships with biotas from the Caribbean and other portions of the tropical Atlantic. It appears that in most clades eastern Pacific taxa are more closely related to Atlantic species than they are to Indo-Pacific ones. This is indicative of a long-standing eastern Pacific barrier separating Eastern Pacific species from the taxa inhabiting the Indo-Pacific. Current estimates of the diversity of Indo-Pacific nudibranchs are reviewed in light of recent field collections from several localities. Recent studies of deep-water Indo-Pacific taxa show extremely high percentages of undescribed species.

Diversity and Biogeography of *Conus*, the Most Diverse Coral Reef-Associated Genus*Alan J KOHN**

Dept. of Biology, Box 351800, University of Washington, Seattle, WA 98195-1800, USA

kohn@u.washington.edu

Conus is the most species-rich genus of animals in the sea, with more than 500 species, and about half of these occupy coral reef-associated habitats. Up to 36 species are known to occur on a single reef, and *Conus* is thus an important contributor to coral reef species diversity, especially in the Indo-Pacific region. This presentation will address hypotheses of the origin of this hyperdiversity, both globally and by habitat, and geographic and habitat-related patterns of diversity on Indo-Pacific reefs. Topographically complex, slightly subtidal reef platforms support the highest *Conus* species diversity. Longitudinally, species richness peaks at about 140°E near the equator, decreasing eastward and westward. Intertidal benches, e.g. on seaward, windward atoll reefs, support the densest *Conus* populations. Here diversity is much lower (5-9 species), and no geographic pattern is evident. Specialization on different microhabitat and food resources by co-occurring species may account for much of the existing species richness but does not explain its origin and evolution. A prior study (in Ormond, Gage & Angell, eds., Marine Biodiversity: Patterns and Processes, 1997) considered three factors that could promote diversification, historical contingency, ecological determinism, and life history strategies. Here I address a fourth: key innovations, with emphasis on recent molecular evidence for the rapid evolution of diverse microprotein venoms and of sibling species.

Molecular Phylogeography Reveals Fine Scale Endemism of the *Astrarium rhodostoma* Complex on Coral Reefs

*Jonathan B GELLER**, *Christopher P MEYER*, *Gustav PAULAY*

8272 Moss Landing Road, Moss Landing, California 95039 United States of America

geller@mml.calstate.edu

The marine biota of oceanic islands is perceived to consist of wide ranging species, with endemism largely limited to the most remote, peripheral archipelagoes. This may be a consequence of planktonic dispersal stages that allow effective island colonization but limit divergence. Contrary to this pattern, we show here that fine scale endemism is pervasive across the presumed wide range of *Astrarium rhodostoma*, a reef gastropod with nonfeeding planktonic larvae. Mitochondrial DNA sequences (Cytochrome oxidase subunit I) and retrospective morphological study indicate that this “species” is comprised of at least 29 geographically isolated genetic clades among 37 localities sampled, separated by as little as 180 km. These non-overlapping clades represent Evolutionary Significant Units (ESU) or species, each with narrow ranges. These results suggest that perceptions of wide ranges of reef organisms may be biased by the larval types of the species previously chosen for study. Endemism among complexes of ESU's or cryptic species may be more common than currently recognized.

Tempo and Mode of Diversification in the Indo-West Pacific

*Gustav PAULAY**, *Christopher P MEYER*

Florida Museum of Natural History, University of Florida, Gainesville FL 32611-7800 USA

paulay@flmnh.ufl.edu

Although the statement that the Indo-West Pacific harbors the greatest marine diversity has become a cliché, not all taxa show high diversity in the region. While some families include hundreds of regional species, others are monospecific. Some groups are diverse both on local and regional levels, while others have modest local, but high regional diversity. What conditions facilitate or impede the development of megadiversity? Intensive biodiversity surveys at several Pacific locations combined with molecular phylogenetic studies reveal varied patterns of diversity and modes of diversification. Speciation can occur at a variety of locations, across a wide range of spatial and temporal scales, driven by varied mechanisms. Although allopatric speciation can occur almost anywhere in the region, speciation events strongly cluster in some areas that serve as diversity pumps. The geographic scale of allopatric speciation varies over orders of magnitude from inter-island to inter-regional scales, substantially correlated with dispersal ability. Nevertheless, even taxa with exceptional dispersal ability can speciate allopatrically within the region. The temporal dynamics of speciation are also highly variable. While sufficient isolation to allow secondary sympatry takes >10 million years in many groups, others diversify much more rapidly. Evidence supports the importance of founder speciation in addition to vicariance, and selection is a powerful force in generating diversity. We will review numerous examples to illustrate these points and explore what combinations of these factors are most conducive for the development of megadiversity.

A Geographical History of Species Diversification across the Indo-West Pacific in an Ancient Clade of Snails

*Melissa FREY**

EVE Department, One Shields Avenue, Davis California 95616 USA

mafrey@ucdavis.edu

Relative to other major biogeographic regions, the Indo-West Pacific (IWP) exhibits remarkable levels of marine biodiversity. Various hypotheses, that describe the spatial and temporal scale over which speciation takes place, have been generated to explain patterns of species richness across the IWP. With the rapid development of molecular tools, coupled with analytical advances in systematics and biogeography, it is now possible to reconstruct the history of diversification in unprecedented detail. Knowledge of phylogenetic relationships, along with data from the fossil record, can provide the historical framework necessary to test hypotheses of species diversification. This study uses two mitochondrial genes (16S and COI) to produce a phylogeny of *Nerita*, a clade of marine intertidal snails that has diversified throughout the tropics and subtropics since the late Mesozoic. As in several marine groups, the highest concentration of *Nerita* species occurs within the central IWP and declines with distance in an outward direction. Through large-scale sampling, geographic range data has been collected and combined with phylogenetic information to examine patterns of species diversity, and to characterize the geographical scale over which diversification occurs. An analysis of geographic range relative to species relationships provides insight into the geographic scale of speciation, and an increased understanding of the historical circumstances that have led to patterns of species diversity in *Nerita*.

Speciation and Diversity of Littorinid Snails on Rocky Shores in the Indo-West Pacific

*David G REID**, *Suzanne T WILLIAMS*, *D Timothy LITTLEWOOD*

London SW7 5BD United Kingdom of Great Britain and Northern Ireland

dgr@nhm.ac.uk

Snails of the genus *Echinolittorina* (Littorinidae) differ from many reef-associated animals in two important ways: they are restricted to rocky shores and have lower powers of larval dispersal (4 weeks or 1400 km), leading to differences in evolutionary patterns. Our analysis of speciation and diversity of *Echinolittorina* is based on a worldwide molecular phylogeny of 60 evolutionarily significant units (ESUs), including all 50 known taxonomic species and an additional 10 ESUs discovered from the molecular data. The 27 ESUs found in the Indo-West Pacific (IWP) region form a single clade, which is consistent with diversification following closure of the Tethyan seaway in the early Miocene. In almost all cases the geographical ranges of sister species show no overlap, indicating that the speciation mode has been allopatric. Furthermore, a high degree of allopatry is maintained through three to five branching points of the phylogeny, perhaps due to limited dispersal and to habitat specialisation on the oceanic/continental gradient. Within the IWP, we find no geographical pattern of speciation events; narrowly endemic species of relatively recent origin are present in both peripheral and central parts of the region. Contrary to evidence from some reef-associated animals, there was no acceleration of diversification during the glacio-eustatic cycles of the Plio-Pleistocene, perhaps because on rocky shores *Echinolittorina* may be less susceptible to extinction or isolation during sea-level fluctuations. The regional species-richness of *Echinolittorina* is highest in the central IWP, and this owes more to the occurrence of a mosaic of allopatric species than to the overlap of a few widespread ones. This study emphasises the plurality of biogeographic histories and speciation patterns in the marine tropics and suggests that habitat specialisation may be as important as isolation by historical vicariance for the interpretation of geographical distributions.

Breaching of the Eastern Pacific Barrier by Transpacific Fishes*Harilaos A LESSIOS**, David R ROBERTSON

Box 2072, Balboa, Panama

Lessiosh@stri.org

The most important barrier to gene flow in the Pacific is the wide stretch of deep water between the Marquesas and the islands off the American coast. Speciation across the Eastern Pacific Barrier (EPB) is the rule for most shallow water groups. There are, however, a number of transpacific shore fish, with populations assigned to the same species on both sides of the barrier. These could be the result of cryptic speciation, recent invasion, or continuous gene flow. We have assayed mitochondrial DNA in 19 of these transpacific fish species to determine whether they really belong to the same species, the level of gene flow through the barrier, the timing of any gene flow restrictions and the direction of larval migration. We found that populations in two species, East and West populations have reciprocally monophyletic mitochondrial DNA clades, suggesting ancient separation and possibly speciation. Among the remaining 17 species, coalescence analysis indicates that 9 were separated 10⁵ generations ago, but have maintained fairly high levels of gene flow since their separation. Three species experienced homogenization of their populations 10⁴ generations ago with ample genetic exchange since then, whereas the remaining 5 have been more or less panmictic due to high migration. Contrary to conventional wisdom that most gene flow through the EPB occurs from West to East during El Niño events, a little less than half of the species show migration in the opposite direction. Thus, the EPB is indeed permeable, but its permeability cannot be assessed by simply counting the number of species in common on either side. When breaching occurs, it can happen in either direction, and it can take the form of either a massive movement at one time, or a steady trickle over hundreds of thousands of years.

Life and Death of Coral Reefs: A Microbial View*Forest ROHWER**, Davey KLINE, Mya BREITBART, Nancy KNOWLTON

5500 Campanile Dr., San Diego, CA 92182 United States of America

forest@sunstroke.sdsu.edu

Coral and bacteria form specific associations that are maintained over space and time. The coral-associated microbes grow at defined rates and their population size remains in tight boundaries. The coral holobiont, therefore, consists of the coral, zooxanthellae, and microbes living together in a regulated manner. However, the relationships between these components can rapidly change when anthropogenic and/or natural stressors are applied to the holobiont. Heat stress, for example, causes expulsion of zooxanthellae and coral bleaching. We have designed the AADACS coral culturing system to determine what types of stressors cause microbe-coral relationships to breakdown. Our results show that carbon-loading leads to coral death by the microbial overgrowth of the coral (i.e., opportunistic infections). In contrast, excess nutrients (e.g., P and N) do not increase coral mortality or change microbial dynamics. We propose that microbialization, via carbon-loading, is directly killing corals and contributing to the destruction of these ecosystems.

Black Band Disease (BBD) Bacterial Mat Produces a Toxic Compound that Kills Zooxanthellae (*Symbiodinium* sp.)*Jorge FRIAS-LOPEZ**, Jim KLAUS, Joanna SHISLER, Mengfei HO, Brenda WILSON, Bruce W FOUKE

245 Nat. Hist. Bldg, 1301 W. Green St. Urbana IL 61801 United States of America

friaslop@uiuc.edu

Black band disease results from the migration of a black mat of microorganisms across the surface of coral colonies consuming healthy coral tissue and leaving dead skeleton behind. The most abundant organism present in the mat is the cyanobacterium *Phormidium corallyticum*. Additionally, *Beggiatoa* spp. and *Desulfovibrio* spp. have been identified as important bacteria in the development of the disease. One of the mechanisms of pathogenesis proposed for BBD involved the reduction of sulfate to sulfide by bacteria. *Beggiatoa* spp. and *Desulfovibrio* spp. would be the organisms responsible of the pathogenesis of BBD. Sulfide is a toxic compound that would be the direct cause of coral tissue destruction. A similar process that involves members of these two groups has been described in marine sediments under anaerobic conditions. However, the obtained results show that an extract from BBD mat has toxic effects on the growth of the symbiotic dinoflagellate (zooxanthellae). Nonetheless, neither pellet recovered from the extraction nor whole cells from BBD have such effect, suggesting that LPS from this bacteria is not involved in virulence. Furthermore, when we assayed the effect of BBD extract on fibroblasts and we have found the same toxic effect. Interestingly, observations under the microscope show cell vacuolation, characteristic of toxins such as El Tor hemolysin of *Vibrio cholerae* and *Helicobacter pylori* toxin, VacA. These results show that there is a toxin possibly involved in the mechanism of pathogenesis of BBD in corals. Further studies will involve the isolation and characterization of this compound or compounds.

Identifying Key Microorganisms in Corals Infected with Black Band Disease*Bruce W FOUKE**, Jim KLAUS, Jorge FRIAS-LOPEZ

245 Nat. Hist. Bldg, 1301 W. Green St. United States of America

fouke@uiuc.edu

Black Band Disease (BBD) is a polymicrobial disease that affects massive framework building coral species worldwide. Culture-independent molecular analyses have recently shown that the BBD bacterial mat is dominated by at least four different species of cyanobacteria, which were previously taxonomically grouped together as *Phormidium corallyticum*. However, the other dominant microorganisms populating the BBD bacterial community have been unknown. We have applied terminal-restriction fragment length polymorphism (T-RFLP) analyses to characterize the infectious bacterial community of the BBD bacterial mat. These analyses indicate that, in order of decreasing abundance after the cyanobacteria, the other dominant BBD mat bacteria include species of γ -Proteobacteria, *Cytophaga-Flexibacter-Bacteroides* group and Firmicutes. Comparative analyses indicate that the BBD bacterial consortium is the same in all species of Caribbean and Indo-Pacific corals. Only members of *Cytophaga-Flexibacter-Bacteroides* group and Firmicutes were unique to the infectious BBD mat when compared to bacterial communities associated with healthy coral tissues. Two of the species identified in this work were previously found in clone libraries obtained from BBD samples. Surprisingly, *Beggiatoa* spp., which was previously optically identified as the possible black band disease pathogen, was not detected in this study. These results will allow us to pursue the isolation, culturing and fluorescent probing of these microorganisms to better determine their role in the development of BBD.

Variability in Coral-associated Bacterial Communities and its Relevance to Infectious Disease*Marshall HAYES**, Jerome DURIVAUULT, Raymond HAYES, Christine FERRIER-PAGES

Av. Saint Martin, MC 98000 MONACO France, Metropolitan

mhayes@centrescientifique.mc

Virtually all animals live in dynamic association with diverse bacterial communities that grow on external surfaces or that colonize functionally significant internal sites (e.g., respiratory and gastrointestinal tracts). In corals, bacterial interactions occur regularly at the highly variable interface between seawater and the mucus-covered epidermis. Molecular analyses (16S rDNA-based fingerprinting and nucleic-acid gel electrophoresis) of coral-associated bacteria reveal that inter-colonial and intra-colonial heterogeneity represent persistent features of numerous coral genera (e.g., *Oculina*, *Stylophora*, *Acropora*, *Porites* and *Corallicum*). Prior to bacterial characterization, all experimental colonies had been maintained in long-term (> one year) laboratory culture and thereby exposed to stable environmental conditions with respect to temperature, light, water chemistry and circulation. This evidence suggests that bacterial community variability on coral surfaces is primarily under biological regulation, presumably by one or more factors that act to maintain heterogeneity in steady state. These would include, but are not limited to, (1) an inherent variability in the chemistry and spatial distribution of mucus on epidermal tissue, (2) the substrate-specific recognition between bacterial cells and complementary host-cell receptors, and (3) the active translocation of mucus sheets by epidermal microvilli that destabilize microbial colonization and proliferation. An additional implication is that certain fundamental aspects of coral-bacterial interactions have not been addressed in current evaluations of coral disease. Further investigation both in the laboratory and in field environments should seek to resolve this issue of bacterial heterogeneity by integrating biochemical and physiological criteria into studies of microbiology, water chemistry and reef ecology.

Bacterial Like Aggregates on Coral Surface

*Ariel KUSHMARO**, *Esti KRAMARSKY-WINTER*, *Itzik BRICKNER*, *Yossi LOYA*

Dept of Biotechnology Engineering, Faculty of Engineering Sciences, Ben Gurion University, Beer Sheva, 84105, Israel.

arielkus@bgumail.bgu.ac.il

Recently we observed a number of scleractinian coral species in the Gulf of Eilat, covered by a white coating on their surface. Careful examination showed this coating to be made up of rounded bacterial like aggregates embedded in the coral mucus. In situ 10 m² belt transects in three reef sites showed that approximately 32 % of shallow water massive corals are infested with dense populations of these aggregates. Coral families with high incidence of aggregate coverage include Fungiidae and Faviidae. The aggregates are round bodies approximately 20 micrometer in diameter. They may be found embedded in coral mucus on the polyp surface, on the coral surface as well as in the gastrodermis. The aggregates are dispersed on the coral surface in a patchy distribution, with the highest density occurring in the area of the polyp mouth. Light and electron microscopy revealed that these aggregates are made up of unique bacterial like bodies of approximately micrometer. During development and growth of primary polyps derived from excision of tissue from the coral *Fungia granulosa* a dynamic change in aggregate density and position were observed. Aggregate density was the highest around the polyp mouth. Bacterial aggregates could also be found in abundance in the gastrodermis, in areas usually lacking the endosymbiotic algae that provide an important carbon and energy source for the coral. Corals that underwent experimental bleaching by being maintained in the dark for three months retained their aggregates. The corals remained alive for over six months in the dark with no external nutrients added to the aquaria. These preliminary results suggest the possibility that the corals utilize these aggregates as an alternative food source that may possibly aid in survival following damage or bleaching episodes.

Changes in Surface Microbial Community Structure and Nutrient Processes after Coral Death

*Andrew M DAVEY**

C/- CMS, Seddon Building North, Slip Road, University of Queensland, St Lucia, Queensland, Australia, 4072 Australia

m.davey@marine.uq.edu.au

Coral reefs worldwide are experiencing a decline in health of a magnitude not recognised in recent history. In view of current trends and events over the last 20 years, it appears inevitable that we will effectively lose a large percentage of global reefs in the coming few decades. Whilst we are developing some understanding of the causes of coral mortality, our understanding of the after effects of mortality due to, for example thermal bleaching, remains unclear. It is recognised that coral skeletons recently devoid of life are rapidly colonised by microbial communities. However, the initial composition of these communities and the role they may play in the development of future communities of algae or other recruiting species remains poorly described and understood. This study attempts to characterise the microbial communities developing on newly exposed coral skeletons produced by coral mortality. The microbial communities were assessed from death through to six months after death with the use of 16S rRNA gene analysis and Terminal Restriction Fragment Length Polymorphism (TRFLP). Microbial community composition has been related to changes in surface biogeochemistry and nutrient processes from live to dead coral, and over a six month period after coral death. Studies indicate substantial changes in nutrient budgets from the surface of dead corals, therefore altering the primary productivity of individual coral skeletons, and of the broader community.

Effects of Depth and Temperature on Bacterial Communities Associated with *Diploria strigosa*

*James S KLAUS**, *Bruce W FOUKE*, *Jorge FRIAS-LOPEZ*

1301 West Green St., Urbana, Illinois United States of America

jklaus@uiuc.edu

Numerous authors have suggested a possible linkage between high frequencies of coral disease and human disturbance and reduced environmental quality. However, due to the low incidence of coral disease, fluctuations in local environmental conditions, and difficulty identifying and quantifying numerous potentially controlling factors, the relationship between coral disease and the environment remains unresolved. In addition to the frequency and distribution of coral diseases and their correlation to different environmental parameters, insights into the relationship between coral disease and the environment can be gained through a better understanding of how bacterial communities of healthy coral colonies vary under different environmental conditions. Due to variations in their associated bacterial communities, corals may be more susceptible under certain environmental settings. To assess the effect of temperature and depth on the bacterial communities of healthy colonies of *D. strigosa* two experiments were conducted. In the first experiment, bacterial communities associated with healthy colonies were compared to those heated in flow-through aquaria. Heated aquaria were maintained at 30.5° C (2.5° C above ambient) and samples were cultured for up to two weeks prior to sampling. Bacterial assemblages were compared statistically through the combined use of Terminal Restriction Fragment Length Polymorphism (T-RFLP) and 16S rRNA gene sequence libraries. In the second experiment bacterial communities associated with *D. strigosa* collected from 5 m and 10 m as well as transplanted colonies from 5 m to 10 m, 5 m to 18 m and 10 m to 5 m were compared. Transplanted colonies were left for two weeks prior to collection, and again, bacterial assemblages were compared through the combined use of T-RFLP and 16S rRNA gene sequence libraries. These experiments document the effect of temperature and depth on healthy bacterial communities. These two factors have previously been shown to have broad controls on disease incidence.

The Induction of Coral Bleaching by Metabolic Inhibitors

Ross J JONES*

Seddon Building No 82C, St Lucia Campus, QLD 4072, Brisbane Australia
rjones@uq.edu.au

Explants of the hard coral *Seriatopora hystrix* were exposed to sublethal concentrations of the herbicide diuron (DCMU) and the heavy metal copper. Pulse Amplitude Modulated (PAM) chlorophyll fluorescence techniques were used to assess the effects on the photosynthetic efficiency of the algal symbionts in the tissue (*in symbio*), and chlorophyll fluorescence and counts of symbiotic algae (normalized to surface area) were used to assess the extent of coral bleaching. At 30 $\mu\text{g DCMU l}^{-1}$, there was a reduction in both the maximum effective quantum yield (Delta F/F_m) and maximum potential quantum yield (F_v/F_m) of the algal symbionts *in symbio*. Corals subsequently lost their algal symbionts and discoloured (bleached), especially on their upper sunlight exposed surfaces. At the same DCMU concentration but under low light (5% of growth irradiance), there was a marked reduction in Delta F/F_m , but only a slight reduction in F_v/F_m and slight loss of algae. Collectively the results indicate DCMU-induced bleaching is caused by a light-dependent photoinactivation of algal symbionts (most probably through singlet oxygen production and photooxidative stress), and that bleaching occurs when F_v/F_m (measured 2 h after sunset) is reduced to a value of $< \sim 0.6$. Elevated copper concentrations (60 $\mu\text{g Cu l}^{-1}$ for 10 h) also induced a rapid bleaching in *S. hystrix* but without affecting the quantum yield of the algae *in symbio*. Tests with isolated algae indicated substantially higher concentrations (300 $\mu\text{g Cu l}^{-1}$ for 8 h) were needed to significantly reduce the quantum yield. Thus, copper-induced bleaching occurs without affecting the algal photosynthesis, and may be related to effects on the host (animal). It is argued that warm-water bleaching of corals resembles both types of chemically-induced bleaching, suggesting the need for an integrated model of coral bleaching involving the effect of temperature on both host (coral) and algal symbionts.

Implications of Reduced Photosynthetic Yields Caused by the Herbicide Diuron for Coral Reproduction and Larval Metamorphosis

Neal E CANTIN*, Andrew NEGRI, Bette WILLIS

Department of Marine Biology, James Cook University, Townsville Qld., 4811, Australia
Neal.Cantin@jcu.edu.au

Low concentrations of the herbicide diuron have been shown to reduce the photochemical efficiency of zooxanthellae within adult and juvenile corals by inhibiting electron flow through the PSII photosystem. Adult *Acropora tenuis* colonies were experimentally exposed to diuron concentrations of 1 $\mu\text{g/l}$ and 10 $\mu\text{g/l}$ for 52 days and compared to control colonies on the reef. Exposure was concluded when the first adult colony visibly set to spawn, in order to test the impact of reduced photosynthesis during gametogenic development prior to spawning. Dark and light adapted photosynthetic yields (F_v/F_m); total lipid content, total egg number and volume and total number of zooxanthellae were used as stress indicators. Immediate reduction in dark and light adapted photosynthetic yields (F_v/F_m) was detected with a pulse amplitude modulation (PAM) fluorometer for both treatments, which remained during the entire exposure. Gametes from the reef control and 10 $\mu\text{g/l}$ colonies were then collected and larval metamorphosis trials conducted with 4-14 day old larvae. Larval settlement and metamorphosis of larvae lacking zooxanthellae was not reduced by constant 10 $\mu\text{g/l}$ diuron exposure during gamete development in comparison to larvae from the control colonies on the reef. These results indicate that whilst coral colonies may be under high photosynthetic stress, they are capable of acquiring sufficient energy for reproduction in order to produce viable gametes. This study provides information to enhance our current knowledge base of coral ecotoxicology, the effects of land-based pollution from flood plume runoff and a wide range of techniques to assess the stress caused by such pollutants on both adult and juvenile corals.

Characterization of the Ceruloplasmin Gene in Corals: An Informative Biomarker of Naphthalene Exposure

Michael B MORGAN*, Terry W SNELL

2277 Martha Berry Hwy, Mount Berry, GA 30149 United States of America
mbmorgan@berry.edu

Molecular techniques now exist that enable researchers to examine differential gene expression in corals. These techniques give coral researchers new tools to evaluate the relative impact of an individual stressor within the context of multiple stressors. In this study, a differentially expressed gene was isolated by differential display PCR from corals that were exposed to naphthalene. This 400bp gene fragment was then developed into a molecular probe and then used on corals exposed to a variety of other natural and anthropogenic stressors. To further characterize this unknown coral gene, the nucleotide sequence was compared to public sequence databases to identify similarities with genes of known function. Results of this study have identified a gene with significant homology (E-value = 1×10^{-29}) to human ceruloplasmin, which is known for copper/iron transport as well as antioxidant capabilities

Coral Mortality Caused by Road Asphalt and Roofing Tar

David I KLINE*, Neilan KUNTZ, Nancy KNOWLTON, Forest ROHWER

Marine Biology Research Division, MC 0202, UCSD, La Jolla, CA 92037
 United States of America
dkline@ucsd.edu

As human populations grow anthropogenic impacts on reefs increase and coral reefs continue to decline. However, little is known about which byproducts of development are most detrimental to corals. We have designed a coral dosing and culturing system that allows rapid assessment of anthropogenic and natural stressors that may be harmful to corals. The Aquatic Automated Dosing and Culturing System (AADACS) allows testing of 40 independent stressors with 10 true replicates per stressor (400 individual coral nubbins total). This system allows statistically powerful experiments to be performed with high levels of replication and independence. After testing large suites of potential anthropogenic stressors, our results show that road asphalt and roofing tar were highly toxic to corals. Levels of roofing asphalt and road tar that may be commonly found in run-off associated with development are likely a significant cause of coral mortality and must be considered in the design of roads and buildings in near-shore reef environments.

Endocrine Disrupter Nonylphenol and Bisphenol a Contamination in Okinawa and Ishigaki Islands, Japan - Within Coral Reefs and Adjacent River Mouths -

*Hodaka KAWAHATA**, *Hidekazu OHTA*, *Mayuri INOUE*, *Atsushi SUZUKI*

Higashi-1-1-1, Tsukuba, Ibaraki Japan

h.kawahata@aist.go.jp

Certain chemicals possess the potential to modulate endocrine systems, and thereby interfere with reproduction and developmental processes in the wild. We analyzed endocrine disrupters nonylphenol (NP) and bisphenol A (BPA) levels at various sites in Okinawa and Ishigaki Islands, Japan. River-water samples showed undetectable to low concentrations of NP and BPA at most of the sites investigated. However, an appreciable amount of BPA was detected in sediments at one coral reef site. In addition, significant numbers of river sediment samples showed appreciable amounts of NP and BPA. Most of the sampling sites for this study are located within a distance of 1 km from the coral reefs, which are under influence of river-waters to a variable extent. Therefore, influence of endocrine disrupters may have already begun on adjacent coral reefs. Both endocrine disrupters were positively correlated with human population densities, but not with the contents of red soil generated by farm land reformation. Therefore, it is concluded that NP and BPA pollution is a consequence of human waste discharge, both domestic and industrial, and not by agricultural activities. Coral reefs are characterized by high biological diversity. Many developed tropical islands, including Okinawa and Ishigaki Islands, are being greatly stressed by human activity. Lagoonal water in the coral reefs have a long residence time, and if these reefs become contaminated by endocrine disrupters, the consequences may be more serious due to the accumulated effect of these disrupters.

A Possible Role for Urea in Mediating Coral Responses to Chronic and Pulsed Doses of Ammonium

*Daniel J BUCHER**, *Esther FISHER*

P.O. Box 157, Lismore, NSW, Australia, 2480 Australia

dbucher@scu.edu.au

In the early 1970s it was observed that some reef-building corals contained surprisingly high levels of urea for an aquatic invertebrate. An hypothesis was proposed at the time whereby hydrolysis of urea might neutralise the protons formed by deposition of CaCO₃, thereby enhancing the rate of calcification. However, since that early work the role of urea in coral metabolism has received little attention. We propose that the primary role of urea is to allow the coral-zooxanthellae association to take advantage of occasional peaks in ammonium availability in an otherwise nutrient-poor environment. Urea would be formed during times of ammonium excess and hydrolysed to release ammonium to the zooxanthellae in times of shortage. An increase in calcification rates could be a beneficial side-effect. Preliminary testing of this hypothesis has demonstrated the following conclusions 1. that urea concentrations can be measured accurately in a field laboratory using a colorimetric kit designed for use with human blood plasma 2. that urea concentrations increased significantly in corals exposed to elevated ammonium concentrations and returned to those of control corals after incubation in low-nutrient seawater, 3. that calcification rates in corals exposed to a pulse of elevated ammonium increased relative to controls when both were incubated in low-nutrient seawater. We further predict that under conditions of chronically elevated ammonium urea concentrations in the coral will reach a maximum tolerable level. A decline in growth and health of the coral would follow. This may explain why most aquarium studies have demonstrated reduced calcification in conditions of elevated ammonium whereas several studies using pulsed treatments have reported increased calcification. The levels of urea in coral tissue may provide another tool by which the nitrogen sufficiency of a coral might be monitored.

Sediment Toxicity Surveys in the Vicinity of Coral Reefs in the Hawaiian Islands

*Marion NIPPER**, *R Scott CARR*, *James BIEDENBACH*, *Russell HOOTEN*, *Mike FIELD*, *Richard BROCK*

6300 Ocean Drive, NRC, Suite 3200, Corpus Christi, TX 78412 United States of America

mnipper@falcon.tamucc.edu

Sediments are considered as sinks and sources of contaminants. The quality of sediments in the vicinity of coral reefs from the Hawaiian archipelago has been the subject of several recent studies, due to concerns with siltation and pollution from a variety of sources, such as extensive urban development, including tourist resorts and golf courses, and agricultural practices and associated contaminants and nutrients. Potential biological impacts by contaminants on coral reefs can be assessed by sediment porewater toxicity testing. Pore water was collected *in situ* off the Hawaiian Islands, and sea urchin fertilization and embryological development tests using *Arbacia punctulata* were conducted. Several toxic sites off southern Molokai were identified during the initial sampling campaign, but a second campaign a year later only produced two sites with mild toxicity. This suggests either a transient nature of the contaminants from the first campaign or very localized sources coincidentally sampled at that time, e.g., groundwater seeps. No toxic samples were collected in Kauai and Niihau, and only one sample from the northern shore of Maui and two from Hawaii were toxic to sea urchin embryological development. Four toxic samples were collected off Oahu, one on the northwest, near Haleiwa, and three off Honolulu, with the most toxic collected off Waikiki beach. Toxicity off Waikiki beach had also been observed in a preliminary survey performed in 1998. It is concluded that despite intense urban development, tourism and agriculture, sediment quality in most of Hawaii is not strongly compromised by anthropogenic activities. The major area of concern in Hawaii would be, not surprisingly, near the largest city, Honolulu. An emerging pattern in this kind of survey suggests that a constant source of contaminants, such as a sewage outfall or heavy urbanization, is necessary for continued toxicity in the coarse sands typically found around coral reefs.

Unusual Coral Morphologies from Turbid and High Sedimentation Environments and their Inferred Analogues of 1) the "Snow-Shoe Effect" 2) the "Phoenix Effect" and 3) a Novel Internal Skeletal Abnormality

*Iain A MACDONALD**

E402, John Dalton Building, Chester Street, Manchester, M1 5GD United Kingdom of Great Britain and Northern Ireland

I.Macdonald@mmu.ac.uk

The areas investigated were Columbus Park and Red Buoy Patch reefs, Discovery Bay, north Jamaica. These two reefs are located in turbid waters and are subjected to moderate and high rates of sedimentation and sediment accumulation. The reefs increase in sediment-dominated substrate with increasing depth. These sediments have a higher proportion of muds with increasing depth. This study describes novel coral colony morphological adaptations that are exhibited in response to the stressful conditions experienced within Discovery Bay. These include descriptions of colony morphologies that are needed to improve our understanding of modern and palaeo- ecology. These novel morphological responses include 1) the occurrence of either a single tier or closely-tiered platy growth morphologies of corals originally thought to be of a domed or massive morphology (cf. the "show-shoe effect"; Thayer 1975), 2) skeletal evidence from *Siderastrea siderea* and *Montastraea annularis* of extreme polyp tissue retraction and subsequent rejuvenation and regeneration (cf. the "phoenix effect"; Krupp et al. 1992), and 3) skeletal evidence from *Agaricia lamarcki* for rapid colony wide vertical "catch-up" growth that reduces colony weight to volume ratios and may facilitate coral growth rates to catch-up or surmount local sediment accumulation rates. Certain corals utilise such innovative, yet not immediately apparent to the observer, methods for adapting to life in such muddy environments. These observed responses to turbid and high sedimentation environments may help answer the paradox of corals surviving within such inhospitable environments.

An Experimental Investigation to Assess the Impact of Natural and Anthropogenic Changes on Reef Environments Barbados West Indies, Using Coral Cores Sclerochronology and Laser Ablation ICP-MS

*Lesley A RUNNALLS**, Max L COLEMAN

University of Reading, Berkshire, RG6 6AB, UK United Kingdom of Great Britain and Northern Ireland

l.a.runnalls@reading.ac.uk

In this paper we document a method of assessing the history of pollution and explain how these effects have influenced the coral communities off the west coast of Barbados. The relative impact of natural stresses within the reef environment and anthropogenic pollutants were evaluated. For a suite of sampled *Montastraea annularis* coral cores, sclerochronology documents framework and skeletal growth rate and records pollution history (manifested as reduced growth). X-radiography shows annual coral growth bands extending back over several decades and indicates significantly lower growth rate in polluted sites. Whole sample Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICP-MS) results show contrasting concentrations of the trace elements (Cu, Sn, Zn and Pb) between corals at different locations and within a single coral. Deepwater corals 7km apart record different levels of Pb, and Sn, suggesting that a current transported metal pollution in the water. Anomalous Sn and Cu values from most sites, are believed to result from dispersion of nearshore polluted water associated with the 1995 hurricanes. Concentrations of trace elements were compared in the coral growth of particular years to those in the relevant contemporaneous seawater. Mean values for the concentration factor in the coral, relative to the water, ranged from 10 for Cu and Ni to 2.4 and 0.7 for Cd and Zn respectively. The uncertainties with the results are large (60-80%) because the whole sample (aragonite, organic matter, trapped particulate matter etc.) was ablated. These values enabled us to demonstrate the possibility of calculating a history of seawater pollution for these elements from 1943 to 1997 from the coral record. Our measured results are much higher than those obtained from analysis of carefully cleaned coral aragonite and cannot be compared with them; they demonstrate the incorporation of more contamination, including that from particulate material as well as dissolved metals.

Evidence for Deleterious Effects of Net Pen Mariculture Effluent on Coral Reproduction

*Esti KRAMARSKY-WINTER**, Craig A DOWNS, Yossi LOYA

Tel Aviv, Israel 69978 State of Israel

wintere@post.tau.ac.il

In recent years increased net pen mariculture effluents in the northern Gulf of Aqaba (Eilat) have caused an increase dissolved nutrients and particulate matter, resulting in water quality deterioration. In order to ascertain the possible effects these effluents may have on overall health and reproductive output of reef corals, a two year study was carried out comparing reproductive efforts of colonies of the coral *Stylophora pistillata* that had been transplanted six months previously from a non affected site to the vicinity of the mariculture facilities and to a reference site 12 km away. Results show that at both sites a majority of the colonies were reproductive. At the mariculture site a higher number of polyps contained oocytes but these oocytes were significantly smaller than oocytes from corals transplanted to the mariculture site and significantly fewer oocytes reached maturity (>200 μ m). This was reflected in the findings that colonies transplanted to the mariculture site contained significantly fewer planulae than colonies transplanted to the reference site. Examination of a number of biomarkers involved in protein turnover (HSP 60 and 70) and in endocrine modulation (CyP 450) in colonies from the two sites revealed significant differences and indicated that the depression of reproductive effort may be the result of endocrine disruption. These significant differences attest to the possibility that the higher levels of dissolved and particulate nutrients from the net pen site may result in a suppression of coral reproduction. Thus although the effects of eutrophication may be subtle and may not directly and immediately alter large scale parameters such as coral biodiversity or coral cover, it may cause subtle physiological changes in parameters such as oocyte development resulting in the inability of corals to complete the reproductive cycle.

Can Mariculture Activities and Coral Reef Reserve Persist Side by Side?: A Case Study from the Northern Gulf of Aqaba (Red Sea)

Avi PEREVOLOTFKY, Alon ZASK, Benny SHALMON, Ezri ALON, Ran AMIR, David ZAKAI*

P.O. Box 667, Eilat, Israel

dudu.zakai@nature-parks.org.il

Anthropogenic stresses from mariculture effluents, sewage, flood waters, ballast and bilge water from boat activities, and discharges of oil, detergents, phosphates, pesticides and recreational activities are damaging the coral-reefs. Coral community structure in the Nature Reserve of Eilat-Israel, reveals that the living cover of stony corals decreased in the last 9 years by 10-50%. Coral recruitment has been declining steadily by 53-96% since 1997. Bacterial diseases of fish are on the increase, in parallel with increases of diseases recorded in the fish of the mariculture farms, located ca.5 km. north of the Nature Reserve of Eilat. During 1990-1998 the waters of the northern Gulf of Aqaba measured max. 0.4 μ mol. l⁻¹ Nitrate and 0.3 μ mol. l⁻¹ Phosphate. In 1999-2000 they were nutrient enriched at > 500 m. depth to 0.7 and 0.5 μ mol. l⁻¹, respectively. This increase results mainly from the mariculture industry, which contributed 40% more nutrients than all other sources together. During winter and spring, nutrient-rich deep water rises cause seasonal blooms of algae. Such bloom was the cause for the lost of 20% of shallow water corals during a severe upwelling in 1992. During the last 10 years, the mariculture industry's yield has grown exponentially from 300 tons/yr in 1993 to 2700 tons/yr in 2000. Cultured fish fed by 5000 tons/year "fish pellets" result in nutrient enrichment throughout the water column by 300 tons of Nitrogen and 50 tons of Phosphate annually. Nutrients originating from the mariculture industry reach the Coral Nature Reserve of Eilat by current derived mass transport, and is probably the major cause for the mortality of 49% of coral colonies and a decrease of 62% in coral cover during 1993-2000. According to international classification standards the coral reefs of Eilat are at present extremely deteriorated and considered to be in a "critical state".

The Coral Reefs of Eilat - Past, Present and Future: Three Decades of Coral Community Structure Studies

*Yossi LOYA**

Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel

yosiloya@post.tau.ac.il

I present a brief review of ca. 35 years of our studies on changes in the coral species diversity and community structure at Eilat, the Red Sea, at several scales in space and time. In the following, I shall: (1) summarize the geographical setting and the geological, physical and biological characteristics of the Gulf of Eilat/Aqaba, then point out the uniqueness of the coral reefs of Eilat situated at the most northerly boundary of coral reef distribution, yet exhibit extraordinarily high within-habitat coral species diversity; (2) present the changes that took place in coral species diversity and community structure on the reef-flats in the northern Gulf of Eilat (during the 1970s), due to natural disturbances (extreme midday low tides) and man-made perturbations (chronic oil-spills); (3) discuss possible mechanisms that generate and maintain the high within-habitat coral diversity typifying the pristine reefs in the northern Gulf of Eilat; (4) discuss the opposite mechanisms that caused a dramatic decrease in coral abundance and living cover at the Eilat Coral Nature Reserve (ECNR) during 1986-2000 pointing out two major anthropogenic disturbances: first, eutrophication caused by Eilat's sewage discharge operations until 1995; and second, further eutrophication originating from intensive net pen mariculture off the northern coast of Eilat, which exponentially expanded activity from 1994-1995 to present times. The grave implications for the coral reefs of Eilat caused by this chronic eutrophication will be presented; (5) conclude with a warning that at present the coral reefs of Eilat are severely damaged and subsist in a critical state. If eutrophication of the northern Gulf is not halted immediately, the final collapse and total destruction of the unique coral reefs of Eilat is definite. In their present fragile state, the only chance for the restoration of the Eilat reefs is instant protection measures against all man-made disturbances.

Effect of Coral Calcium on Diabetic Mellitus

Norio SATO, Akbar Mohammad ALI, *Shigeru KOUCHI**, Shinichi SOMEYA
1 Kitanorimono-cho, Kanda, Chiyoda ku, Tokyo 101-0036, JAPAN
norio-s@marine-bio.co.jp

Effect of Coral Calcium on Diabetic Mellitus At present, Ministry of Welfare and Labor, Japan reported about 16 million peoples are suffered from diabetes mellitus in 2003. It is caused from the comfortable food habit and life style as it is very difficult to abandon these pleasant habits when someone accustomed with. Therefore, it is difficult for the patients to prevent or cure from diabetes mellitus. CCP (Brand name of coral calcium of Marine Bio products) contains minerals such as Calcium, Magnesium, Chromium and Vanadium with other trace minerals. Worthy to note that, Chromium and Vanadium are well established as the minerals for diabetes mellitus. In 1977, Dr. Curry reported that the ratio of (15 : 1) of Calcium to Magnesium has an influence to increase the insulin production. Furthermore, in 1985, Dr. Ishi reported that Magnesium activates insulin receptor. Dr. Ishitani in Higashi Sapporo Hospital, performed the clinical trial and administered 1g of CCP to the patients before taking each meal. He reported that blood sugar level is declined after one month administration. As CCP has the ability to decline the blood sugar level, a combination product is developed for addressing the diabetes mellitus by using the Coral Calcium with *Salacia oblonga* extract, Guava leaf extract, Citrus extract, Chromium yeast and indigestive dextrin. A clinical trial is performed by the new product in diabetic patients. This clinical study shows the decreasing of blood glucose level, HbA1c, glyco-albumin, total cholesterol and triglycerides.

The Ecology and Ecological Impact of a Highly Invasive, Alien Soft Coral Species on Hawaii's Coral Reef Communities

*Samuel E KAHNG**
1000 Pope Road, Honolulu, HI 96822 United States of America
kahng@hawaii.edu

Carijoa riisei, a shallow-water soft coral species native to the tropical Western Atlantic, is the most invasive of the 287 nonindigenous marine invertebrates in Hawaii. *C. riisei* was first discovered in Hawaii in 1972 and has since spread to all the main islands. In 2001 and 2003, deep-water surveys near Maui discovered *C. riisei* killing >50% of black coral colonies (*Antipathes dichotoma* and *A. grandis*) and overgrowing large beds of *Leptoseris* sp. at depths of 65-115 m. As an alien invasion on coral reefs, the potential scale and severity of this impact may be unprecedented. This bio-invasion now threatens the \$30 million precious coral industry in Hawaii with potentially wider ecological implications throughout the Pacific. Despite this emerging notoriety, relatively little is known about *C. riisei* and the process of invasion in tropical coral reef communities. In 2002, the *Carijoa* research project was launched with support from Sea Grant to determine the ecology and ecological impact of this highly invasive alien in Hawaii. Preliminary results reveal not only traditional r-selected characteristics commonly associated with opportunistic invaders but also k-selected traits typical of dominant competitors. Time series analysis of gonad development suggests that *C. riisei* is highly fecund and spawns continuously throughout much of the year. Analysis of distribution & abundance imply that viable habitat results from both the paleoceanography of the Hawaiian Islands and modern anthropogenic activity. Management of the proliferation and dispersal of *C. riisei* presents a challenging ecological problem. In the Western Pacific, several populations of *Carijoa* have been identified. However, taxonomy has not been resolved at the species level, and whether these populations also represent alien invasions is unknown. The *Carijoa* project has recently been expanded to incorporate molecular genetic techniques to determine the phylogenetic origin and dispersal history of *Carijoa* in the Pacific.

Tactile Dancing in Cleaner Fish as a Pre-conflict Management Strategy

*Alexandra S GRUTTER**
School of Life Sciences, University of Queensland, Brisbane, Queensland, Australia, 4072 Australia
a.grutter@uq.edu.au

How cooperation is maintained among unrelated animals despite profitable cheating is highly controversial. In cleaning symbioses many cleaner fishes remove parasites from piscivorous client fishes, yet how they avoid being eaten and thus cheated by clients is unclear. Although several theoretical models have examined cheating behaviour in clients, no empirical tests have been done. That cleaners are susceptible to predation is not unheard of, thus cleaners should have evolved strategies to avoid conflict or being eaten. In primates, conflicts are often resolved using conflict or pre-conflict management behaviour. To determine whether cleaner fish use specific strategies when exposed to a perceived risk I manipulated the hunger levels and parasite loads of the piscivorous client fish *Plectropomus leopardus* and recorded the relations between cleaner fish *Labroides dimidiatus* and the clients. I found that cleaner fish tactically stimulated clients while swimming in an oscillating 'dancing' manner (tactile dancing) more when exposed to hungry clients than satiated ones, regardless of the client's parasite load. Tactile dancing thus may function as a pre-conflict management strategy that enables cleaner fish to avoid conflict with potentially 'dangerous' clients. Foraging tactile stimulation frequency was higher on fish with many parasites than those with few, regardless of hunger level suggesting it did indeed represent feeding. Client posing frequency, a measure of a client's desire to be cleaned, was higher for fish with many parasites, regardless of hunger level. That client posing did not vary with hunger level suggests that it does not serve as a form of appeasement behaviour by potentially dangerous fish towards cleaner fish. Tactile dancing as interspecific signalling to manage conflicts adds to the increasing list of the cleaner's abilities to deal with complex social environments, abilities usually the focus of cognitive studies of primates.

Trophic Structure Patterns of Brazilian Reef Fishes: A Latitudinal Comparison

*Carlos Eduardo Leite FERREIRA**, Sergio FLOETER, Joao Luiz GASPARI, Beatrice FERREIRA, Jean JOYEUX
Rua Kioto 253, Arraial do Cabo, RJ 28930-000 Federative Republic of Brazil
kadu@alternex.com.br

The importance of macroecological and large-scale studies to the understanding of main ecological processes is now very clear. However, few studies have examined possible latitudinal gradients in reef fishes, mainly due to logistical and financial constraints. Such data on reef fish latitudinal distribution is also a priority to management and conservation efforts on reef systems. In order to investigate how reef fish trophic structure responds to latitudinal changes, we used the extensive Brazilian coast as model. Six Brazilian tropical and subtropical coral and rocky coastal reefs, plus the oceanic island of Atol das Rocas, between latitudes 0° and 27°S were included in the comparison. Underwater visual census data collected by the authors (5 locations) or obtained from the literature (2 locations) were used to estimate the relative abundance of 123 fish species belonging to 33 reef-associated families. Cryptic species were excluded from the analysis. Fishes were grouped in eight trophic categories: roving herbivores, territorial herbivores, mobile invertebrate feeders, sessile invertebrate feeders, omnivores, planktivores, piscivores, and carnivores. The trophic structure of Brazilian reef fish assemblages clearly changed with latitude. Roving herbivores such as scarids and acanthurids were proportionally more abundant at low latitudes. The browsing herbivores kyphosids followed an opposite latitudinal pattern. The relative abundance of territorial herbivores did not decrease towards high latitudes. Mobile invertebrate feeders were the most important (in low latitudes) or the second-most important trophic guild (in high latitudes) at all coastal sites. Sessile invertebrate feeders did not show any clear latitudinal trend, despite an expected increase in abundance towards low latitudes. Omnivores dominated high latitude reefs (27°S) and planktivores the oceanic island Atol das Rocas. Piscivores and carnivores were proportionally better represented in high latitudes. Latitudinal patterns seem to be influenced by phylogeny, physiological constraints (mainly related to temperature), as well as anthropogenic impacts.

Effect of Temperature on Fertilization, Embryonic Development and Growth Performance of Early Larval Stages of the Two Sea Urchin Species (Genus *Echinometra*) in Coral Reef

*M Saifur RAHMAN**, *M Aminur RAHMAN*, *Yuji HIRATSUKA*, *Tsuyoshi UEHARA*

Department of Chemistry, Biology and Marine Science, Faculty of Science, University of the Ryukyus, 1 Senbaru, Nishihara-cho, Okinawa 903-0213, Japan
r7saif@yahoo.com

Two closely related tropical sea urchin, *Echinometra* sp. A and *Echinometra* sp. C are abundant on Okinawan intertidal reef. In natural habitat, *E. sp. A* and *E. sp. C* inhabits tide pools of reef flat and burrows in reef margins, respectively. The reproductive season of these two species is in summer months. Previous studies on thermo tolerance of adult sea urchins revealed that *E. sp. C* could tolerate higher temperature than *E. sp. A*. Based on these results; we are interested to check the temperature sensitivity of gametes as well as embryos and early larvae of these two sea urchins. On the fertilization success, the eggs of *E. sp. C* can tolerate higher temperature than that of *E. sp. A*. The lower temperature limit for embryonic development of *E. sp. A* and *E. sp. C* are 18°C and 20°C and the higher limits are 31°C and 33°C, respectively. Development to Echinoplutei for both *E. sp. A* and *E. sp. C* is proceed normally at lower temperature of 22°C, and the higher temperatures of 31°C and 33°C, respectively. The effects of different temperature on the developmental speed of larvae of the both species are observed to be Significant. The above findings will be a great help in attracting the problem of the dispersion, growth, settlement of the larvae as well as distribution of the sea urchins in various geographical location of the sea.

Spatial and Short-term Temporal Variability of Macrofauna Communities in Sediments: A Fringing Reef from Reunion Island (Indian Ocean)

*Dorothee TADDEI**, *Patrick FROUIN*, *Thomas MONDON*

15 avenue Rene Cassin, 97715 Saint-Denis, Ile de La Reunion Messag cedex 9
Dorothee.Taddei@univ-reunion.fr

This study is a first approach insight on macrofauna communities in sediments at la Reunion Island. Environmental features (grain-size data, fine sediment, total organic matter) and communities parameters (density, species richness, biomass) are studied during the warm season in 6 stations of the reef complex of Saint-Gilles La Saline. Short-term temporal variability was studied on density over two months at Trou Eau back reef station. Temporal fluctuations were considered for days, weeks and months. The communities are poorly diversified (64 taxa, N2 = 4,9). They are dominated by actiniarians, amphipods and molluscs, with 98 % of the total density. At scale of the reef complex, 3 groups of stations occur. The environmental variables can not explain the macrofauna spatial pattern as they show strong homogeneity. Hydrodynamics and eutrophication factors seem to play a major role. Analysing the trophic structure showed a domination of deposit-feeders group (65 % of the total density) probably favored by the conditions of low eutrophication. Deposit-feeders create trophic group amensalism. Back reef stations are unbalanced (but one) whereas the stations located on the other geomorphological zones (areas with dispersed colonies and inner flat) are more mature. Nested ANOVA showed stable communities on two months study at Trou Eau back reef. Finally, short-term temporal variability study suggests that the fringing reef ecosystem is resistant or resilient despite subject to recent disturbance (cyclones) and this stability is related to low specific richness. Key words: coral reef, macrofauna communities, sampling, sediments, spatial and short-term temporal variability.

Traditional Resource Use of Sea Algae and its Social Importance in Shiraho Coral Reef, Ishigaki Island, Okinawa

Kyoko ISHIKAWA, *Kanako AOKI*, *Takashi KOBAYASHI*, *Masahito KAMIMURA**, *Tetsu SATO*

118 Shiraho, Ishigaki, Okinawa Prefecture, 907-0242 Japan
kamimura@wwf.or.jp

Natural resources that communities utilize as a base of minor subsistence play an important role in shaping close relationship between local residents and surrounding natural environment. Such resources are often shared within the community. Natural environment with such resources (commons) maintains sense of ownership of the community members, which has crucial importance in community-based management of natural environment. We investigated patterns of traditional use of sea algae resources in the coral reef of Shiraho, Ishigaki Island, from April 2002 to December 2003 by interviews to the elderly people in the community to clarify the factors affecting mental and social ties and sense of ownership toward coral reefs among local residents. Sea algae and other resources found along the shallow coastline of the reef has been known to support life of Shiraho residents as a source of revenue as well as daily nutrition. The resources within a moat are accessible to farmers and other residents who do not have expertise and skills of fisheries, but the patterns of use of sea algae resources are likely to have changed during rapid growth of Japanese economy and associated changes in local life style. At the same time, these resources are vulnerable to environmental changes that affect the moat. Our preliminary analyses of the interview records revealed that sea algae was mainly collected by elderly women in the community, and sold or consumed through their social ties specific to each individual or family. We identified variety of traditional skills and indigenous knowledge on algal resources that seemed rarely shared with the younger generations. In this paper, we describe recent patterns of algal resource use and potential factors that may affect recognition of importance of natural environment and sense of ownership among local residents

Algal Farms in Coral Reefs: Intensive Management by Territorial Damselfish

*Hiroki HATA**

Yoshida-Nihonmatsu, Sakyo, Kyoto 606-8501 Japan
hata@d01.mbox.media.kyoto-u.ac.jp

In contrast with the findings that most herbivores in marine ecosystems are euryphagous, territorial damselfishes in coral reefs show specialization to limited host algae by highly developed algal-resource management, i.e., farming. Among these damselfishes, dusky farmerfish, *Stegastes nigricans*, manages a unique algal farm which is strongly predominated by a filamentous rhodophyte *Polysiphonia* sp., and thus its host-specificity is remarkably high. To detect actual processes of farming by *S. nigricans* and its effects on algal community, field experiments and observations were conducted in coral reefs in Okinawa. Throughout the year of observations, *S. nigricans* maintained a unique monocultural algal farm of *Polysiphonia* sp. by selectively weeding out other indigestible algae. After exclusion of *S. nigricans* by experimental cage, the monocultural algal farm was rapidly deteriorated by late-colonizing algae, which had been weeded by the fish, and eventually *Polysiphonia* sp. was completely taken over by the end of the 12th week. Additionally, monoculture of *Polysiphonia* sp. did not colonize inside herbivore-exclusion cages settled outside the territories. As most territorial damselfishes do, a sympatric congener, *S. obrepus*, maintained a mixed-culture farm by extensive management without weeding, involving only delayed exclusion of invading herbivores. On the contrary, *S. nigricans* maintained small but high biomass per area, monocultural farm of one palatable alga by intensive management involving weeding and prompt exclusion of invaders. *S. nigricans* exclusively depends on the crop alga for nutrients, while *Polysiphonia* sp. can grow and reproduce only in the algal farms managed by the fish. In this relationship, the fish guards the alga from other herbivores and competitively superior algae, and in turn the alga provides photosynthetic products as rewards. These results clearly suggest that the interaction between *S. nigricans* and *Polysiphonia* sp. is a species-specific mutualism, illustrating a novel example in plant-herbivore interactions in marine ecosystems.

Population Genetic Structure of the Hawaiian Precious Coral, *Corallium lauense*, Based on Microsatellites

Amy R BACO*

WHOI Biology Dept., MS#33, 214 Redfield, Woods Hole, MA 02543, USA
abaco@whoi.edu

Hawaiian deep-sea precious corals support an extremely profitable fishery, yet little is known about the life history and dispersal of the exploited species. Recent studies indicate significant genetic structure between shallow-water coral populations, including several species capable of long distance dispersal. If significant genetic structure exists in populations of precious corals, this could suggest that the elimination (through overharvesting) of a bed of precious corals would result in loss of overall genetic diversity in the species. The goal of this study is to determine the appropriate management units (or stocks) for Hawaiian deep-sea precious corals. Stocks are identified for *Corallium lauense* based on 3 microsatellite loci. Microsatellites are segments of DNA that consist of repeated units of short (di- or tri-nucleotides) sequences. Microsatellites are highly variable, making them ideal for kinship and population-level studies. By determining the stock structure of the harvested species and providing information on dispersal and recruitment in these species as a function of life history, this project will substantially improve our ability to manage the Hawaiian coral fishery as a sustainable resource. This project will also provide insights into dispersal and gene flow of seamount fauna.

Species Diversity and Spatial Distribution of Invertebrates on *Lophelia pertusa* (L., 1758) Reefs in Norway

Paal B MORTENSEN*, Jan H FOSSAA, Haralds FOSSHAGEN

Institute of Marine Research, N-5017 Bergen, Norway
paal.mortensen@imr.no

This paper describes the species diversity and spatial distribution patterns of invertebrates on *Lophelia pertusa*-reefs in mid-Norway. Coral samples from six reefs (three coastal and three offshore) were collected with Remotely Operated Vehicle, triangular dredge, and van Veen grab. A total of 366 species were identified among which two, Anarthropoda monodon (Bryozoa), and *Leptasterias islandica* (Asteroidea) are new to Norway. Even though none of the species are found exclusively on the reefs some are seldom found in other habitats. The diversity was highest among dead corals, and lowest among live. Only three species were found living in direct contact with the corals soft tissue. The fauna of the continental shelf-reefs differs from that of the coast and fjord-reefs. This was most evident for Foraminifera, Cnidaria, Amphipoda, Bryozoa and Tunicata. The results of the present investigation were compared with those of three earlier studies in the Northeast Atlantic. Together with these a total of 775 species have been recorded. However, only 14 were common for all four studies. Foraminifera and Bryozoa were the most species rich groups with 52 and 50 species, respectively. Number of species and individuals in a sample were highest for triangular dredge and lowest for ROV, but the average number of individuals per 100 g corals was comparable between dredge and grab. To describe the spatial distribution of invertebrates within a *Lophelia*-reef, and to increase the sampling precision, we recommend to use grab equipped with a video camera because it effectively samples the fauna and damages less coral compared to a dredge.

The Association of Subphotic Fish Assemblages with Precious Corals in the Hawaiian Archipelago

Frank A PARRISH*

2570 Dole Street, Honolulu Hawaii 96822 United States of America
Frank.Parrish@noaa.gov

Submersibles were used to survey fourteen sites across the Hawaiian Archipelago to document subphotic communities (300-500 m). Surveys systematically identified and measured fish and corals while tracking changes in substrate type and bottom relief, with the greatest attention focused on the three commercially harvested coral species (*Gerardia* sp. *Corallium secundum*, *Corallium regal*). Species richness of fish was not observed to differ between areas with corals and those without. Most fish taxa were observed in low numbers with only a couple of species dominant. Areas with corals often supported greater fish density, than adjacent areas without corals, but statistical evaluations suggest that this is due to co-occurrence of fish and coral in areas of relief and high flow and not a dependency of fish on corals. No difference was seen in mean fish size in or outside of the coral beds. Of the three commercial coral species, fish oriented mostly around *Gerardia* sp. probably because it is significantly taller than the two *Corallium* species. Classifying the fish into functional groups revealed "benthic hoverers" as the segment of the fish community that most frequently used *Gerardia* sp. as shelter.

Deep-Sea Coral Geochemistry: Potential Proxy for Paleoclimate Reconstruction

Kotaro SHIRAI, Minoru KUSAKABE, Hajime HIYAGON, Shunichi NAKAI, Yuji SANQ*

3-17-16 Minamidai, Nakanoku, Tokyo Japan
kshirai@ori.u-tokyo.ac.jp

Long record of ice and oceanic sediment cores revealed the glacial climate changed rapidly. Deep-sea circulation plays important roles in the climate system, but the role is uncertain because core record doesn't have enough time resolution to study mechanisms. Deep-sea coral may have high time resolution record since it has growth banding structure, ~1 mm/yr of growth rate. However there are a few studies about the relationship between minor- and trace-element and environment factors. In this study, we have measured Sr/Ca, Mg/Ca, Ba/Ca and U/Ca ratios in deep-sea coral skeleton collected from 80-1000 m deep at bulk and 30um scale. We also measured bulk stable isotopic ratio of carbon and oxygen. In bulk scale measurement, Sr/Ca and Mg/Ca ratios have weak negative and positive correlation with sea water temperature estimated from collected depth, respectively. Deep-sea coral $\delta^{18}O$ deviation from inorganic aragonite doesn't show any correlations with the elemental ratio deviation from reef-building coral. In micro-scale measurement using an ion probe, large variation has been found for the count ratio (cps/103cps) on $^{88}Sr/^{44}Ca$ (413.9-455.9), $^{24}Mg/^{44}Ca$ (15.74-26.63), $^{138}Ba/^{44}Ca$ (0.6268-0.7625), and $^{254}UO/^{44}Ca$ (0.02067-0.04444). Since the sample was collected from ~1000 m deep on relatively stable environment, the variation may be derived from a biological process, not from environmental change such as ambient temperature. $^{254}UO/^{44}Ca$ ratio shows a positive correlation with the $^{88}Sr/^{44}Ca$. A least-square fitting yields a regression line of $(^{254}UO/^{44}Ca) \times 10^3 = 0.3787(^{88}Sr/^{44}Ca) - 13.095$ ($R^2=0.5107$), where this slope is similar to the value reported about reef-building coral (0.3366-0.3755 mmol/mol, compiled by Wei et al., 2000). This may imply uranium incorporation mechanism into deep-sea coral skeleton is similar to strontium, uranium and strontium incorporation mechanism of deep-sea coral is also similar to reef-building coral. Deep-sea corals seems to be largely affected by a biological process. We need further investigation to use them for paleoclimate proxy.

Fibreglass Artificial Reef Units as a Method of Reef Rehabilitation in the Sedimented Waters of the Southern Islands of Singapore

*Tse-Lynn LOH**, *Loke Ming CHOU*

14 Kent Ridge Road Singapore 119223 Republic of Singapore
tmslohtl@nus.edu.sg

More than 60% of the original coral reefs in Singapore have been lost due to extensive coastal developments. The remaining reefs are subjected to high sedimentation rates and have poor hard coral cover. Hard coral recruitment rates are also low due to a lack of stable substrates for coral larvae to settle on, as the reefs contain a high percentage of coral rubble. Artificial reef units serve to provide a stable and suitable surface for coral recruitment, and help to rehabilitate degraded reefs. Fibreglass was used as the material for specially designed Reef Enhancement Units (REUs), for three sites in the Southern Islands of Singapore. The units are small and light enough to be deployed from passenger boats for divers to manipulate underwater, compared to using barges and heavy machinery as for denser materials. This is more suitable for a sedimented environment as the reefs are too shallow for barges to approach. The REUs were monitored monthly over two years for community development using line transects, and hard coral recruits were counted and identified to family or genus level. The REUs at all three sites were immediately colonised by turf algae within the first month, which was then replaced by crustose coralline algae, macroalgae, ascidians and hydroids. The first incidence of coral recruitment was 8 months post deployment. Coral recruitment rates at the end of the monitoring period ranged from 0.45-7.0 recruits/m² for the three sites. The most abundant recruit was *Pocillopora* sp., followed by favids, acroporids and poritids. The REUs require intensive labour and dive time to deploy, but serve the purpose of enhancing coral recruitment, which could aid in increasing the hard coral cover on the degraded reefs in Singapore.

The Effect of Substratum Stability on Benthic Artificial Reef Communities: Biological and Hydrodynamical Aspects

*Shimrit PERKOL-FINKEL**, *Gregory ZILMAN*, *Tuvia MILOH*, *Yehuda BENAYAHU*

Ramat Aviv, Tel Aviv 69978, Israel
sperkol@post.tau.ac.il

Despite the proliferation of coastal development worldwide, including deployment of man-made structures, and in particular the use of floating structures, little is known of their performance in reefal environments. This study examines the hypothesis that floating artificial structures are likely to be inhabited by a unique species assemblage, different to that of identical fixed structures. Our goals were 1) to examine the development of benthic communities on floating experimental modules vs. fixed ones; 2) to determine the differential effects of the artificial substratum stability, orientation, and position in the water column on development of fouling assemblages; and 3) to characterize the current regime in these habitats. The study was conducted at the northern tip of the Gulf of Eilat (Israel). The experimental set-up constituted three-dimensional modules made of metal mesh with settlement plates attached to each module. Each installation comprised three modules, suspended at seabed level, mid-water and sea-surface. There were two types of installations: floating installations, subject to motion, and fixed ones, attached to a firm substratum. Plates were sampled every 6 months and examined for settled invertebrates, organic weight and chlorophyll content. Flow regime on the installations was characterized. Accumulated organic matter on the floating installations was higher than that of the fixed ones, while chlorophyll content exhibited an opposite trend. Higher coral settlement was found on the fixed installations. There was a significant increase in organic matter and in the number of coral recruits with time. Hydrodynamic analyses indicated an increased mass transfer at the floating installations. The depth of the module was inversely related to the intensity of water movement, for both the floating and the fixed installations. It is therefore suggested that it is the stability of the habitat that determines its hydrodynamic regime, which in turn shapes its community structure.

Assessment and Restoration of the M/V Wellwood Grounding Site, Molasses Reef, Florida Keys National Marine Sanctuary, Florida, USA

*James H HUDSON**

P. O. Box 1083, Key Largo, Florida, USA 33143 United States of America
harold.hudson@noaa.gov

The purpose of this report is to document assessment methods used to quantify post-grounding injury to the M/V Wellwood grounding site and to provide information on restoration techniques and materials used to repair fourteen craters excavated at the site by a post-grounding hurricane. Vertical underwater photography was used to calculate each crater's area and excavation volume was determined by diver measurements. Nine craters were infilled with specially designed "Reef Replacement" modules and tremie-pour concrete. Five of the excavations had insufficient depth to accept modules. Repair of these areas was effected by substituting 1/2 to 2 ton (450-1,800kg) limestone boulders for precast modules. A barge, crane and commercial divers were used to place modules, boulders, and tremie-pour concrete. Exposed concrete was ornamented with randomly placed limestone rock dressing stones to increase rugosity and create a more natural appearance. Restoration was initiated and completed in the summer of 2002. Key Words: coral, reef, restoration, assessment, grounding, crucial

Rehabilitation at Ecologically Significant Scales for Coral Reefs Damaged by Blast Fishing

*Helen E FOX**, *Peter J MOUS*, *Jos S PET*, *Andreas H MULJADI*, *Roy L CALDWELL*

PO Box 1346, Kane'ohe HI 96744 United States of America
hfox@hawaii.edu

Illegal fishing with bombs or dynamite has damaged coral reefs throughout Southeast Asia, shattering coral skeletons in addition to killing fish and other organisms. Chronic blasting leaves fields of broken rubble that shifts in the current, abrading or burying any new coral recruits and thereby slowing or preventing reef recovery. Successful rehabilitation efforts can contribute to coral reef conservation. In this project we assessed the effectiveness of different low-cost methods for coral reef rehabilitation in Komodo National Park, Indonesia. Our experiments were conducted at three different spatial scales. At a scale of 1 x 1 m plots, we tested three locally-available methods: rock piles, cement slabs, and netting pinned to the rubble, at nine sites beginning in 1998. Significantly more corals per square meter grew on rocks and cement compared to netting or untreated rubble, although many plots were scattered by strong water current or buried by rubble after 2.5 years. Next, to test the benefits of the most successful treatment, rocks, at more realistic scales, we established 10 x 10 m plots of rock piles at each site in 2000. Three years post-installation, coverage by hard corals on the rocks continues to increase, although rehabilitation in high current areas is the most difficult. Finally, in 2002, rehabilitation efforts in KNP were further scaled up, testing four rock pile designs at each of four rubble field sites, covering more than 6,000 m² total. Economically, substrate stabilization using locally available rock compares favorably with other methods. Using rocks for simple, low-cost, large-scale rehabilitation appears to be a viable option for restoring the structural foundation of damaged reefs, assuming there is an adequate larval supply.

Coral Recruitment to Three Reef Restoration Sites in the Florida Keys

Alison L MOULDING*

4600 Rickenbacker Causeway, Miami, FL 33149 United States of America
amoulding@rsmas.miami.edu

One of the major physical threats to coral reefs is damage caused by vessel groundings. In an effort to repair this damage, reef restoration projects have been undertaken in the Florida Keys National Marine Sanctuary to speed the recovery process. A number of different restoration methods have been attempted, but consensus on the best approach has not yet been reached due to limited monitoring of site recovery. As a result, success of these restoration efforts is unclear. Since recruitment is the first step in the reestablishment of the coral community after damage has occurred, coral recruitment can be used as a measure of one aspect of the success of reef restoration. Three reef restoration sites, the Elpis, Houston, and Iselin, were chosen based on their size and the different restoration techniques employed. These sites were examined for scleractinian coral recruitment and compared to reference sites. The goal was to determine if differences in coral recruitment existed both between restoration and reference sites, as well as among all restoration sites and among all reference sites. Density of coral recruits at the restoration sites ranged from 8.9 ± 2.2 to 77.8 ± 37.3 recruits m^{-2} . Recruit density at the control sites ranged from 4.7 ± 1.4 to 7.3 ± 1.4 recruits m^{-2} . When compared to the reference sites, density of recruits was significantly higher at the restoration sites for two out of the three sites examined. In addition, coral generic richness was higher at all restoration sites. There was no significant difference in the density of recruits among reference sites. However, there was a significant difference in the density of recruits among the restoration sites. All reef restoration efforts were successful. However, due to age differences, it is not possible to make any definitive conclusions about which restoration method worked best.

Biological and Physical Restoration of a French Polynesian Damaged Reef Site: Success and Frustration

Muriel SCHRIMM*, Bernard SALVAT, Yannick CHANCERELLE, Michel PORCHER, Richard MORANCY, Mehdi ADJEROUD, Annie AUBANEL

Universite de Perpignan, 52 avenue Paul Alduy, Perpignan France, Metropolitan
schrimm@univ-perp.fr

Because the coral reef ecosystem is degrading in an alarming way all over the world, there was a growing trend, in the last two decades, to restore coral reef habitats. The present work reports the evolution of a reef restoration project (20,000 m^2) experienced in French Polynesia. In the lagoon of Bora Bora, a fringing reef flat was degraded by coral sand dredging, leading to an erosion of the coast. Because the site was of very high tourist interest, French Polynesian Ministry of Environment planned a study to define technical solutions to return the degraded site to its original state with protection against erosion. The restoration was "physical" at first and required shoreline remodelling with filling up holes, implantation of spurs and putting into place a breakwater system composed of artificial concrete structures, which were also intended to promote the natural colonisation of corals and other reef organisms. A "biological" restoration was also part of the project with the creation of a coral garden by transplanting corals (311 colonies collected in the vicinity) on the artificial structures or on the seabed between them. Two and a half years after this restoration, the project proved to be successful. Coral communities flourished in the coral garden: recovering and growth rates were high, with only 3% mortality. Natural colonisation on artificial structures was teeming with corals, sea urchins, mollusks and fishes. But 30 months after the coral garden creation, an exceptional meteorological event led to massive mortality among transplanted as well as natural coral colonies in this part of the lagoon. If techniques for the restoration of degraded zones are highly controlled to date, these expensive works do not escape the temporal variations of environmental conditions. The experiment could serve as a base of reflection to promote the development of low coasts techniques.

Patterns of *Acropora palmata* Recovery at the Fortuna Reefer Ship-grounding Site: Survivorship of Restored Fragments and Recruitment Success Over Six Years

Robin J BRUCKNER*, Andrew W BRUCKNER

1315 East West Highway, F/HC3, Silver Spring, Maryland 20910 United States of America
robin.bruckner@noaa.gov

Patterns of survivorship and mortality of restored *Acropora palmata* (elkhorn coral) fragments were examined over six years at the Fortuna Reefer ship grounding site off Mona Island, Puerto Rico to evaluate the benefits of coral restoration in enhancing elkhorn coral recovery. Within 3 months of the grounding, restoration specialists reattached coral fragments ($n=1857$) to the reef substrate or to standing dead colonies using wire. A large number of fragments died or were detached and removed from the site in the first two years, and a midcourse correction was undertaken to rewire the remaining fragments in July, 2000. While this reduced fragment loss due to wire breakage ($n=15$ between 2001-2003), only 20.3% ($n=377$) of the restored fragments were alive in August 2003. Surviving fragments had tissue on 60% of the original branch surface, and 58% exhibited substantial amounts of new growth in the form of protobranches (4.4 branches per fragment; 21.4 cm in length) and 30% had fused to the substrate. While signs of *A. palmata* recovery were noted, including sexual recruitment and regrowth of fragments, a severe white-band disease outbreak was documented within the restoration site and in neighboring control sites. Stabilization of *A. palmata* fragments appears to be an effective strategy to speed up recovery processes of elkhorn coral populations following physical impacts like ship groundings, primarily by reducing fragment loss during periods of high wave action. However, *A. palmata* has undergone a regional decline and disease continues to affect this species. Efforts are needed to better understand and address the causative agents, vectors and impacts of coral diseases, which remain a major threat preventing reestablishment of elkhorn coral population

Coral Reef Mitigation and Restoration Techniques Employed in the US Affiliated Pacific Islands: Practices, Problems and Prospects

Steven P KOLINSKI*, John NAUGHTON, Paul L JOKIEL

1601 Kapiolani Blvd., Suite 1110, Honolulu, HI 96814-0047 United States of America
steve.kolinski@noaa.gov

A variety of actions have been employed throughout U.S. affiliated Pacific Islands to mitigate losses to coral reef habitat resulting from anthropogenic activities. Direct attempts have included efforts at reef repair, coral transplantation, placement of shipwrecks and construction of artificial reef substrate. Indirect actions, involving the reduction or removal of reef stressors to accelerate natural recovery, have included displacement or removal of shallow water sewage outfalls, other forms of discharge, derelict nets, debris, ship wrecks, destructive military activity, goats and the establishment of marine reserves. Mitigation in the form of negotiated settlement has occurred to compensate coastal communities for damage to reef habitat deemed critical to social needs. A catalogue of mitigation actions is being created and long-term follow-up assessments are taking place to evaluate parameters related to technique success for coral reef mitigation and restoration guideline development.

A Biological, Biochemical and Behavioral Approach to Coral Reef Restoration and Remediation

*Aileen N C MORSE**

Marine Science Institute, University of California, Santa Barbara, CA 93106,
USA United States of America
a_morse@lifesci.ucsb.edu

To effect successful restoration of corals to denuded reefs we must broaden our approach to include consideration of key biological, biochemical and behavioral factors that operate to control the recruitment process. One of the first biological processes that we must bring under control is that of reproduction. We can expect the availability of gametes to be very low on a reef in need of restoration, in most cases well below the threshold numbers required to make a significant impact on natural larval supply. Additionally, we now understand that, on the reef, success of sexual reproduction depends on availability of nearby colonies of the same species. For these two reasons, alone, our approach to larval supply for restoration purposes should be to develop land-based aquaculture facilities for collection and defined-colony crosses from nearby plentiful sources. We can then control the number and species composition of developing larvae that, after rearing under optimal physiological conditions, can be used for out-planting to the reef. Secondly, we can exploit the biochemical requirement of larvae of many important reef species for a specific reef alga-associated chemical cue for controlled induction of metamorphosis by providing these hatchery-raised larvae with substrates containing this natural cue, in any particular physical array that is appropriate for the local habitat of the reef under restoration. Also, very importantly, the structuring of restoration arrays should address the species-specific behavioral requirements of larvae that, we have found, influence larval ability to select favorable niches for subsequent growth and survival. By behavioral niche-selection, larvae optimize grow-out conditions for light, depth and uptake of endosymbionts; they also optimize survival by protection from predators, disturbance and overgrowth by other species. As we report here, we found it may be possible to predict the potential outcome of the success of coral restoration by these approaches.

Response of Fishes and Corals to Removal of Macro-algae on Degraded Reefs in the Philippines

*Melita A SAMOILYS, Brian CABRERA, Denise MCCORRY**

P.O. Box 68200, Nairobi Republic of Kenya
mas@iucnearo.org

Reefs that have been severely degraded by dynamite fishing in the central Philippines present as banks of rubble with high cover of brown macro-algae, especially *Sargassum* spp. We tested the hypothesis that macro-algae inhibit coral growth and hence recovery of coral reef communities by conducting an algal cropping experiment. All macro-algae were removed from five 25m² treatment plots and five control plots were established in a marine protected area on Pinamgo Reef, Bohol. Coral colonies and all demersal fish species larger than 4cm TL were counted and their sizes measured through regular visual census surveys in all 10 plots. Monitoring began 1 month prior to treatment and then for 12 months after treatment, monthly for the first six months, and thereafter every other month. Response to removal of algae was variable between taxa and species. In general, abundance and diversity of fish species increased in response to removal of macro-algae. The implications of the results will be discussed in the context of rehabilitating severely degraded reefs.

Large-scale (300 Colony) Transplantation of Healthy *Acropora palmata* Colonies in Boca Chica, Dominican Republic: A Possible Control for Remediation Projects

M Bernadette BEZY, Oswaldo E VASQUEZ*

CIMAR, Ciudad de Investigacion, Universidad de Costa Rica, 2060 San Jose, Costa Rica
b_bezy@hotmail.com

In 2002, the approval of a port terminal in Punta Caicedo, Boca Chica, Dominican Republic demanded the adoption of large-scale transplantation measures to protect *Acropora palmata* and other corals in the area. Most large-scale coral transplant projects dealing with *Acropora palmata* in the Caribbean are a response to extensive reef degradation events, such as ship groundings. In such cases, the colonies being stabilized were subject to sometimes violent disturbances that could either impact their initial live tissue cover at the time of transplantation or their ability to recover from the disturbance. However, in this study we transplanted 300 colonies of previously physically undisturbed *Acropora palmata* all with 100% live coral tissue cover from their location at a international port construction site, to a hurricane-damaged reef located approximately 1500 m. upstream of the port. Depending on size, the colonies were transplanted using Portland type II cement, stainless steel wire, and/or tiewraps. Colonies were either cemented to hard substrate or tied to existing dead *Acropora palmata* reef buttresses. The survival rates, live coral cover, growth rates and reproduction were tracked during the first year of the project. Preliminary results yield a survival rate of 95%, and an average growth rate of 3.0-3.5 cm/yr. Live coral coverage estimates are approximately 70-80%. 100% of the colonies have overgrown their wire and 95 percent have fused with the substrate. During eight nights of nocturnal SCUBA dives from August 14 to 19 of 2003 (10 months after transplantation), no gametes or spawning were observed. This transplantation of previously undisturbed *Acropora palmata* could possibly represent the upper potential for large-scale remediation (mitigation) project transplantation success, given the state of each coral colony prior to transplantation, the proximity of transplant sites, and the size-specific techniques employed to transplant the colonies.

Evaluating the Success of a Major Coral Relocation Exercise at Rackhams Cay, Kingston Jamaica

Peter E T EDWARDS, George F WARNER, Peter H WILSON-KELLY, Marlon H HIBBERT*

University of the West Indies, Mona, Kingston 7, Jamaica W.I. Jamaica
peter.edwards@uwimona.edu.jm

Rackhams Cay lies outside the Kingston Harbour along the southern border of the East Ship Channel. It can be described as a semi submerged sand bar, surrounded by extensive seagrass beds along its sheltered western and southern margins. Prior to dredging activities the main coral reef community was located on the exposed eastern and northern margins in water 3m to approximately 18m deep. The northern and eastern margins of the Cay were dredged in order to facilitate the widening of the shipping channel, as part of a large port expansion project undertaken by the Port Authority of Jamaica. Prior to dredging the developers were required to physically remove all corals, gorgonians and urchins from the dredge site to the sheltered western side of Rackhams Cay. The relocation of over 60,000 units of living coral reef organisms (hard and soft coral, sponges and urchins) was the first project of its kind in Jamaica. Preliminary investigations have shown that the relocation of coral units has had a significant impact on the structure of the benthic community in the relocation areas. Permanent video transects of 50m length were used to capture data on benthic community composition with an emphasis on percentage hard coral. Growth and mortality rates of corals at the study site were assessed. High mortalities of transplanted gorgonian species were observed, but there has been some success with some hard coral species in particular *Acropora palmata*. It is hoped that the results of this study will be used to assist the National Coastal Zone Planning Unit on the effectiveness of the relocation methodology and the implications for future relocation exercises of this nature.

Environmental Restoration Technologies on Coral Communities in Harbor Facilities Improvements

*Yasuhiro AKAKURA**, *Seizou HANASHIRO*, *Shinichi URABE*, *Hiromi MAEHARA*, *Masahiro ONO*, *Tadahiro MIZOGUCHI*, *Hidekazu YAMAMOTO*
2-21-7 Maejima Naha City, Okinawa, 900-8530 Japan
akakura710@ogb.cao.go.jp

In the course of the harbor facilities improvement project, Okinawa General Bureau of the Cabinet Office has been conducting research focusing on the environmental restoration technologies on coral communities. The effects and efficiency of the technologies have also been examined by field experiments and monitoring surveys. The environmental restoration technologies on coral communities are classified into three areas: technologies for constructing coral settlement substrate expecting multiplication through sexual reproduction, technologies for direct introduction of coral communities expecting multiplication through asexual reproduction, and technologies for establishing environmental conditions needed for coral growth. As for the construction technologies for coral settlement substrate, field experiments were conducted in Naha, Hirara, and Ishigaki Harbors. The structures constructed in places where coral larvae are produced function as good coral settlement substrate. The settlement and growth process on the substrate were found to vary depending on the surrounding environmental factors; however, it was confirmed that applying uneven surfaces on substrate could facilitate coral settlement. As an approach through direct introduction technologies, the transplantation of coral colonies had been conducted in Naha, Hirara and Ishigaki Harbors in the 1980s, followed by monitoring surveys. Recent developments of artificial concrete blocks to facilitate transplantation as well as the developments of relocation methods of large coral communities have also been recognized to support these technologies. By the study on technologies to establish preferable environmental conditions, the environmental factors mainly influencing the coral growth on artificial structures in Naha Harbor were determined to be light and waves. This indicates that adequate amounts of light and current velocity are to be secured to create the suitable environment for coral growth. With this in mind artificial structures that secure these aspects were constructed in Naha and Hirara Harbors and their effectiveness was confirmed by the monitoring surveys that followed.

Growth and Survivorship of *Meandrina meandrites* and *Montastrea cavernosa* Coral Core Transplants and Effectiveness of Plugging Core Holes in Transplant Donor Colonies

*Elizabeth GLYNN FAHY**, *Thomas P QUINN*, *Daniel P FAHY*, *Richard E DODGE*, *Richard E SPIELER*, *David S GILLIAM*
8000 North Ocean Drive, Dania Beach, Florida United States of America
glynn@nova.edu

To evaluate restoration of reefs utilizing transplanted corals, information is needed on effects on donor corals and transplants. This study investigated effects of coring on donor corals and success of core transplants for two species of massive corals. Two skeletal cores containing live coral tissue were sampled, using a hydraulic drill with four-inch core barrel, from each of forty donor colonies of two species of scleractinian coral. The core holes were filled with concrete plugs in order to prevent bioerosion. The eighty coral cores were transplanted to forty Reef Ball™ modules in 2001. Transplant corals, core holes, and control corals of equivalent size were monitored quarterly for mortality and change in surface area using photographic techniques. *Meandrina meandrites* transplants exhibited substantial mortality and grew significantly less than *M. cavernosa* transplants and *M. meandrites* controls. *Montastrea cavernosa* transplants experienced significantly higher growth than same species controls. For corals that were cored, tissue did not completely regenerate over the surface of the concrete core hole plugs in either species. There was no significant difference in mortality or between the initial area of the core holes and the final area for either species. While donor corals were not found to be adversely affected by coring, this study found that species-specific differences in transplant growth and mortality were important considerations in coral transplantation.

Establishing Coral Seedlings Production for Reef Restoration

*Masayuki HATTA**, *Yuko SHIMOMURA*, *Kenji IWAO*, *Akira WATANUKI*, *Toru AOTA*, *Makoto OMORI*
Tokyo 112-8610 Japan
mhatta@cc.ocha.ac.jp

Restoration of denuded reefs is largely dependent on the recruitment of coral larvae from “source” reefs where coral populations are capable of producing large numbers of propagules by sexual reproduction. However, only a small fraction of larvae are likely to succeed in traveling a long distance through the ocean, even if enormous quantities of gametes were released in mass spawning events. On the other hand, slicks are often lost by landed on shores or driven away from reefs by currents and waves, resulting high mortality in the drifting period. Transportation of slicks through human intervention would be an effective way of enhancing sexual recruitment of corals. Further, if coral larvae collected from slicks were grown to polyps under control, greater successes at coral propagation would be expected than simple transportation of larvae accompanied by low frequencies of settlement in natural conditions. We focused on mass-spawning acroporids that are major components of reef communities and slicks around Okinawa. The following methods have been established: (1) large-scale *in situ* collection of gametes using funnel-shape equipments, (2) culturing over 250,000 larvae, either from *in situ* collected gametes or from slicks, in a 1 ton-tank till they gain competence of settlement, (3) transportation of larvae over distance, (4) induction of metamorphosis and settlement with nearly 100% efficiency using a peptide hormone, (5) efficient introduction of zooxanthellae into primary polyps in culture. We believe that these results pave the way for “coral seedlings production”, production of a large number of larvae and primary polyps to enhance sexual recruitment without damaging existing coral populations, therefore contribute for active restoration of coral reefs.

Development of Coral Reef Restoration Technology through Mass Culture, Transportation and Settlement of Coral Larvae

*Toru AOTA**, *Akira WATANUKI*, *Sanae SHIBATA*, *Makoto OMORI*, *Hiroki TANIGUCHI*, *Kenji IWAO*, *Makoto KUCHINOMACHI*
2-7 Higashi Nakanuki, Tsutiura, Ibaraki Japan
aota@tetra.co.jp

The depletion of coral reefs continues in the Okinawa Islands, Japan, due to a variety of factors such as coral bleaching due to high water temperature, feeding pressure from crown-of-thorns starfish, and runoff and sedimentation of red soil from radical land development. Here, we report the first of a series of coral reef restoration experiments by *in situ* mass culture, transportation, and settlement of coral larvae in Okinawa. Akajima Island, the site of the culture experiment, has healthy coral reefs and is about 50 km west of the Okinawa main island. There is little genetic difference between the coral species of Akajima Island and Okinawa main island. Gametes and embryos were collected from a surface slick after mass spawning of corals in the early summer at Akajima Island. The planula larvae were kept in floating culture ponds until they were competent to settle onto the substratum. They were then transported by car and boat to the sowing experimental station inside the breakwater of Naha Port in the Okinawa main island, and released over existing concrete blocks that had been surrounded by 0.2 mm-mesh nets to prevent dissipation of the larvae. The experiment has so far been carried out three times and a total of about 6,000,000 individual larvae have been released at the same station since 2002. The net enclosure was removed after settlement of the corals was confirmed. The number and condition of coral colonies on the concrete blocks are monitored regularly. At present, the corals seem to be growing well after 16 months. The results demonstrate the applicability of this restoration technology to the rehabilitation of coral reefs in defined areas where natural recruitment is limited.



Oral Session
June 29 (Tue)



Status of Coral Reefs of Southwest Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands Tuvalu & Vanuatu in June 2004

Reuben SULU

Laucala Bay Road, Suva, Republic of Fiji

sulu_r@usp.ac.fj

Significant efforts are underway in the Southwest Pacific GCRMN node to mitigate current threats to coral reefs. This paper provides a snap shot of the status of coral reefs in these countries as at June 2004 and a summary of the initiatives undertaken by various communities, governments, organisations and agencies to protect and conserve coral reefs.

Regional Coral Reef Monitoring Program and Status Report in the South East Pacific Countries, GCRMN Polynesia Mana Node

Caroline VIEUX, Dave FISK, Peter PETELO, Taratau KIRATA, Brendon PASISI, Antoine NIA, Annie AUBANEL, Mary POWER, Bernard SALVAT

B.P. 1013, Moorea, French Polynesia

criobe@mail.pf

The Cook islands, French Polynesia, Kiribati, Niue, Tokelau, Tonga and Wallis and Futuna progress in order to assess coral reef health and exploitation on a regional basis (Polynesia mana node). The 7 independent or autonomous countries or territories including 347 islands with coral reefs are half a million inhabitants whose 80% are concentrated in 7 islands urban centers. Monitorings programmes are effective or on the way in French Polynesia, Wallis and Futuna, Cook islands, Tonga and Tokelau and will be developed in other islands. A major bleaching event occurred in 2002 with up to 50% coral mortality in Tokelau but minor one in French Polynesia. This bleaching has also been reported in Kiribati in the Tarawa lagoon but its extent is unknown. In Tokelau, overfishing has depleted most of the lagoon and slope areas in reef fishes and giant clams. Touristic development in Kiribati (Christmas Island) and land reclamation for building in Tarawa are a threat for reef health in Kiribati and are to be monitored. Niue has been struck by the cyclone Heta early this year and 90% of the corals have been devastated on the west coast. Rarotonga (Cook) is facing a COT outbreak affecting hard corals. Marine protected areas are planned in many islands of the Polynesia mana node and reef monitoring will be developed in these areas. Only French Polynesia has taken part to the Reef Check program in the node with 13 sites monitored in Bora-Bora and Moorea. The GCRMN node Polynesia mana, South East Pacific, plan to set up a regional database under coordination and/or cooperation with the South West Pacific node (University of South Pacific coordination), the South Pacific Regional Environment Programme (SPREP), The International Coral Reef Action Network (ICRAN, ICRI) and Reefbase of the World Fish Center (WFC).

Status of Coral Reefs in Micronesia

Jason KUARTEI

PO Box 1811 Republic of Palau

jkuartei@yahoo.com

The US Affiliated and Freely Associated islands of the tropical Pacific include American Samoa and the islands of Micronesia (excluding Kiribati). Most lie north of the equator, except American Samoa, which is considered part of Polynesia, but has the high coral diversity and cultural dependence on coral reefs similar to Micronesia. Micronesia is made up of a group of small tropical islands and atolls in the central and Indo-west pacific, and encompasses an area of approximately 11.6 million km². The vast majority of their area is ocean, with a landmass just over 3000km². From east to west, the US affiliated and Freely Associated states include: American Samoa, the Republic of the Marshall Islands, the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, Guam, and the Republic of Palau. As a region, Micronesia possesses a high diversity of corals and associated organisms and the human population is heavily dependent on coral reefs and related resources both economically and culturally. The coral reefs of American Samoa and Micronesia range in condition from nearly pristine to seriously damaged by human disturbance and climate change. The human impacts include overfishing, ship groundings, sedimentation and coastal pollution. In the past, human impacts were largely related to the size of the resident populations, however fishing fleets from other nations have taken their toll on even the most remote islands and atolls. Micronesia is a highly rated scuba diving destination and rapid tourism development including new roads, hotels, golf courses and personal watercraft, is having substantial effect on coastal reefs on some islands. In the last two years, there have been monitoring activities in the islands north of CNMI by the National Oceanic and Atmospheric Association (NOAA) and new information is now being collected for this area.

Consolidation of the STA-GCRMN Regional Node and Status of Coral Reefs in Southern Tropical America

Jaime GARZON-FERREIRA, Jorge CORTES, Aldo CROQUER, Hector GUZMAN, Zelinda LEAO, Alberto RODRIGUEZ-RAMIREZ

Cerro de Punta Betin, Zona Portuaria, Santa Marta Republic of Colombia

jgarzon@invemar.org.co

Since 1999 five countries (Brazil, Colombia, Costa Rica, Panama and Venezuela) are cooperating for developing coral reef monitoring in Southern Tropical America (STA) under the framework of GCRMN, the support of UNEP-CAR/RCU and the coordination of the Institute for Marine and Coastal Research (INVEMAR, Colombia). Several actions have been carried out that have conducted to the consolidation of the STA Node: (1) a study of the capacity and needs for reef monitoring; (2) establishment of formal agreements between INVEMAR and the other institutions; (3) support of monitoring activities during 2000, 2002 and 2003; (4) expansion of monitoring programs in all countries; (5) preparation of regional reef status reports and contribution to the global reports published in 2000 and 2002; and (6) production of a strategic plan (2004-2013) and a 5-years project proposal. The STA region includes reefs in Pacific, Caribbean and Atlantic waters, and most of them are strongly influenced by continental runoff. There has been major damage to coral reefs of this region in the last 35 years that has been caused by a mix of natural agents and direct human impacts. Nevertheless, significant coral cover can still be found at several reef locations of both Caribbean and Pacific coasts. Monitoring data suggest that reefs of the STA region have not undergone noticeable changes or damages during the last two years (2002-2003). Live coral cover in the Caribbean averaged between 1.4% (Playa Caiman) and 50.3% (Cayo Norte) in Venezuela, between 18% (San Andres) and 41% (Uraba) in Colombia and between 8% (Manzanillo) and 26% (Cahuita) in Costa Rica. Pacific reefs showed both low and high levels of coral cover, ranging between 57% (Utria) and 75% (Gorgona) in Colombia, between 6% (Coco) and 8% (Ballena) in Costa Rica, and between 2% (Canal de Afuera) and 54% (Iguana) in Panama.

Report on the Activities of the GCRMN Northern Caribbean and Atlantic (NCA) Node in 2003

Dulcie M LINTON, Loureene A JONES, Peter E EDWARDS

Mona, Kingston 7, Jamaica, W.I. Jamaica

dulcie.linton@uwimona.edu.jm

Through funding from the ICRAN project (UNEP-CEP) the CCDC has been actively encouraging greater coral monitoring and reporting among node countries. A survey of institutions identified financial and human resource limitations as the main constraints to sustained monitoring. A draft document for sustaining the node over a five-year period has been produced. The CCDC spearheaded the formation of the Jamaica Coral Reef Monitoring Network (JCRMN) on June 27, 2003. Seventeen individuals, representing 12 organizations agreed on the development of an organized approach to monitoring of coral reefs in Jamaica, with south coast reefs as priority. Reef Check training and data collection workshops were conducted during September and November in Negril and in Port Royal, Jamaica. Approximately 30 individuals representing a number of different institutions and organizations participated. A similar Reef Check training and data collection workshop was held in Haiti. Data from these surveys have been submitted to Reef Check and preliminary reports produced. JCRMN activities climaxed with a survey of the reefs of Portland Bight Protected Area, Jamaica. Twenty-five participants collected data from 6 reef sites during a 4-day exercise from December 4-7, 2003. This initial survey will be followed up in 2004 with more detailed surveys of these reef sites as well as of others in Jamaica and other node countries. Project funding is being sought to continue activities in node countries such as Haiti, the Dominican Republic, the Turks and Caicos islands, where coral reef monitoring data is scarce. Additionally, if funding is available, it is envisaged that a workshop of NCA node participants will be conducted in 2004 to allow sharing on best practices in coral reef monitoring and to encourage collaboration and agreement on building capacity to monitor reefs within node countries.

Status of Coral Reefs in the Red Sea

Moshira HASSAN, Georg A HEISS, Mohammed M A KOTB

The American University in Cairo, Biology Dept.; Cairo 11511 Arab Republic of Egypt

moshira@reefcheck.de

The status of coral reefs bordering the Red Sea and Gulf of Aden is generally good, with live hard coral cover averaging 20-50%. However, data show recent decreases in live coral cover. The highest average live hard coral cover was recorded in Yemen (53%), despite the poor development of reefs, compared to more complex reefs in the Central and Northern Red Sea. Edible sea cucumbers are currently being fished in most countries (legally as well as illegally) for export to Southeast Asia. Density reached from almost zero in Egypt and Sudan up to 3 individuals per 100m² in Yemen. Fish populations have declined slightly and several outbreaks of COTS were reported. Some local bleaching events and an increase in bioeroding organisms such as the urchin *Diadema setosum* and the coral eating gastropods *Drupella* sp. and *Coralliophila* sp. have been reported from several areas. Some of the most damaged reefs were seen in Yemen and Djibouti in the Southern Red Sea. The highest numbers of butterfly fish were found on Egyptian Red Sea reefs (>8/100m²). In general, the Red Sea shows comparatively low levels of human impact, as most of the coastline is sparsely populated. Threats to coral reefs differ within the region, and are continuously increasing with the increasing rate of coastal development. The impacts are most obvious around the larger ports and major tourist resorts. The major threats are land filling, dredging, sedimentation, sewage discharge and effluents from desalination plants. In tourism areas, there is physical damage by tourists and boat anchors as well as other impacts related to urbanization. Fishing pressure is constantly increasing throughout the region to satisfy demands of growing and more affluent populations. Deterioration was also found away from coastal developments, where it is probable that COTS and other natural disturbances have damaged the reefs.

Status of Coral Reefs in East and North Asia (China, Taiwan, Korea and Japan)

Tadashi KIMURA, Put O ANG, Chang-Feng DAI, Huang HUI, Jong-Geel JE

3-10-10 Shitaya, Taito, Tokyo 110-8676 Japan

tkimura@jwrc.or.jp

China, Korea and Japan belonging East and North Asian are located at the north edge of coral distribution of Pacific. Because of connectivity with the Philippines by the flow of the Kuroshio Current, coral diversity is quite high in Japan. On the contrary, there are patchy distribution of coral communities along China and Korea where some branch flows from Kuroshio Current. Coral reefs well develop from Nansha Island to Hainan in the South China Sea. Coral reefs also develop along the southern coast of Taiwan comparing with northern coast, which has patchy coral communities. In the north of this region, soft corals are dominant with a few stony coral species around the Jeju Island at southern coast of Korea

Major threats on Japanese corals are crown-of-thorns starfish, bleaching, *Drupella*, and soil runoff from land. A large number of corals were killed by sedimentation after heavy rain in 2001 and the starfish is increasing in number since 2000. China and Korea also have serious disturbances of environment by marine tourism and coastal development. Destructive fishing practice and soil runoff are major causes of coral disturbance in Hainan Island and Taiwan. Coral destruction by tourists is another threat in Hainan Island and Korea.

Against these threats, China, Korea and Japan begin to grapple with the integrated coastal environment conservation including coral ecosystem. Moreover, paying attention to marine protected area, that number is increased gradually to use it as an important tool for the coastal management in China, Taiwan and Korea. For exchange of own experiences and information, cooperation among the countries of this region is being expected to be made more active with becoming more strong, however, there are still issues remained on establishment of local network system and effective management practice to utilize protected areas in these countries.

Coral Reefs of Southeast Asia: 2004 Status Report

Karenne P P TUN, A CABANBAN, L M CHOU, Sour K PHILREEFS, Vo S T SUHARSONO, T YEEMIN

PO Box 500, GPO, 10670 Penang, Malaysia

karenne@ecounlimited.com

National reef monitoring programmes continued throughout the region and were maintained at previous levels or expanded. Capacity transfer was increased to countries or provinces to involve them fully in regional reef status assessments. Various bilateral and major regional initiatives in recent years helped to enhance monitoring and management capacity. These include the ICRAN project, which focuses on the transfer of reef management capacity from successful demonstration sites to target sites in need of such capacity in the region. The region's coral reefs continue to face widespread impacts from human activities and are clearly in need of greater management. Monitoring data indicate significant improvements in the condition of reefs under effective management by government agencies or communities. Public education, awareness raising and community involvement remain important activities that contribute positively to reef protection.

Coral Reef Monitoring in the South Western Indian Ocean Islands "COI/GCRMN" Node - Year 2003 Results and First Trends

Lionel BIGOT, Said AHAMADA, Jude BIJOUX, Meera KOONJUL, Tara LYNCH, Jean MAHARAVO, Sabrina MEUNIER, Marylene MOYNE-PICARD, Jean Pascal QUOD

ARVAM - 14 rue du stade de l'Est - 97490 Ste Clotilde - La Reunion - FRANCE

lbigot.arvam@wanadoo.fr

A regional monitoring network of the GCRMN was set up for the South Western Indian Ocean islands (Comoros, Madagascar, Mauritius, La Reunion and Seychelles) in 1998 coinciding with the circum-tropical mass coral bleaching event. The ongoing 3 years regional project which is financed by the Global Environment Facility (World Bank) and the European Union aim to :- increase coral reef monitoring in the SWIO islands, - strengthen the capacity of national networks to provide data, - advice stakeholders for marine resource management. Principal objective of 2003 annual network report are to recapitulate the annual regional activities linked to reef monitoring. More precisely, it aims to analyse actual coral reef health situation on reference sites and general trends (1998-2003) of coral reef recovery and take stock of the various regional and national actions carried-out by the networks. The number of monitoring stations covered by this project has increased from 43 stations in 1998 to 88 stations in 2003, with more than 20 stations located in Marine Protected Areas. Data (benthos, fish, etc) are processed with a database system called "COREMO II" used by all technical stakeholders. This software is flexible to cater for various methodological protocol (Reef Check, GCRMN, "expert" level) and allow several possibilities (screen consulting, printing of graphics, export data, etc). It has been recognized by Reef Base as a powerful and evolutive tool for monitoring and help decision making. On many sites, first trends show spectacular increase of coral cover recovery, particularly in Comoros (Moheli island). More often, situation is gradual with slow increase (Seychelles, Madagascar), or show a good stability of coral cover (Reunion, Mauritius). Information gathered under this programme is helping Coastal Zone managers to conceive concrete actions in conservation, management and sustainable use of the Indian Ocean reefs.

Status and Management of South Asian Coral Reefs

Arjan RAJASURIYA, K VENKATARAMAN, Hussein ZAHIR, J R B ALFRED, M A HAQUE

Crow Island, Mattakkuliya, Colombo 15 Democratic Socialist Republic of Sri Lanka

arjan@nara.ac.lk

Coral reefs in South Asia were severely damaged due to the 1998 coral-bleaching event in the Indian Ocean. Post bleaching recovery of coral reefs has been variable. In the Gulf of Mannar coast of India live coral cover has increased. In the Lakshadweep Islands there is little recovery in the shallow waters and the only appreciable live coral exists below the depth of 20m. There is no evidence of bleaching impact in Andaman and Nicobar Islands. In the Maldives there is better recovery and overall reef condition in the southern atolls with variable recovery in the rest of the country. Widespread bleaching was reported in the Maldives and Gulf of Mannar during April-May 2003; however, quick recovery has been observed with minimal mortality. High rates of recruitment indicate good potential for recovery in the central and southern atolls in the Maldives. In Sri Lanka most inshore coral habitats on the west coast have indicated poor recovery whilst there is good recovery with rapid recolonisation by branching *Acropora* species in the south coast. Recovery is patchy in the Bar Reef Marine Sanctuary in the Gulf of Mannar. Monitoring and management capacity have improved in the region. The Department of Environment and Forests has formed a Gulf of Mannar Trust. Legislation has been improved to protect corals and many other species under the Wildlife Act of India. In the Maldives a protected area system management protocol and an Atoll Ecosystem Management Project has been developed. Several legal instruments with respect to marine and coastal environment has been developed and reviewed. In Sri Lanka, two new Marine National Parks have been declared in 2003 and Special Area Management Programmes at three coral reef areas are being implemented. Status of coral reefs in the region since 2003 and their management are discussed.

Status of Coral Reefs in East Africa, 2004

David O OBURA

P.O.BOX 10135, Mombasa Republic of Kenya

dobura@cordio.info

This paper will summarize the findings of biophysical and socio-economic monitoring of coral reefs conducted during 2002-2004, and as reported in national GCRMN reports to be prepared in 2004. East African coral reefs that were severely impacted by the El Nino Southern Oscillation of 1997-98 have subsequently experienced a variety of recovery trajectories, varying from high recovery to further degradation. Surveys in the Songo Songo archipelago of Southern Tanzania in early 2003 revealed reefs that potentially experienced negligible bleaching in 1998, perhaps due to shading by consistently high turbidity levels from the Rufiji River. A moderate bleaching event was documented from central Tanzania to northern Kenya (and in the Seychelles) in early 2003 that resulted in negligible to low mortality. Socio-economic monitoring of coral reefs has been built up in 2002-2003 as a GCRMN activity, involving 4 sites in East Africa, resulting in the development of a manual and methodology to be applied more broadly in the region. New Marine Protected Areas (MPAs) incorporating coral reef areas designated or instituting management in 2002-2004 include: the Quirimbas National Park (Mozambique), Quilalea and xxx reserves (private, Mozambique), and Mnazi Bay-Ruvuma Estuary Marine Park (Tanzania). These and a number of fisheries and community-oriented initiatives, and management effectiveness and capacity building regional programmes are progressively increasing the area of coral reefs brought under management regimes, and increasing local to national capacities to manage coral reefs and threatening resource use patterns. Nonetheless, increasing regional coordination is desirable, as well as expansion of the scope of coral reef conservation and management through collaborative management schemes to attempt to approach the goal set by the World Parks Congress of 30% of marine areas effectively managed by 2010.

CORDIO a Regional Initiative for Monitoring and Research in Central and Western Indian Ocean

Olof LINDEN*, David OBURA, David SOUTER, Rolph PAYET, Dan WILHELMSSON

PO Box 500, S-201 24 Malmo, Sweden

olof.linden@cordio.org

Elevated water temperatures associated with the 1997/98 El Nino caused widespread bleaching of coral reefs around the world. The reefs of the Central and Western Indian Ocean were severely affected. The CORDIO project was launched in January 1999 in order to assess the impacts of the acute phase of bleaching. CORDIO was initiated as a regional initiative supporting activities in 11 countries. Funding was provided by Sweden, Finland, the Netherlands and WWF. These activities yielded data from several monitoring stations in most of these 11 countries during 1999. In several cases, data from previous years monitoring were also available. Most of the research is carried out by local experts in each country. Follow-up research conducted during 1999 showed that the mortality of corals on reefs along East Africa, Seychelles, Sri Lanka and the Maldives ranged between of 50 to 90 %. CORDIO has since supported long-term studies in most countries of the region. These studies show a mixed picture. In several areas, significant recovery is now underway, while in other areas very little recovery has occurred. Research also shows that the diversity of many reefs has changed significantly since 1998, and that an evolution appears to be taking place. This evolution may result in a shift from reefs dominated by certain groups (such as *Acropora*) to reefs where other species dominate. Research under the CORDIO project will continue to carry out monitoring activities on reefs in the region where long-term data exist. In addition, CORDIO is becoming more involved in research on other stress factors affecting the survival of coral reefs, and on research related to management of reefs in the context of integrated coastal area management.

Coral Reef Monitoring- Which Methods?

Jos HILL*

James Cook University, QLD 4811 Australia
jos.hill@jcu.edu.au

Coral reefs around the world are at risk from many threats. Monitoring the ecology of the reefs and socioeconomics of stakeholders is necessary to identify the nature of these threats and feasible solutions. Different management questions require different levels of monitoring intensity, data and detail. No single methodology will address all aspects deemed relevant and there is insufficient advice to help managers decide which methods they should use. Unfortunately lack of standardised protocols for addressing particular questions has led to a proliferation of survey methods, surveyed variables and variable definitions in different regions. This makes comparisons between areas difficult. We review the different methods, the extent of their use and their advantages and limitations and provide advice to managers on the best method to suit their needs.

Monitoring for Management Using Reef Check

Gregor HODGSON*

1362 Hershey Hall, Institute of the Environment, Mailcode 95 1496 United States of America
gregorh@ucla.edu

Even in small countries, the number of individual sites that should be monitored to obtain a reliable estimate of coral reef status is on the order of 30 to 50. In large countries, this number would expand to hundreds of sites and in some cases over 1000. The reality is that few governments have been or will be willing to pay for this level of monitoring using highly detailed monitoring protocols and monitoring teams comprised of coral reef ecologists. This is why many governments around the world have turned to Reef Check, as the lowest cost method of monitoring reefs. The advantages of Reef Check are that the method is now a global standard, is extremely rapid, can be carried out by trained volunteers, and a new website will soon allow on-line, automated comparisons between reefs by time and location. By involving the community in monitoring, Reef Check builds support for government conservation initiatives. More importantly, Reef Check has been shown to be highly effective as a tool for judging conservation success at Marine Protected Areas in all tropical oceans. Of the 101 coral reef countries, the 30 or so that are not yet part of the Reef Check/GCRMN network are invited to appoint coordinators so that a complete picture of the health of the world's reefs can be tracked and appropriate management actions taken.

Reefbase: A Global Information System on Coral Reefs

Marco NOORDELOOS*, James K OLIVER, Nasir Bin NAYAN, Yusri Bin YUSUF, Moi Khim TAN, Calvin FOO, Dilla Binti Mohd Shukri SHAHRIYAH
 PO BOX 500, Bayan Lepas, 11680 Penang Malaysia
m.noordeloos@cgiar.org

ReefBase (<http://www.reefbase.org>) is a global information system on coral reefs, and was developed by the WorldFish Center and the International Coral Reef Action Network (ICRAN). This online database provides quality information on the location, status, threats, and management of coral reefs in nearly 100 coral reef countries and territories. ReefBase serves as the central database for the Global Coral Reef Monitoring Network (GCRMN) and ICRAN, and continues to provide valuable information services to managers, policy makers, researchers, conservationists, educators, and students around the world. Through its central function within the GCRMN and continued collaboration with numerous coral reef organizations, ReefBase is focused on producing the key statistics and data summaries for coral reef status reports on national, regional, and global scales. In addition, ReefBase stores over 20,000 references (many of which can be downloaded), providing access to a wealth of management-relevant publications that are often difficult to access otherwise. ReefBase's online Geographic Information System (GIS), allows for display of a range of coral reef related datasets on interactive maps. With continued development of contents and functionality, ReefBase aims to facilitate informed management of coral reefs, and ultimately benefit poor people in developing countries who depend on these resources for food, income, and livelihoods.

Status of Coral Reefs of the World: 2004, the Road to Recovery?

Clive R WILKINSON*

PO BOX 772, TOWNSVILLE 4810, AUSTRALIA
CLIVE.WILKINSON@IMPAC.ORG.AU

The status of coral reefs has declined since the first global assessments of the mid 1980s and early 1990s through three parallel destructive forces. Reefs are damaged by direct human impacts of over- and destructive fishing, sediment and nutrient pollution and damaging shoreline modifications; from outbreaks of coral and fish diseases and predators such as the crown-of-thorns starfish, all of which may be exacerbated by human activities; and the more recent global climate change impacts of coral bleaching mortality and the potential for damage from rising concentrations of carbon dioxide. The major El Nino/La Nina event of 1998 resulted in the near destruction of approximately 16% of the world's reefs, however about half of these now show encouraging recovery, particularly those in well managed MPAs. However, assessments by the GCRMN, World Resources Institute, Reef Check, CORDIO, AGRRA and ReefBase show an increasing rate of direct human impacts with rising populations resulting in major damage to reefs in Eastern Africa, mainland South Asia, Southeast Asia and the wider Caribbean. There are, however, major national, and international activities by governments and NGOs to conserve coral reefs, which are showing encouraging results in reversing the decline over larger coral reef areas with greater recognition of the value of community involvement. This session summarises 80 national status reports documenting greater efforts that are resulting in the sustainable conservation of many coral reefs. All this could be jeopardised if the present rate of global climate change continues and results in more coral bleaching episodes like those of 1998. The predictions are cautiously optimistic. Cold water coral reefs are finally gaining recognition just as destructive deep sea trawling is causing havoc to these slow growing structures. These are now added to the ecosystems in need of urgent conservation.

Scientific Rigour, Uncertainty and the Burden of Proof in Research for Management on Coral Reefs (What If We Get it WRONG?!)

*Laurence MCCOOK**

PO Box 1379, Townsville, Qld, 4810 Australia

L.McCook@GBRMPA.Gov.Au

Recent management initiatives on the Great Barrier Reef, including the Representative Areas Program, and Reef Water Quality Protection Plan, have highlighted several misunderstandings about the levels of scientific evidence or certainty required to justify management actions, especially pre-emptive initiatives intended to prevent environmental degradation. In particular, it is often suggested that future threats require proof before management action is appropriate. The mandate, and statutory obligation, of the Great Barrier Reef Marine Park Authority, as with other natural resource management agencies, is to ensure the protection and sustainable use of the marine park. This requires management strategies that prevent possible future damage, and prior demonstration that any proposed use or impact is sustainable. This requires that researchers concerned with assessing impacts, frame their research, analyses and conclusions, critically. This talk will review the logical bases of scientific and management decision-making processes, and compare hypothetico-deductive science (i.e. hypothesis-tests such as anova) and Bayesian approaches. I advocate risk assessment approaches that consider both likelihood, and full consequences and costs, of management strategies. This assessment must explicitly consider environmental and economic costs, of both management action and inaction / delay, and the consequences of making mistakes due to inadequate scientific evidence (type I & II errors). In summary: It is not appropriate, nor scientifically rigorous, to require proof of impending environmental problems before implementing solutions; It is not appropriate for environmental scientists to simply test null hypotheses in management / impact assessments; Use Bayesian or likelihood approaches, estimates of sizes of effects, & epidemiological approaches to causality; The general public readily appreciate the concept of risk assessments; It is not appropriate for natural scientists to make assumptions about social or economic costs or evidence: we need evidence (& solutions).

Measuring Management Effectiveness in Coral Marine Protected Areas

Charles EHLER, Gonzalo CID, Lani WATSON, Leah BUNCE, Arthur PATERSON*

1315 East-West Hwy. #5637. Silver Spring, MD 20910. USA

Arthur.E.Paterson@noaa.gov

Coral reefs sustain an important number of terrestrial species, as well as many coastal human settlements. Many marine protected areas (MPAs) have been created and designed to protect coral reefs ecosystems and harmonize activities in these areas. However, most of the MPAs are inadequately managed, and that they are not reaching the basic goals and objectives for which they were created. The increasing need for evaluating and understanding the effectiveness of MPAs operating around the world has driven international efforts to provide instruments for that purpose. In 2000, the WCPA-Marine and the WWF jointly initiated an MPA Management Effectiveness Initiative (MEI), with the participation of NOAA. The MPA-MEI is an international collaborative project designed to create a methodology for planning and conducting performance evaluations of MPAs. This initiative has identified and described a set of indicators that can be adapted to a range of MPAs. The MPA-MEI has completed an initial measuring phase of the indicators on a group of MPAs around the world, including 10 MPAs with important coral reef ecosystems. The results of the MEI process and indicators are contained in an IUCN Guidebook soon available through IUCN. This presentation provides an overview of the MPA-MEI methodology, some results of the testing phase of the guidebook and indicators in coral reef MPAs, some case study experiences, and potential benefits and considerations for its application. A well-managed MPA may protect or restore biodiversity and ecosystems, reduce poverty, and provide coastal communities with a sustainable foundation for economic growth. Thus, evaluate management effectiveness is an important way to identify failures, build on strengths, and plan adaptations to improve the performance of MPAs.

Developing Indicators of Effectiveness for Marine Protected Areas: A Comparison among Fishing Villages

Marivic G PAJARO, Monica E MULRENNAN, Amanda C J VINCENT*

2204 Main Mall, Vancouver, British Columbia Canada

m.pajaro@fisheries.ubc.ca

Application of the participatory process in the development of culturally appropriate indicators of success can help sustain efforts to monitor, evaluate and improve MPA performances. This paper presents a participatory framework for the development of such indicators. We also analyse the extent to which local communities (and the groups therein) shared and differed in their perceptions of MPA effectiveness, considerations that are particularly important when fostering a locally managed network of MPAs. Interviews were conducted with women, fishers, elders, youth and leaders in 10 village-based MPAs in the central Philippines; these sites had been protected for half a year to 20 years. Results suggested no significant differences in community perceptions across sectors, gender and age groups. However, the age of the MPAs appeared to influence perceptions among communities. Responses from communities with younger MPAs defined their goals and indicators with respect to preventing destructive fishing techniques, strict enforcement of regulations and regular patrols. On the other hand, respondents from older MPAs mentioned secure fishery yields, higher catch, better incomes and presence of visitors. Feedback and workshop sessions validated the interview results and led to an agreement on the indicators important to the local people. These will now be used to collect data through monitoring by community volunteers.

Evaluating the Effectiveness of and Building Capacity for Locally Managed Marine Areas within a Learning Network

Michael D GUILBEAUX, Pamela SEETO, Bill AALBERSBERG, Daisy FLORES, Wayne ANDREW*

212 Merchant Street, Suite 200, Honolulu, Hawaii 96813 USA

mike@conservationpractice.org

A Locally Managed Marine Area (LMMA) is, as the name implies, an area of marine habitat that is managed by resident communities, either on their own or in conjunction with other organizations and/or collaborative arrangements with government agencies. Although this strategy seems effective in theory, will it work in practice? The LMMA Network is comprised of a group of community-based projects and conservation practitioners who have come together to increase the success of their marine conservation efforts. Initiated in 2000, the LMMA Network now includes approximately 40 participating marine managed areas in coral reef and/or associated habitats in seven countries in the Asia-Pacific region. Its goal is to help build the capacity of communities and practitioners who are implementing LMMA projects and to assist and support the evaluation of these efforts over time. The LMMA Network facilitates cross-project exchanges and sharing of resources among project members, and uses a shared framework for learning and communication that transcends geographic, linguistic, and cultural barriers. This framework embraces a holistic monitoring approach that includes bio-physical, socio-economic, and implementation factors. It is designed to be simple enough for community members and their supporting partners to carry out, yet rigorous enough to provide an indication of the effectiveness of these projects, as well as a comparative framework to assess the overall conditions under which different LMMA approaches lead to greater or lesser success. So far, approximately 25 projects have implemented the Networks analytical framework and are actively using results to communicate findings to relevant audiences and further modify and adapt their management approaches. This presentation will identify some of the successes and challenges of the LMMA Network, as well as findings from early analysis of results to date.

Coral Reef Protected Areas in Brazil: The Analysis of Representativeness and Effectiveness of Biodiversity Conservation

*Ana Paula L PRATES**, *Beatrice Padovani FERREIRA*

Esplanada dos Ministerios, Bloco B, Sala 731, Brasilia/DF, 70.068-900, Brazil
ana-paula.prates@mma.gov.br

Global concern for coral reef is reflected in Brazil by the growing interest in the development of actions to conserve this ecosystem. One of the main strategies used in conservation, protected areas should be designed to be representative of the environments to be protected and managed to be efficient in order to fulfill their purpose. Like other global conservation efforts, Brazil has also been building its representative system of protected areas. The National System of Conservation Units divides protected areas into two main groups: the full protection units, where only the indirect use of their resources is permitted and the sustainable use units, where the direct use of some of their natural resources is allowed. Mapping allowed us to calculate the area of the shallow reefs, which amount to 1,008.49 km². Comparison of these results to the established protected areas showed that approximately 80% of the mapped shallow reefs are already under some category of protection. However, only 22% of these environments are included in full protection or no-take zones. Drafting of maps was executed incorporating digital image from Landsat images and processing tools with geographical information system. All the stages were developed in SPRING, a Brazilian software. The maps of the protected areas were published in the Atlas of Coral Reef Protected Areas in Brazil. To analyze the effectiveness of MPAs different methodologies as well as suitable indicators for assessing marine protected areas in Brazilian were adapted. We discuss the challenge in applying the methodology such as selection of appropriated indicators and choice of scale and actors to be interviewed. Based on the joint analysis of the results obtained on the representativeness and the effectiveness of the MPAs, it was possible to discuss and suggest various activities and actions that should be taken to conserve the Brazilian reef environment.

The Assessment of Management Effectiveness of Marine Protected Areas in Kenya

*Nyawira MUTHIGA**

P. O. Box 99470, Mombasa, Kenya
nmuthiga@wcs.org

Marine protected areas are reported to be effective means of managing coral reefs, consequently, many developing countries have established MPA programs. However, whether these MPAs are achieving their objectives has rarely been assessed. An assessment of the management effectiveness of the MPAs of Kenya was conducted under a regional project using a workbook that was developed for the Western Indian Ocean based on the WCPA/Management Effectiveness Task Force (METF) framework methodology. The assessment was conducted using existing information, monitoring programs and research studies and with broad consultation with stakeholders. The main factors that were assessed included; institutional support for management of MPAs, assessment of coral reef health, the presence of management plans and extent of plan implementation, level and type of conflict, the level of compliance to MPA regulations, type and level of stakeholder collaboration and community participation and effects of external factors including coral bleaching and political strife. Results indicate that marine parks that are managed as no-take areas are making progress towards meeting their stated objectives as outlined in the management plans but marine reserves that are managed as restricted fishing zones are not as effective as evidenced by some biophysical parameters that indicate less biodiversity in the Reserves than in the parks.

Evaluating the Effectiveness of Community Based Refuge Areas in Fiji

*Alifereiti TAWAKE**

Institute of Applied Sciences, University of the South Pacific, P.O.Box 1168, Suva, Fiji
tawake_a@usp.ac.fj

More than 60% of communities in Fiji depend on the sea particularly on mangrove, seagrass and reef ecosystems, for their livelihood and the use of traditional management practices such as "tabu" or refuge areas are increasingly being revitalized by resource owners as a tool to sustain local fisheries. One of the main challenges is the limitation in the scientific or appropriate skills to judge their effectiveness, which is traditionally based upon beliefs and casual observations. Through a Biodiversity Conservation Network (BCN) project, people in the Verata district in Fiji have developed skills and participatory techniques to help address marine issues. Community members were also trained to perform simple biological monitoring techniques to assess the effectiveness of the use of refuge areas. Two target species; mud lobsters (*Thalassina anomala*) and clams (*Anadara* sp.) have been monitored. Since the baseline surveys in 1997, catches have tripled and household income has increased by 35% in three years. In collaboration with the government and other NGOs and community leaders, efforts are also underway to replicate this 'Veratavou model' in other parts of Fiji and to create a learning network of locally managed refuge areas called the Fiji Locally Managed Marine Area (FLMMA) network. Monitoring and evaluating the effectiveness of these locally managed marine areas using a developed learning framework, have also been undertaken by both communities and co-managers and results have been encouraging. This will help determine conditions under which the declaration and monitoring of locally managed fishery refugia can be an effective tool in sustaining local fisheries. This FLMMA Network initiative was recently awarded one of the six best practices for sustainable development projects award by the Equator Initiative for the World Summit for Sustainable Development.

Does Partial Protection Benefit Fish Communities? Evidence from Tanzania, E Africa

*Elizabeth H TYLER**, *Martin R SPEIGHT*, *Andrea MANICA*

Tropical Ecology and Entomology Group, Zoology Department, South Parks Rd., Oxford OX1 3PS United Kingdom of Great Britain and Northern Ireland
elizabeth.tyler@zoo.ox.ac.uk

Large, community-based marine reserves, where destructive fishing practices are banned and fishing is restricted to locals, are being favoured over no-take areas in Tanzania, E. Africa. However their effectiveness as fisheries management tools is untested. We compare the density, mean length and species richness of 12 commercial and non-commercial reef fish families between 14 sites around Unguja island, Zanzibar, Tanzania. Five sites within a large community-based reserve, Menai Bay Conservation Area, (470 km²) were pooled with two no-take marine reserves, Chumbe Island Coral Park and Mnemba Island (1km² each) and compared to seven unregulated fishing sites. Sites were surveyed using underwater visual census transects of 100mx10m. Fish length was estimated and placed in 5cm categories. Data were analysed with one-way ANOVAs, using Welch's ANOVA if variance was not equal. Mean fish length and species richness were significantly higher in managed sites ($p=0.018$ and $p=0.038$ respectively), but fish density showed a non-significantly higher trend in unmanaged sites. When the two no-take areas are removed from the analysis, mean length remains significantly higher in the community-based reserve ($p=0.016$), but not species richness. Density also becomes significantly higher in unmanaged sites ($p=0.007$). These results suggest that the community-based reserve is enhancing fish size, but that full protection is required to significantly enhance species richness. In neither case was density a good predictor of protection. Individual fish family responses to full and partial protection and the potential of community-based reserves as fisheries management tools are discussed.

The Coral Reef Management in Zamami Village, Okinawa*Hiroki TANIGUCHI**179 Aka, Zamami-son, Shimajiri-gun, Okinawa 901-3311 Japan
taniguchi@amsl.or.jp

Zamami village consists of some small islands in the Kerama Islands group located 40 km west of Okinawa main island. About 1,000 people live there. The village is surrounded with beautiful fringing coral reefs, and many resort divers visit there every year. The coral reefs of the Kerama Islands are a source of coral larvae for the Okinawa main island, where coral reefs had been severely damaged by human activities and outburst of the crown of thorn starfish. Members of the local Zamami village fishing cooperation and diving association have taken action to protect coral reefs with the help of scientists from Akajima Marine Science Laboratory. In July 1998, the villagers closed the three dive sites that had been most frequently used for resort diving. Volunteers from the local diving association monitored one of three sites periodically for three years prior to re-opening of the dive sites, and confirmed a drastic increase in coral coverage. Maintaining healthy coral reefs in Zamami may be critical to the health of the Okinawa main island because it is a source of coral larvae. Autonomous management of the precious coral reefs will be done by rotating closures of overused dive sites and will include other dive sites in the near future.

Recommendations Driven by an Assessment of Coral Reef Management Effectiveness to the National Park Corales Del Rosario and San Bernardo, Colombia*Nohora GALVIS**Calle 97 A No. 42-48 Bogota, Colombia
nohora_galvis@ecoportal.zzn.com

A quantitative assessment of the management effectiveness of the National Natural Park Corales del Rosario and San Bernardo completed the following phases in 2003: 1) stakeholder analysis 2) multicriteria selection 3) weighted indicators of effectiveness 4) goals setting 5) performance measures 6) interpretation, 7) recommendations to the National Park Authority considering the different perspectives of diving operators, tourism operators, local park authority, the fisheries authority and ecologists. The methods, results, discussions and recommendations will illustrate the operational proposal to be adopted by any marine protected area of the world.

Case Studies of Embedment Anchor Mooring and Zone/Boundary Buoy Systems as a Management Tool for Marine Protected Areas*John C HALAS, Judith F HALAS**FKNMS, P. O. Box 1083, Key Largo, FL 33037 U.S.A.
John.Halas@noaa.gov

Use of environmental mooring buoys has become a widespread management tool for marine protected areas and has proven successful in diminishing impacts to sensitive sea bottoms. An environmentally sensitive embedment anchor mooring buoy system has been used to protect coral reefs from physical damage caused by boat anchors since 1981. In newly formed marine protected areas, a mooring buoy system often becomes the most visible reef protection tool. With multiple-use zoning practices becoming commonplace, embedment anchor technology is now used to establish and enforce MPA regulated zones and boundaries. This presentation provides case studies of the application of embedment anchor buoy systems in marine protected areas around the world. With increasing worldwide coral reef degradation, environmentally friendly embedment anchor mooring buoys will assume a critical role in coral reef conservation and management.

Identity and Diversity of Coral Endosymbionts (Zooxanthellae) from Three Palauan Reefs with Contrasting Bleaching, Temperature and Shading Histories

Katharina FABRICIUS, *Jos C MIEOG**, P L COLIN, D IDIP, Madeleine J VAN OPPEN

PMB 3, Townsville Qld 4810, Australia

k.fabricius@aims.gov.au

The genetic identity and diversity of zooxanthellae was investigated at three reefs with contrasting histories of bleaching mortality, water temperature and shading, in the Republic of Palau (Micronesia). At a high-irradiance cool-water reef (Oikull Reef), a high proportion of clade C zooxanthellae and low representation of clade D were found in the 12 different algal communities in the few corals that had survived the severe mass bleaching event in 1998. At a partly shaded, cool-water reef (Taoch) that housed a species-rich coral community, ten zooxanthella communities were identified, consisting of approximately even proportions of clade C and D. A partly shaded coral reef in a marine lake that is hydrographically well-connected but chronically $>0.5^{\circ}\text{C}$ warmer than the surrounding waters, harbored only one Symbiodinium community consisting of D-strains in 13 non-poritid coral species investigated. The Taoch and lake reefs did not suffer coral mortality during the 1998 bleaching event. Bleaching-sensitive coral families and genera were absent in the warm marine lake and rare in the surviving corals at Oikull Reef. The data suggest that whole coral assemblages, when growing in elevated seawater temperatures and at reduced irradiance, are able to shift in situ to associations with the more thermo-tolerant clade D zooxanthellae, even when they are hydrographically well-connected to more diverse zooxanthella populations in surrounding waters. Future increases in seawater temperature might therefore result in an increasing prevalence of Symbiodinium phylotype D in scleractinian corals, possibly associated with a loss of diversity in both zooxanthellae and corals. The high number of different zooxanthella communities in corals that had survived on the severely bleached Oikull Reef in 1998 also suggests that a shift to better-adapted zooxanthellae will probably be slow, involving a number of catastrophic or sub-catastrophic bleaching events through which less thermo-tolerant coral reef communities are gradually replaced.

Distribution of *Symbiodinium* in Extremely Disturbed Reefs of the Dominican Republic

Adrienne M ROMANSKI*, Andrew C BAKER

MC5557, 1200 Amsterdam Ave., New York, NY 10027 United States of America

amr2007@columbia.edu

Coral reefs are among the most productive and diverse habitats on the planet. They are economically valuable as a source of tourism, food, shoreline stability, and pharmaceuticals. However, anthropogenic disturbance increasingly disrupts the coral-algal symbiosis that is fundamental to the structure and function of reef ecosystems, thereby threatening the continued existence of coral reef ecosystem services. It has been proposed that physiological and biochemical differences between algal symbiont clades (genus *Symbiodinium*) contribute to phenotypic variation in the resistance of different host-symbiont complexes to environmental stressors. The results reported here represent a preliminary exploration of the *Symbiodinium* taxa associated with reefs experiencing intense anthropogenic disturbance in the Dominican Republic. These results are a component of a larger project explicitly testing preliminary observations that *Symbiodinium* clade D is positively correlated with stressed and degraded coral reef ecosystems.

Variation in Bleaching Sensitivity of Two Coral Species with Contrasting Bleaching Thresholds across a Latitudinal Gradient on the GBR

Karin E ULSTRUP*, Ray BERKELMANS, Peter J RALPH, Madeleine J H VAN OPPEN

Cnr. Pacific Highway & Westbourne Street, Gore Hill, PO Box 123 Broadway, NSW 2007, Australia

karin.ulstrup@uts.edu.au

The ability of corals to cope with extreme environmental conditions, such as increased temperature, relies on the physiological mechanisms of acclimation and long-term genetic adaptation. We experimentally examined the range of thermo-tolerance exhibited by explants of two ecologically distinct species of coral, *Turbinaria reniformis* (3-15 m) and *Pocillopora damicornis* (0-10 m) at three locations across a latitudinal gradient on the Great Barrier Reef (GBR). Corals were acclimated to 26°C after which temperature was raised to three different levels: 29, 31 and 33°C for two weeks. Surviving explants were returned to 26°C and onset of recovery was monitored for another two weeks. The bleaching sensitivity and recovery of the two corals correlated with latitude i.e. high latitude corals bleached earlier and at lower temperatures than low latitude corals. This pattern was supported by a decrease in both coral species in maximum quantum yield (Fv/Fm), zooxanthellae density and chlorophyll content with *T. reniformis* showing less sensitivity than *P. damicornis*. No *P. damicornis* explants survived the first week of elevated temperatures to 33°C whereas *T. reniformis* explants resisted complete bleaching for up to two weeks. Recovery of explants exposed to 29 and 31°C was evident in both species after two weeks and there was a faster recovery of low-latitude than high-latitude explants of *T. reniformis*. The thermo-tolerance results obtained from this study are correlated with symbiont identity in the two coral species at 14 different reefs at a latitudinal and cross-shelf gradient of the GBR using the ribosomal DNA ITS1 marker. This allows us to determine to what extent acclimatory and adaptive processes contribute to the differences in ranges seen in thermo-tolerance across a latitudinal gradient. Future climate models may ultimately benefit from this study by estimating bleaching resistance and survival robustness during climate change of corals with flexible and non-flexible symbiont populations.

Depth-dependant Genotypic and Phenotypic Changes in Coral Symbiotic Dinoflagellates

Annika NOREEN*, William LOH, Selina WARD

904 21st Ave East, Seattle, WA 98112 United States of America

anoreen@scrippscol.edu

Reef-building corals form an obligate symbiosis with single-celled photosynthetic dinoflagellates (SD). There are at least several dozen genetically distinct SD genotypes and up to three different SD genotypes have been found in an individual colony. Three factors can significantly influence coral survival under stress: 1) the phenotypic plasticity of the SD hosted, 2) the ability of the coral to change the SD hosted, and 3) the ease by which the SD change. A previous transplant experiment where corals at 2-4 m were relocated to 20-23 m used a very conservative genetic differentiation technique (RFLP). I investigated both genotypic and phenotypic change in *Pocillopora damicornis* SD when moved from 1 m to 13 and 20 m for seven weeks. For genotypic results I used a highly sensitive method, Single-Strand Conformation Polymorphism, to identify distinct banding patterns representing multiple genotypes. After seven weeks, all but one transplant at 13 m contained the same two banding patterns found at 1 m. At 20 m, 95% of the transplants showed one of two distinct banding patterns not found at 1 or 13 m. The ease of change among SD genotypes over a short time period suggests that the coral-algal symbiosis in *P. damicornis* is a remarkably fluid, dynamic relationship under the conditions tested.

Phylogeography of Zooxanthellae, *Symbiodinium*, in the "Weedy" Coral, *Oulastrea crispata*, (Scleractinia; Faviidae) in the West Pacific

*Yi-Ting LIEN**, *Ho-E LIN*, *Yoshikatsu NAKANO*, *Katherine K LAM*, *Sakanan PLATHOG*, *Padersak JARAYABHAND*, *Chaolun Allen CHEN*
Institute of Zoology, Academia Sinica, Nankang, 11529, Taipei, Taiwan
dinosaur@gate.sinica.edu.tw

The "weedy" coral, *Oulastrea crispata*, occurring commonly on shallow reef depressions and on turbid bay bedrock, is a pioneer coral colonizing substrates where environmental disturbance is high. Previous survey on the subtropical non-reefal coral communities indicated that *O. crispata* is associated with *Symbiodinium* clade D, a zooxanthellae clade thought to be stress-tolerant. In this study, we extended the investigation of biogeographic diversity of zooxanthellae (*Symbiodinium*) associated with *O. crispata*, from the West Pacific, including high-latitude Japan (temperate), Okinawa, Japan, the Penghu Islands, Taiwan, Hong Kong, China (subtropical), Hainan Island, China, and Sichang Island, Thailand (tropical). PCR-RFLPs surveys of partial nuclear large subunit ribosomal DNA (nlsrDNA) indicated that *O. crispata* hosted exclusively clade D in both temperate and subtropical populations, while individuals collected from the tropical populations (Hainan and Sichang) showed polymorphic symbiosis of clade C and D. Analysis of molecular variance (AMOVA) analysis of ribosomal internal transcribed spacer (ITS) showed that *Symbiodinium* clade D has a significantly genetic differentiation between temperate and subtropical populations. Nested clade analysis (NCA) indicated that population subdivision among temperate, subtropical, and tropical populations probably reflected the restriction of gene flow by distance due to the current circulations within the South China Sea and the northern-ward connection to the high-latitude West Pacific.

Scaling Non-linear Physiological and Cellular Mechanisms to Ecological Processes: The Role of Symbiont Specificity in Coral Bleaching

*Roberto IGLESIAS-PRIETO**

Apartado Postal 1152, Cancun QR 77500 United Mexican States
iglesias@mar.icmyl.unam.mx

The phenomenon known as coral bleaching (the disassociation of symbioses between invertebrates and dinoflagellates) affects coral reef ecosystem on a planetary scale. This phenomenon is initiated when corals and other invertebrates are exposed to elevated temperatures. These symbioses play a fundamental role in coral reef ecosystems and can be characterized as diverse and specific. Although these two properties have been recognized for more than a decade, their possible ecological consequences are still under considerable debate. On one hand, one school of thought tends to emphasize the role of symbiont flexibility as a possible mechanism of acclimation to changing environments. While, some researchers stress the importance of symbiont specificity as the limiting factor in the capacity of symbiotic invertebrates to respond to rapid environmental changes. Considering that most climatic change models predict significant increases in sea-surface temperatures during the next years, it is important to resolve this debate. A key element in the debate emerges from several observations indicating that different algal symbionts have different sensitivity to thermal stress. Using cultured symbiotic dinoflagellates and intact corals as experimental models I will show how thermal sensitivity in algal symbionts may result from the complex interactions of membrane and enzyme stability and photoprotective capacity. The results indicate that symbionts have narrow limits of acclimation to thermal stress. I will explore how some non-linear physiological and cellular responses propagate during thermal stress from the partial impairment of the photosynthetic apparatus to the collapse of the symbioses and eventually to the death of the host. As specificity in coral-dinoflagellate symbioses is a relative term, I will discuss the possible limits of thermal acclimation for holosymbionts under four specificity determinants: a) symbiont transmission mode, b) cellular compatibility between partners, c) local availability of potential symbionts and d) competitive exclusion of some algae.

The Role of Multiple Scattering by Coral Skeleton in the Amplification of the Solar Radiation Absorbed by Coral Tissues

*Susana ENRIQUEZ**, *Eugenio R MENDEZ*, *Ove HOEGH-GULBERG*, *Roberto IGLESIAS-PRIETO*

Apdo. Postal 1152, Cancun
enriquez@mar.icmyl.unam.mx

The evolutionary success of coral reef ecosystems relies on the mutualistic symbioses between scleractinians and dinoflagellates. Some emergent properties of the holosymbiont are not fully understood, limiting our abilities to assess the mechanisms behind the origin and stability of these symbioses. One of such emergent properties is the role of hosts in regulating the light environment experienced by the algal symbionts. Recently, it has been shown that algal pigments in the intact tissues of *Porites branerii* have between 2 and 5 fold more efficiency in its light absorption capacity, relative to freshly isolated cell suspensions containing the same amount of pigments. The mechanism that explains such a strong increment in pigment light absorption efficiency, is the multiple scattering produced by the highly reflective aragonite coral skeleton and the resulting increment in the path length traveled by photons through the coral tissue. Variations in algal cell density and pigment content contribute to regulate the optical properties of intact coral surfaces, and the light environment within the host tissue. Consequently, pigment density and coral skeleton morphology are two key factors for understanding algal light environment and the degree of pigment packaging within coral tissue. The effect of pigment density on the variation of light absorption properties of intact corals will be discussed, as well as the role of coral skeleton in the regulation of the photosynthetic performance of endosymbiotic dinoflagellates. We will discuss the ecological and evolutionary consequences of changes in total solar radiation dose experienced by coral tissues as a function of chlorophyll a density, stressing its implication for coral photoacclimation, and during coral bleaching.

Investigating the Physiology of *Symbiodinium* Populations from Multiple Species of Reef Corals

*Mark E WARNER**, *Todd LAJUNESSE*, *Jennifer ROBISON*

700 Pilottown Rd., Lewes, Delaware, 19958, United States of America
mwarner@cms.udel.edu

Recent efforts by several investigators have led to a better understanding of the phylogenetic diversity of *Symbiodinium* spp., ranging in scales from centimeters within a single host to global patterns of algal lineage distribution as well as the degree of host specificity. It is now clear that photosynthetic processes in symbiotic dinoflagellates are especially susceptible to environmental perturbation (e.g. elevated temperature and light). These findings have spurred much interest in understanding how these symbioses may adapt or acclimatize to changing environmental conditions associated with global climate change. However, to approach this topic, we must first have a better understanding of the photo-physiology of multiple *Symbiodinium* populations across many spatial and temporal scales. The potential for physiological differences in these algae at the homeostatic level and how such differences may affect algal distributions or provide the power to predict a response to future environmental threats is largely unknown. With the rapid rise in the use of active chlorophyll fluorescence to assess some aspects of algal photosynthetic capacity, there is a specific need to understand how (or if) complex photosynthetic processes may be assessed with current fluorescence methodologies. In order to approach this topic, several species of Caribbean reef-building corals are being investigated at two geographic locations (Key Largo, Florida and Carrie Bow Cay, Belize) and different depths in order to assess the diversity of *Symbiodinium* and the photosynthetic response of these algae in relation to in situ light exposure and the potential for diel photodamage and repair. Current results will be presented in the context of what is presently known from experimental bleaching studies.

An Experimental Approach to Thermal Stress Physiology and Acclimation in Coral/Algal Symbioses

*Ranjeet BHAGOOLI**, Irina YAKOVLEVA, Michio HIDAKA

Senbaru 1, Nishihara, Okinawa 903-0213, Japan

coral@scientist.com

Under elevated temperature and high light intensities algal endosymbionts of scleractinian corals suffer from photosynthetic apparatus impairment and thus corals respond by losing their symbionts, a process termed coral bleaching. The present study investigates damage to the photosynthetic machinery, using pulse-amplitude-modulated (PAM) fluorometry, in coral symbionts during and after thermal stress, and also in previously bleached but recovered specimens treated at high temperature. Exposure to elevated temperatures for 1 (*Pachyseris rugosa*), 6, 12 (*Stylophora pistillata* and *Platygyra ryukyuensis*) or 30 (*Platygyra ryukyuensis*, *Porites cylindrica*, *Montipora digitata* and *Seriatopora caliendrum*) h in six coral species revealed that maximum electron transport rate (ETR_{max}) is more sensitive than the maximum quantum yield of photosystem II (F_v/F_m). Differential damage to both ETR_{max} and F_v/F_m were evident when bleaching susceptible and bleaching resistant corals, whose symbionts also exhibited genetic diversity, were compared. Experiments with combined elevated temperatures and high light intensities showed that high temperature lowered the photoinhibitory light levels differently in bleaching susceptible (*S. pistillata*) and bleaching resistant (*P. ryukyuensis*) corals. When bleached/recovered coral specimens (*Favia fava*, *P. ryukyuensis* and *M. digitata*) exposed to high temperature (32°C) under 850 $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$ for 3 h were compared to their respective previously non-exposed parent fragments, the former exhibited significantly better photo-physiological responses than the latter in terms of ETR_{max} and F_v/F_m . Taken together, these experiments demonstrate that 1) the maximum electron transport rate is more temperature sensitive than the maximum quantum yield of photosystem II, 2) differential damage to the photosynthetic apparatus of the genetically different symbionts or differential lowering of photoinhibitory light levels of symbionts might reflect bleaching susceptibilities and 3) previously bleached but recovered corals can acclimatize and respond better to repeated thermal stress.

Pigment Profiles and the Bleaching Susceptibility of *Symbiodinium*

*Alexander A VENN**, Michael A WILSON, Henry TRAPIDO-ROSENTHAL, Brendan J KEELY, Angela E DOUGLAS

Department of Biology (Area 2) University of York, PO Box 373, York, YO10 5YW, UK United Kingdom of Great Britain and Northern Ireland

Alexandervenn@yahoo.com

Pigment profiles i.e. the abundance of photoprotective xanthophylls and carotenenes relative to chlorophyll a, are widely accepted as important physiological parameters shaping bleaching susceptibility among *Symbiodinium* strains. The impacts of acute bleaching were assessed in three *Symbiodinium* rRNA gene phylotypes, by subjecting a panel of anthozoans to elevated temperature and irradiance. Zooxanthella density, pigment profiles and host protein content were used as indicators of response to bleaching stress. Pigment profiles and bleaching response varied between and within *Symbiodinium* phylotypes. The results illustrate how zooxanthella and host bleaching responses can vary dramatically among associations. In a parallel field study, the responses of two *Symbiodinium* phylotypes to chronic bleaching stress were assessed in a single host. The phylotypes responded differently to summer elevated water temperatures, demonstrating the impact of the identity and physiology of the algal partner on the stability of the symbiosis.

Thermal Acclimation Potentials in Two Pocilloporid Corals

*Sean P GRIFFIN**, Ranjeet BHAGOOLI

P.O. Box 908, Lajas, Puerto Rico 00667 Puerto Rico

griffin@caribe.net

This study investigates the physiological acclimation potentials of *Pocillopora damicornis* from Kaneohe Bay and of *Pocillopora meandrina* from a thermal outfall (5°C higher than ambient) and a control site at Kahe, Hawaii, exposed to three different temperatures (29, 32 and 33°C) over a five-day exposure period. Light levels at the sampling points were 1000 to 1500 and 25 to 60 $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$ in the morning (0800) and during the afternoon (1200 and 1600), respectively. The ELISA for catalase and the ferric reducing antioxidant potential (FRAP) assay showed similar patterns in the physiological response of corals to elevated temperatures and increased irradiance. Antioxidant concentrations were highest in the morning for *P. damicornis* and *P. meandrina* outfall samples while there was no significant change through the day for *P. meandrina* samples from the control site. Photosynthetic efficiency (F_v/F_m), measured at 2300 and 0400, decreased with time for all species at 32 and 33°C, but at a slower rate in *P. meandrina* from the outfall than from the Kahe sites at 32°C. These results show that *P. meandrina* from the Outfall site has acclimated to the environmental conditions at that site as a result of the heated effluent from the electric plant as they exhibit a better physiological behavior compared to their conspecifics from a nearby control population. Their reactions are similar to *P. damicornis* which is a species adapted to shallower environments with greater fluctuations in temperature and irradiance. Acclimation to these conditions has occurred in less than 30 years. This implicates the possibility for some coral species to acclimate to the present trends in global warming although only after initial episodes of mass mortality which could be already occurring on reefs around the world.

Zooxanthellae Clade, Zooxanthellae Nitric Oxide Synthase Activity, and Susceptibility of Corals to Bleaching

*Henry TRAPIDO-ROSENTHAL**, Jessica ARCHER, Ranjeet BHAGOOLI,

Brian BOEING, Alexander VENN, Sandra ZIELKE

17 Biological Lane, Ferry Reach GE-01, Bermuda

hank@bbsr.edu

Although coral bleaching is a widespread phenomenon that has been increasingly observed over the last 30 years, the biochemical basis of bleaching has not as yet been identified. A widely held assumption has been that bleaching results from expulsion of the symbiotic microalgae, or zooxanthellae, found within the coral endodermal tissue, by the host in response to a number of stressors that include thermal shock, UV light and pathogenic infection. We present data that suggest that, rather than being mediated by the coral host, bleaching is in fact initiated by the zooxanthellae, by induction of nitric oxide synthase (NOS) and formation of membrane-permeable nitric oxide (NO). We propose that oxidative damage to host endodermal cells, mediated or enhanced by NO resulting from inducible zooxanthellae NOS activity, leads to coral bleaching, allowing the zooxanthellae to vacate the symbiosis and assume a possibly temporary, but physiologically-preferable free-living form. Strengthening this proposition are the observations that, when subjected to thermal stress: (1) zooxanthellae of Clade A (*sensu* Rowan) show little elevation of NOS activity, and that corals harbouring zooxanthellae of this clade are resistant to bleaching, whereas (2) zooxanthellae of Clades B and C show substantial increases in NOS activity, and corals harbouring zooxanthellae of these clades are susceptible to bleaching. Furthermore, the degree of bleaching, as measured by reduction in density of zooxanthellae per unit area of coral tissue, can be correlated with the amount of algal NOS activity. Taken together, these findings corroborate the hypothesis that NO generated by symbionts is associated with the dissolution of the symbiotic relationship. In addition, they point to one particular physiological mechanism that may be associated with the flexibility and specificity of the relationship between corals and their algal symbionts.

Functional Genomics of the Coral-Dinoflagellate Symbiosis

*Jodi A SCHWARZ**, Chitra MANOHAR, Dave NELSON, Alina SZMANT, Mary Alice COFFROTH, Monica MEDINA

Dept. Microbiology, 305 Fairchild Building, 299 Campus Drive, Stanford, CA 94305 United States of America
jschwarz@stanford.edu

The coral-dinoflagellate symbiosis is an intimate association between two partners, in which one of the partners is internalized and comes to reside within cells of the other. The host-symbiont interaction must be regulated by suites of genes that are co-expressed at different stages of the symbiosis, and under different environmental regimes. Only recently, through the development of microarray technology, has it become feasible to take a genome-wide approach to studying the coral symbiosis. We are interested in identifying genes from each partner that are expressed during the symbiosis, and ascribing putative functions to these genes in the *Montastraea faveolata* symbiosis. To accomplish this, we are creating a transcriptome of the symbiosis, by designing microarrays consisting of ESTs derived from both partners at various timepoints during symbiosis. We rear each partner independently, and then experimentally bring them together to form the symbiotic association, and sample RNA from each partner throughout the process. The microarrays will be used to survey gene expression patterns by each partner living independently, and each partner as the symbiosis is initiated and develops into a mature association. We will determine which genes or gene pathways are transcriptionally regulated by the initiation and maturation of symbiosis and how they are affected by changes in environmental factors such as temperature and light exposure. Sequencing of the transcriptome will reveal the identities of some of the genes, by homology to other organisms, whereas genes with no homologs likely represent novel genes used in coral-dinoflagellate symbiosis. Such approaches have been very successful at elucidating interactions in analogous systems, for example host-parasite interactions.

Coral Reef Genomics: A Genome Wide Approach to the Study of Cnidarian Symbiosis

*Monica MEDINA**, Mary A COFFROTH, Alina SZMANT, Jodi SCHWARZ, Jeff FROULA, Astrid TERRY, Chitra MANOHAR, David NELSON

2800 Mitchell Drive, Walnut Creek CA 94598 United States of America
m_molina@lbl.gov

The symbiosis between scleractinian corals and *Symbiodinium* is highly susceptible to changes in environmental factors (e.g. seawater temperature, light levels). Global warming has affected coral reefs worldwide leading to a disruption of these symbioses (coral bleaching) and subsequently resulting in widespread coral mortality. Little is known about the molecular basis for the establishment and maintenance of this important biological relationship. We will use microarray expression profiling developed from Expressed Sequence Tags (EST) data to identify genes involved in the *Montastraea faveolata*-*Symbiodinium* symbiosis on Caribbean reefs. Sequencing of Bacterial Artificial Chromosomes (BAC) clones containing putative symbiosis genes will help us understand how these genes are regulated in both host and symbiont. This research will look at an important mutualistic relationship using a genome wide analysis of gene expression. Gaining a better understanding of host-symbiont relationships in coral reef ecosystems can have implications for atmospheric and ocean sciences, conservation biology and the study and diagnosis of microbial diseases in corals.

New Frontiers in Recognition and Specificity in Cnidarian/Algal Symbioses: Lessons from Pathogenesis Pave the Way for New Breakthroughs

*Virginia M WEIS**, Jodi A SCHWARZ, Brett K BAILLIE

3029 Cordley Hall, Corvallis OR, 97331 United States of America
weisv@science.oregonstate.edu

The study of recognition and specificity in cnidarian/algal symbioses is poised to take significant steps forward in the coming years. Investigators are increasingly using cellular and molecular technologies to build on seminal early work that examined onset of symbiosis and sought to understand patterns of host/symbiont combinations. This presentation will provide an overview of past, present and possible future studies in recognition and specificity in cnidarian/algal symbioses. Dramatic progress has been made within the past 20 years in the understanding of host/symbiont specificity, with the birth of zooxanthellae molecular phylogenetics and population genetics. The early hypothesis of a one host/one symbiont mutualism has been replaced with a complex picture of multiple host/symbiont combinations that can shift in time and space. However, virtually nothing is known about the mechanisms by which host and symbiont recognize and evaluate each other as potential partners. How do the partners come into contact, and what are the relevant protein components of recognition? How does the symbiont avoid digestion by host lysosomes? Why do the host non-self recognition processes not eliminate symbionts? The fields of medical and agricultural microbiology ask many of the same questions about host-microbe interactions, but are at a more advanced state of knowledge. Such information can be used to guide future efforts in understanding recognition in cnidarian/algal associations. Future studies will benefit from such techniques as: functional genomics to identify suites of genes that play roles in symbiosis, genetic techniques to evaluate the roles of specific genes, and microscopy techniques to examine the dynamics of gene and protein expression. Just as the last 20 years has revolutionized our thinking about the nature of host/symbiont specificity, the next 20 years will revolutionize our understanding of how mutualisms are structured, and whether mutualistic host-microbe interactions are fundamentally similar to, or different from, pathogenic interactions.

Programmed Cell Death in *Aiptasia* sp. Plays an Important Role in *Symbiodinium* Release during Bleaching and Is Controlled by a Highly Conserved Suite of Genes

*Simon R DUNN**, Wendy S REYNOLDS, Virginia M WEIS

3029 Cordley Hall, Corvallis, Oregon, 97331 United States of America
dunns@science.oregonstate.edu

During hyperthermic-stress-induced bleaching, an increase in apoptosis or programmed cell death (PCD) of *Aiptasia* sp. host cells has previously been shown to be an important mechanism for the release of symbiotic algae. We have now described some of the key genes that play a role in the cnidarian PCD pathway, using a suite of molecular techniques. Two of these key components are a caspase-like protease that includes a characteristic activation site or caspase recruitment domain (CARD) and a Bcl-2-like pro/anti apoptotic trigger molecule. These highly conserved members of the apoptotic pathway are now shown to be present in both lower and higher metazoans. We are currently manipulating the activity of these pathway members with the use of inhibitors and gene silencing techniques to examine the functional significance of PCD and its role in bleaching. Addition of a broad-range caspase inhibitor to *Aiptasia* subjected to hyperthermic stress resulted in increased bleaching compared to anemones subjected to hyperthermia alone and those subjected to inhibitor at control temperatures. These data suggest that host PCD mitigates tissue damage resulting from hyperthermic stress.

Nutrients, Light and Corals

Zvy DUBINSKY*, Noa EDEN, Noga STAMBLER

Ramat Gan, 52 900, Israel

dubinz@mail.biu.ac.il

Nutrients such as nitrogen and phosphorus, in addition to carbon, are essential and major components of the biomass of any plant and animal. However luxuriant coral reefs succeed in dominating coastal zones in the tropical, nutrient-poor waters. Their success resides on the mutualistic symbiosis between endocellular microalgae, the zooxanthellae, and their host corals. Under normal oligotrophic conditions, shallow water corals are nutrient limited, since N and P influxes are insufficient to match the high-light driven carbon flux. These nutrients are obtained by predation on zooplankton. Under dim light, the same low nitrogen and phosphorus availability poses no problem at the slow photosynthate supply rates, and prey must be used primarily as a nutrient source. Under high light the symbionts readily leak photosynthate to the host, since they cannot multiply on carbon alone. A putative Host Factor to which only nutrient limited zooxanthellae respond enhances this leakage dramatically. Low-light, nutrient sufficient conspecifics are not susceptible to such Host Factor induced excretion. Anthropogenic, and occasional natural eutrophication exposes reefs to elevated nutrient concentrations. These stem from human activities such as sewage disposal, agricultural runoff, forest destruction, coastal development and intensive mariculture. When exposed to elevated nutrient levels the fine-tuned zooxanthellae-host symbiosis fails. The zooxanthellae now retain carbon and use the nitrogen and phosphate to proliferate, thereby reducing the supply of high energy photosynthate translocated to their host. Symbiont densities may increase five fold, with their photosynthesis becoming now limited by carbon and light. In addition, under increased nutrient availability phytoplankton stocks increase reducing water transparency, and rapidly growing seaweeds proliferate, out-competing corals for light and substrate.

Metabolism and Photosynthesis of Hermatypic Corals

Noga STAMBLER*

Ramat-Gan 52900, Israel

stambln@mail.biu.ac.il

The mutualistic symbiosis between zooxanthellae and hermatypic corals is based on the photosynthetic process of the algae. This dependence sets constraints on the association since low light intensity limits photosynthesis while very high intensity causes photoinhibition. Photoinhibition is the result of damage to the D1 protein in PSII by free radicals. Chemical or physical stress that impedes the electron flow to the dark reactions will lead to photoinhibition even at low light intensities. Chronic inhibition of photosynthesis will lead to bleaching. Any stress such as UV radiation, high and low temperature, pollution (eutrophication, herbicides, heavy metals), pathogens, and sedimentation, will increase the metabolism of the coral association and reduce the photosynthesis rate. Under stress, various defense mechanisms in both the animal and the zooxanthellae are activated. These mechanisms include behavioral responses, radical scavenging compounds such as MAAs and carotenoids, and antioxidative enzymes.

Diurnal Hysteresis in Coral Photosynthesis and Calcification

Oren LEVY*, Zvy DUBINSKY, Kenneth SCHNEIDER, Yair ACHITUV, David ZAKAI, Jonathan EREZ, Maxim Y GORBUNOV

Weizmann Institute, PO Box 26, Rehovot 76100, Israel

levysher@netvision.net.il

In oxygenic photosynthesizing organisms, it has been noticed in a number of occasions that photosynthetic performance was lower in the afternoon than in the morning, at the same light intensities. This hysteresis phenomenon is called the "afternoon depression" and has been observed in phytoplankton, macroalgae, and higher plants. Here we characterize, with high temporal resolution, *in situ* diel courses of oxygen evolution and chlorophyll fluorescence yields in three Indo-Pacific corals; *F. fавus*, *G. lobata*, *P. sinuosa* and two Caribbean symbiotic corals; *M. faveolata* and *P. astreoides* using a submersible respirometer and a SCUBA fast repetition rate fluorometer. In contrast to all previously published cases, the oxygen measurements revealed an unexpected "reverse hysteresis", with higher photosynthetic rates occurring in the afternoon than in the morning. These patterns were highly consistent in all three corals from the Red Sea. Surprisingly, the diurnal patterns of the quantum yields of photochemistry in PSII, assessed from variable fluorescence (Delta F/Fm), exhibited much higher variability and often showed a hysteresis pattern opposite to that of oxygen. In most organisms the values of (Delta F/Fm) and the deduced rates of photosynthetic electron transport were higher in the morning than in the afternoon, however, the opposite trend with lower values of Delta F/Fm in the morning was also observed. Lower values of (Delta F/Fm) were always accompanied by higher quantum yields of non-photochemical quenching, consistent with the energetic balance within the primary photosynthetic reactions. The direction of the diurnal hysteresis in variable fluorescence appears to be species-specific and may vary even within the same species, reflecting microscale variability in bio-optical properties. Measurements of calcification rate showed the same patterns of a counter-clockwise hysteresis as noticed via the oxygen measurements. The results presented reveal the strong relationship between photosynthesis and calcification on short time scales of daily cycles.

Seasonal Photoacclimation in the Reef-building Coral *Montastraea annularis*, c.f. *faveolata*, in the Florida Keys

James W PORTER*, Jennifer I TOUGAS, Alina SZMANT, Peter K SWART

1033 Green St., Athens, GA 30602 United States of America

jporter@uga.edu

Seasonal photosynthetic and respiratory patterns were measured *in situ* for specimens of the reef-building coral *Montastraea annularis* c.f. *faveolata* in the Florida Keys. Temperature and irradiance show marked seasonal variation on Floridian coral reefs, with summer highs (30.4 °C) at least eight degrees higher than winter lows (21.9 °C). Both maximum and total irradiance values at 8 m depth are almost twice as high in summer ($I_{max} = 1,732 \mu E m^{-2} s^{-1}$; $I_{tot} = 31.3 E m^{-2} d^{-1}$) than in winter ($966 \mu E m^{-2} s^{-1}$; $10.7 E m^{-2} d^{-1}$). At depth, summer day length (14.0 h) is three hours longer than winter day length (11.0 h). P-I curves indicate that zooxanthellae adjust to low winter irradiance by an increase in from $0.12 \mu g O_2 cm^{-2} h^{-1} / \mu E m^{-2} s^{-1}$ in August to 0.22 in February. Respiration rates are highly correlated with temperature, ranging from $26.7 \mu g O_2 cm^{-2} h^{-1}$ in August to 14.5 in February. In contrast, P_{net} max achieves high rates in early summer ($49.0 \mu g O_2 cm^{-2} h^{-1}$) as well as in winter (47.2). Coral genets are significantly more similar in their photosynthetic oxygen flux characteristics than are non-clone mates. Measured *in situ* integrated net P/R ratios are highest in summer, but, due to photoacclimation, remain above 1.0 throughout the winter. An annual integrated net P/R model, which uses surface irradiance to predict photosynthesis at depth, demonstrates that *Montastraea annularis* is fully photoautotrophic, with respect to carbon, for the entire year, even at 8 m depth. During our sampling program, we detected strongly inhibitory effects on coral photosynthesis (but not respiration) in September, 1993, which corresponded with the arrival of Mississippi River flood waters, and therefore may be related.

Cell Migration of Zooxanthellae in the Coral *Montipora capitata*Junko TOYOSHIMA*, Robert A KINZIE

2538 The Mall, University of Hawaii at Manoa, Honolulu, HI 96822 United States of America

jtoyoshi@hawaii.edu

Reef-building corals have evolved an elaborate symbiotic relationship with zooxanthellae which plays an important role in supporting the productivity and diversity of coral reef ecosystems. Very little is known about mechanisms by which the population density of symbionts is maintained in the healthy symbiotic relationship, although such information may be helpful for understanding coral bleaching, that is, an abnormally low density of zooxanthellae. In Hawaiian plate-shaped colonies of *Montipora capitata*, the dividing cells were selectively labeled by exposing live colonies to 5-bromo-2'-deoxyuridine (BrdU) to see where cell division takes place and to test the hypothesis that cells may move within the colony. When visualized with immunohistology, the dividing cells were found in higher proportion in the shaded part of colony. Long-term (up to 3 weeks) tracking of the labeled cells indicated that there is a vertical migration of zooxanthellae in an upward direction through the plate. This may be a mechanism for protecting the cells from high solar radiation, preventing coral bleaching, and facilitating recovery of corals from bleaching.

Estimation of the Primary Productivity of a Temperate Coral PopulationEriko NAKAMURA*, Yasutsugu YOKOHAMA, Jiro TANAKA

Konan 4-5-7, Minato-ku, Tokyo 108-8477, Japan

rico123@mail.goo.ne.jp

Acropora pruinosa is a temperate hermatypic coral distributed in the non-reefal area. On the southern coast of Izu Peninsula, which is the central part of the Pacific coast of Japan, well-developed colonies of *A. pruinosa* are observed. The water temperature in the district reaches 14°C in winter and 26°C in summer. The aim of this study is to estimate the primary productivity for a population of the temperate scleractinian coral *A. pruinosa* on the southern coast of the Izu, Shizuoka Pref., Central Japan. Photosynthetic oxygen evolution was measured for each replicated small pieces of the coral with a gas-volumeter and the photosynthesis-irradiance (P-I) curve for each season was determined. The gross photosynthetic rate for small pieces of the coral was read from the P-I curve corresponding to the ambient irradiance at the depth where the coral was distributed. As the daily average irradiance was below approximate 100 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$, the photosynthetic rate in lower irradiance was shown by the initial slope of P-I curves. The respiration rate for small pieces of the coral was measured under dark condition. The gross photosynthetic rate and the respiration rate per unit area of coral colonies were determined in consideration of the colony structure. The net photosynthetic rate for each season is calculated as the difference between the gross photosynthetic and the respiration rate. As the result, the net photosynthetic rate in winter was estimated as 14 % of that in summer. The primary productivity or the annual net photosynthesis of the temperate coral population, was $3.3 \times 10^3 \text{ l O}_2 \text{ m}^{-2} \text{ year}^{-1}$, which was influenced with the low net photosynthesis by low temperature and irradiance during winter.

Variability of Pigmentation in the Coral *Porites lobata*Amy M APPRILL*, Robert R BIDIGARE, Ruth D GATES

1000 Pope Rd., Honolulu, Hawaii United States of America

apprill@hawaii.edu

Coral bleaching refers to an observable color change in a normally pigmented coral caused by a loss of endosymbiotic algal pigmentation, a loss of the endosymbiotic algae, or a combination of the two processes. Measurement of coral pigmentation is undoubtedly important to understanding coral color changes and provides a quantitative understanding of the ranges of variability. We are investigating variability of pigmentation in the common coral *Porites lobata* using HPLC analysis and methods that minimize the previously encountered problems of sampling from a complex surface area, extracting pigments embedded in a tissue matrix, and minimizing the amount of coral tissue sampled. Preliminary data from Hawaiian colonies of *P. lobata* include quantification of six pigments - chlorophyll *a*, chlorophyll *c*₂, peridinin, diadinoxanthin, diatoxanthin, and β -carotene - in relation to surface area and per algal cell. Our approach to quantifying the variability of these pigments in *P. lobata* includes a large field sampling of colonies in Hawaii as well as laboratory induced bleaching experiments using elevated UV-radiation and temperature treatments. We are also accounting for the possible variability caused by multiple symbiont populations by identifying the taxonomy of the resident *Symbiodinium* spp. population in each coral colony sampled using denaturing gradient gel electrophoresis to examine and compare the internal transcribed spacer 2 region of DNA. By focusing on a single species and using robust quantitative sampling methods, we expect this study to provide an indication of the flexibility of algal pigmentation in corals under various conditions.

Spatial Variation in Coral Reef Biodiversity along a Gradient of Nutrient Supply on the Southern Red Sea Coast of Eritrea

*Mehari Y GHILGABER**, *Bruce G HATCHER*

Dept. of Biology, Dalhousie University, Halifax, NS, Canada B3H4J1 Eritrea
mghilaga@dal.ca

The coastline (ca. 1200 km) and Islands of Eritrea comprise the least developed coral reef province in the Red Sea, supporting no more than 100,000 residents. For three decades (1960-1991) the area was inaccessible and unexploited due to a prolonged war. Coastal development and fishing have experienced limited and localized growth since, so the extensive reef communities are essentially free of any major anthropologic impact. Fringing and patch reefs grow in a hot and saline environment with mean surface temperatures of 27 (February) to over 32 degree celsius (July and August), and salinities typically reaching up to 37ppt. The desert coast experiences very low rainfall (ca.150mm/yr), and only a few seasonal drainage channels bring water to the sea. Nutrient inputs to reefs from land is thus small and localized. The major source of dissolved macronutrients to the southern Red Sea is advection of Indian Ocean water through the Bab-El-Mendeb, especially during the SE Monsoon (October to April), and concentrations decrease markedly from south to north along the Eritrean coast. In this scenario we hypothesize that coastal-scale variation in coral reef biodiversity reflects a gradient of interaction between corals and algae as mediated by nutrient supply. Specifically, we predict that high algal productivity in the south will support higher abundance of herbivorous fishes and their predators than in the north; that benthic algal assemblages will show a north-south trend from turf algal dominance to fleshy and canopy forming macro algae; and that the abundance and diversity of scleractinian corals will decrease from north to south. The hypotheses are tested using pattern analysis of benthic survey data, and an experimental regime is proposed for elucidating causal mechanisms.

Algal Overgrowth, Coral Disease and Phase Shifts on Coral Reefs: Are They Linked?

*Maggy M NUGUES**, *Garriet W SMITH*, *Rolf P M BAK*

PO Box 59, 1790 AB Den Burg, Texel Kingdom of the Netherlands
mnugues@nioz.nl

Within 30 years, sudden and large-scale increases in the abundance of macroalgae have led to widespread and dramatic shifts from coral to macroalgal abundance on coral reefs. It is widely assumed that there has been a shift in the competitive environment, due to reduced herbivory or increased nutrient availability, so that macroalgae have been overgrowing and killing corals. However, an alternative view has been proposed in which macroalgae in general cannot kill corals through competitive overgrowth, but take advantage of coral mortality from external disturbances to increase in coverage. We transplanted the brown alga *Lobophora variegata* next to colonies from six species of scleractinian corals at 20-26 m depths on a coral reef in Curacao, Netherlands Antilles. Our aims were to estimate coral mortality from macroalgal overgrowth and to establish whether coral species differ in their susceptibility to overgrowth. The results of the experiment show that coral tissue mortality was greater in the presence of the alga, but that this effect differed among coral species. Most importantly, coral mortality was rarely due to the alga directly overgrowing living coral tissue, but was rather associated with disease-like signs. In a second transplant experiment with the green alga *Halimeda opuntia*, we show that the overgrowth of *H. opuntia* caused a significant increase in the incidence of white plague on the coral *Montastraea faveolata*. We suggest that the close proximity of macroalgae can cause localised stress and damage to adjacent coral tissue, subsequently facilitating invasion by pathogens. We propose a new alternative explanation to coral-algal phase shifts in which macroalgae cause coral mortality, not by direct competitive overgrowth, but by promoting coral disease.

Disturbance and Recovery of Reef Communities in the Great Barrier Reef

*Scott BURGESS**, *Greg COLEMAN*, *Angus THOMPSON*

PMB 3, Townsville MC, Queensland 4810 Australia
s.burgess@aims.gov.au

We analysed 11 years of benthic data collected annually at fixed sites on 48 reefs in the Great Barrier Reef (GBR) to quantify disturbance and recovery in terms of absolute, relative, and community changes over time. Reefs at inner, mid, and outer shelf locations were surveyed in 5 sectors covering a total distance of approx. 1300 km along the GBR. We identified periods of constant change where, for a particular reef, the trajectory of coral cover over time continues in the same direction. Of the 48 survey reefs, the overall magnitude of declines was slightly less than the magnitude of increases. Large increases, however, only occurred at 9 of the 48 reefs and were the result of excellent recovery from initially low cover (<20%). Recovery at these reefs was driven by fast-growing *Acropora* spp. It occurred in the absence of major disturbances (e.g., Crown-of-Thorns starfish [COTS]), occurred mostly at outer-shelf reefs, and took about 10 years to reach the currently high levels of coral cover (~60-80%). The single greatest change in coral cover was in a positive direction, with 73% over 10 years at One Tree Island. The largest decline recorded was 52% (84% of initial cover) over 9 years at Gannet Cay. Most longer-term declines were associated with COTS predation and large shorter term declines were associated with cyclones. Large changes in percent cover were associated with changes in the composition of the community, mostly involving *Acropora* spp. Most reefs where there were large declines in percent cover showed poor recovery (<20%) in the time period of surveys (up to 6 years after declines).

Coral Diversity across a Disturbance Gradient in the Pulau Seribu Reef Complex

*Daniel F R CLEARY**, *Bert W HOEKSEMA*

P.O. Box 9517, 2300 RA Leiden, Kingdom of the Netherlands
cleary@science.uva.nl

The coral reefs of Indonesia are among the richest in the world but are also among the least studied and least understood. Here we compare the impact of a large-scale disturbance gradient with local-scale disturbance on coral richness, cover and composition in the Pulau Seribu complex off of Java, Indonesia. We found no effect of local land-use type on taxon richness, composition or cover nor did taxon richness differ among large-scale disturbance zones. There was, however, a pronounced difference in composition and coral cover among zones. Coral cover was very low and composition differed markedly in zone 1 (Jakarta Bay) where human-induced disturbance is most intense. Cover was highest in the outlying reefs of zone 3. The highly perturbed zone 1 reefs were, furthermore, distinguished by the virtual absence of otherwise abundant coral taxa such as *Acropora hyacinthus* and *Porites rus* and the prevalence of taxa such as *Oulastrea crispata* and *Favia maxima*. Almost 60% of the spatial variation in composition was explained by variation in shelf depth and island size. The importance of shelf depth is related to the prevalence of a strong environmental gradient in depth, human-induced pollution and mechanical reef disturbance and salinity from Jakarta Bay to the outlying reefs in addition to naturally greater compositional heterogeneity in areas with a greater depth range. Although there was a significant univariate relationship between spatial variation in composition and distance this did not enter into the multivariate model, except when presence-absence data was used, indicating that environmental processes are the primary structuring forces in determining coral assemblage structure across the Pulau Seribu.

Philippine Offshore and Shelf Reef Areas: Coral Community Structure and Recruitment Dynamics

*Miledel Christine C QUIBILAN**, Porfirio M ALINO

Velasquez St., University of the Philippines Diliman, Quezon City 1101
Republic of the Philippines
mags@upmsi.ph

The underlying mechanisms that determine the patterns in the structure of reef communities west of the Philippines were investigated. From 1997-2000, a total of 17 reef areas were assessed and monitored in the Kalayaan Island Group (KIG), South China Sea, Palawan shelf and Sulu Sea. Various indices and multivariate analyses reveal a west to east trend in reef benthos. Differences in the patterns in coral community structure were linked to physical forcing such as degree of exposure the northeast and southwest monsoons and disturbances (e.g. tropical cyclones). Significant changes in coral community structure were also observed after the 1997-1998 El Nino. Reefs had varying degrees of susceptibility to elevated sea surface temperatures (SSTs) due to differences in benthic composition and community structure. Moreover, rates and patterns of recovery seemed affected by the synergistic impacts of the prevailing human and/or natural disturbances in these areas. The influence of important coral recruitment processes: post-settlement mortality and larval supply on reef recovery and potential community succession was also studied. Abundance, composition and sizes of visible recruits on concrete blocks were observed in-situ every six months for two years while the non-visible recruits on terracotta tiles were investigated for two monsoon seasons. Post-settlement mortality was highest for reef sites in the KIG followed by Palawan and Sulu Sea. Visible recruit to adult relationships reveals that reefs in the Sulu Sea have better concordance which implies a greater tendency for faster recovery here than in the two other areas. In addition, larval supply was higher in the Sulu Sea for both monsoon seasons, giving reefs an opportunity each year to replenish their populations. This study provides initial insights on how the patterns and the understanding of processes and their linkages may be used for conservation and management of Philippine offshore and shelf reef areas.

Direct Competition for Space between Coral Colonies at Heron Island, Australia

*David B GREENBERG**, Joseph H CONNELL, Alex M KERR, Lloyd GOLDWASSER

Department of Ecology, Evolution, & Marine Biology, University of California, Santa Barbara, CA 93101, U.S.A.
greenber@lifesci.ucsb.edu

Competition for space on the sea floor, both within and between species, is an important factor governing the abundance and species diversity of reef corals. Corals may compete for space via overgrowth and overtopping, or via physical and chemical attacks between neighboring colonies. We have studied the extent to which competition via direct attack occurs between coral colonies at Heron Island, Great Barrier Reef, Australia, using census data collected from fixed square meter plots at intervals since 1963. Attacks between coral colonies occur along neighboring portions of their perimeters, where each colony's polyps can physically reach each other. Competition for space should then constrain growth along these closely-neighboring perimeters more than along other regions further from neighbors. We tested this hypothesis using maps drawn from color photographs which show the perimeters of all colonies within each plot for each census year. The maps allow us to track changes in size and position of individual colonies as a function of their proximity to other colonies. We regard parts of colony perimeters relatively far from any neighbors as controls for the neighbored portions, but also analyze the extent to which this "neighbor effect" varies continuously, rather than discretely, along a colony's border as a function of distance from its nearest neighbored region. For each colony in each census year, the analysis involves: a) viewing its perimeter as a series of evenly-spaced points, b) computing each point's distance from the nearest point on the perimeter of its nearest neighbor, and then c) measuring its growth at that point to the next census. Under competition, growth at points on a colony border should vary as a continuously increasing function of each point's distance (measured in the first census) from a neighbor.

Spatial Variation in Patterns of Coral Settlement at Sodwana Bay, South Africa, a High Latitude Coral Community

*David GLASSOM**, Louis CELLIERS, Michael SCHLEYER

PO Box 10712, Marine Parade 4056, KwaZulu-Natal, Republic of South Africa
davidg@ori.org.za

Settlement of scleractinian corals on artificial substrata was monitored for 2.5 years at Sodwana Bay on the east coast of South Africa, where the southernmost coral-reef communities on the African coast occur. In addition to high latitude, the high wave energy and strong Agulhas current are factors that potentially influence settlement patterns. Coral settlement was monitored on three reefs, separated by 1-3km, of the central reef complex. Settlement peaked in late summer (February-March), when Acroporidae was the most abundant family, reaching a maximum of 4027 recruits.m². Settlement remained high between March and May, but spat of the family Pocilloporidae were numerically dominant during this period. Low settlement, almost exclusively of pocilloporid corals, continued for most of the year. Settlement levels were high compared to other high-latitude reef locations. Unusually, most settlement occurred on the upper surface of the tiles, possibly because the average depth at which they were deployed exceeded 15m. Settlement varied between the 3 reefs of the complex and between sites on the southernmost reef, where more intensive sampling was undertaken. This work constitutes the first record of coral settlement for South Africa, or the south-western Indian Ocean, provides a snapshot of spatial variation in settlement and confirms the importance of sexual reproduction in maintaining these high-latitude coral communities.

Spatio-Temporal Variability of Age and Size at Colonization of Four Coral Fish Species from Uvea Island (Wallis and Futuna)

*Mathieu JUNCKER**, Laurent WANTIEZ, Dominique PONTON

Mathieu Juncker, Service de l'Environnement, PB 294 Mata'Utu, 98600 Uvea. Territoire de Wallis et Futuna
juncker@univ-nc.nc

Age and size at colonization of four coral reef species were studied from competent individuals caught by crest nets set in September 2002, December 2002, March 2003, and June 2003 at three sites >10 km apart on the barrier reef of Uvea Island, Wallis and Futuna, Western Pacific. Benthic spawners *Abudefduf sexfasciatus* and *Dascyllus aruanus* presented a shorter pelagic life duration (PLD) and a proportionally greater flexibility (F) in age at colonization than benthic spawners *Parupeneus barberinus* and *Acanthurus triostegus* (*A. sexfasciatus*: mean PLD= 19d, F = 8d, n = 85 ; *D. aruanus*: mean PLD = 18d, F = 9d, n = 122 ; *P. Barberinus*: mean PLD = 35d, F = 13d, n = 45 ; *A. triostegus*: mean PLD = 42d, F = 11d, n = 33). Age and size at colonization was found to significantly vary between periods for *D. aruanus* only, and between sites for *A. sexfasciatus* only. The more important variability in age and size at colonization shown by benthic spawners is discussed within the framework of reproductive strategies of coral reef fishes.

Palaeoecology and Trophic Settings of Upper Eocene and Upper Oligocene Coralline Algal Dominated Carbonates (North-Eastern Italy)

*Daide BASSI**, James H NEBELSICK

Corso Ercole I d'Este 32, Ferrara Italian Republic

bsd@unife.it

On geological time scales, tropical marine ecosystems have exhibited a broad spectrum of responses to differing spatio-temporal scales of nutrient loading. During the Cenozoic, two main extinction events of marine benthic taxa took place in the Indo-Pacific area: a broad interval from the Middle-Late Eocene and a shorter interval during the Late Oligocene-earliest Miocene. These extinction highs coincide with changes in climate, upwelling (ocean fertility) or both. The Mid-Late Eocene interval overlaps a period of cooling that culminated in the initiation of Antarctic glaciation including possibly shallow tropical habitats. Slight cooling accompanied by enhanced upwelling also ensued across the Oligo-Miocene boundary. During these periods, coralline red algae and larger foraminifera were important sediment producers while corals play a subordinate role in the northern margins of the Tethys. Priabonian (Late Eocene) and Chattian (Late Oligocene) coralline algal facies are identified in an extensive geographic area in north-eastern Italy including the Colli Berici, Monti Lessini area, the Piedmont Flexure (southern Monte Grappa), and Alpage area (northern Lake S. Croce). These facies, found in both pure shallow water carbonate as well as mixed siliciclastic-carbonate settings, are compared in terms of taxonomic diversity, coralline growth-forms, and taphonomic signatures. Priabonian crustose coralline algal pavement is represented by a coralline crust bindstone with a wackestone-packstone matrix, and is characterised by the dominance of coralline crusts. Large rhodoliths occur commonly within this facies and are characteristically discoidal in shape. Chattian rhodolith pavements consist of a rudstone with a packstone matrix dominated by large spheroidal rhodoliths (up to 12 cm in diameter). These different biotic responses to ecological disturbances, probably due to increased rates of weathering and nutrient supply, associated with new trophic resources, promoted the flourishing of coralline algal rather than corals.

Introducing Coral Geographic, a Website Tool for Coral Biogeography

*JEN VERON**

PMB 3, Townsville 4810, Australia

j.veron@aims.gov.au

Coral Geographic is in the process of being built as a website tool for planning, managing, monitoring and research on global, regional and marine protected area scales. It is intended to contain geographic information about corals linked to supporting data to produce interlinked GIS maps, statistical analyses and data reports. It will integrate biogeographic knowledge of corals, have internal links between taxonomic, distribution and ecological data and also external links to environmental and management datasets. It will be encyclopedic in content, having fully referenced GIS maps for all coral species with linked databases to species attributes, abundances and habitats.

Unlike *Coral ID*, which is a self contained program (using the Lucid™ technology), *Coral Geographic* will be web based via a central server. This allows the data to be integrated with sophisticated server based statistical, modeling and reporting tools to extend the capabilities past just biogeographic data presentation. In principal, *Coral Geographic* is designed to store a range of user-selected options, and then to execute these options to produce either a map or a report, or both. Maps, such as grid or contour maps showing measures of similarity or diversity, can be produced at any scale. Reports may be lists (such as taxa or places) or analyses (such as regressions, similarity measures or dendrograms). It is intended that maps and reports can be generated directly by *Coral Geographic* or linked to other programs as required by the user. Users may also have customised data input protocols and products. Being located on a central server, the data used by *Coral Geographic* can be continually updated and new data can be combined with existing data to give up-to-date outcomes.

Multiple-analysis Provides Greater Insights into Coral Demography: An Example Using Genetics, Size-Structures, Demographics and Experiments for a Mushroom Coral

*James P GILMOUR**

35 Stirling Hwy, Crawley, Perth, Western Australia, 6009 Australia

jgilmour@cyllene.uwa.edu.au

A primary goal of ecology is to understand how population demography is affected by environmental change. To this end, a variety of methods of analysis are used, each of which address certain aims and hypotheses. Although each method provides valuable insights, each also has its limitations, whether in the type of data it produces, the accuracy or precision of estimates, the underlying assumptions, or the ease of application. Concurrently collecting data from a variety of methods of analysis, however, can provide greater insights into population demography. Methods commonly used to investigate populations of corals involve genetic, size-structure, life-history and experimental data. These methods were used to investigate populations of the mushroom coral, *Fungia fungites*, with contrasting levels of exposure to cyclones and sedimentation over three years. Of particular interest were the levels of sexual and asexual recruitment at each population, the importance of different life history stages to population maintenance, and the predicted changes in size-structure of each population. Different conclusions about each of these were drawn from the different methods of analysis, which either partially supported or contradicted the other methods. Erroneous conclusions were drawn from the results of a single method alone, whereas combining the results of all methods lead to a much better understanding of population demography.

Spatio-Temporal Juvenile Community Structure: Deriving Recruitment Patterns of Coral Reef Fishes in the Philippines

*Hazel O ARCEO**, Cleto L NANOLA, Porfirio M ALINO

Velasquez St., Marine Science Institute, University of the Philippines, Diliman, Quezon City, PHILIPPINES 1101

hoarceo@yahoo.com

Recruitment is one major factor that could establish, maintain and replenish local population structure of reef fishes. In the Philippines, previous studies have focused on recruitment of pelagic species and of reef fishes to artificial habitats. This study is one of the first few attempts to examine recruitment patterns of reef fish to natural reefs. Spatial and temporal patterns are investigated, as well as whether recruitment aids in biomass build-up inside marine protected areas (MPAs). Juvenile reef fish abundance and species composition in 30 localities around the country were obtained using underwater fish visual census (over 400 transect observations). Physical factors that could influence the patterns, such as wind exposure, slope and substrate attributes, as well as hydrographic features that were used to assess entrainment potential, were correlated with the community structure data. Preliminary analyses show that the observed spatial patterns were more influenced by wind exposure and reef slope. No apparent pattern was seen over large biogeographical scales. Instead, more localized patterns (i.e. regional scale, island clusters) were observed, suggesting that smaller-scale factors, such as reef morphology or benthic attributes, may have a more structuring influence. Juvenile abundance is high during summer (March-May), and some areas were consistently high or low in abundance during different seasons, identifying areas that potentially favor recruitment. Lastly, juvenile information was analyzed with data on adult reef fish community structure in selected MPAs to determine whether recruitment contributes to the biomass build-up inside no-take zones in addition to the protection of adult spawning stock biomass. Information on recruitment patterns can be used to improve MPA design, particularly in site selection, as well as in establishing MPA networks, since recruitment (together with adult emigration) can be another mechanism for causing or enhancing fish biomass build-up inside MPAs and spillover effects.

Distribution and Large-scale Abundance Patterns of Herbivorous Reef Fishes along the Tropical and Subtropical Southwestern Atlantic

*Rodrigo L MOURA**, *Ronaldo B FRANCINI-FILHO*

Rua das Palmeiras, 451 Caravelas BA 45900-000 BRAZIL
r.moura@conservation.org.br

In tropical and temperate reefs, herbivory by fishes and macroinvertebrates provides central nutrient pathways, and also shapes the abundance and structure of seaweed assemblages. If not removed by herbivores, algae can destroy entire coral reefs, and there is growing concern on the conservation implications deriving from this balance. Despite their ecological importance and significant role in the evolution of reef ecosystems, herbivorous fishes are still poorly known along the unique, small, and highly threatened Brazilian reefs. We provide an overview of distribution and large-scale abundance patterns of herbivorous reef fishes in this region, based on an extensive sampling program (1,607 stations) designed to evaluate variability in reef fish assemblages at several spatial scales. Sampling was stratified among different habitats of inner and mid-shelf reefs encompassing a broad latitudinal range (~0°50'-27°20'S). Abundance of large-sized roving herbivores and small-sized territorial herbivores showed different responses to the latitudinal and longitudinal gradients. Large-sized and roving species such as kyphosids, parrotfishes and surgeonfishes were more important in tropical mid-shelf reefs, while small-sized territorials such as blennies and damselfishes were more important in the subtropical region, as well as on tropical inner reefs. Hierarchical and mixed ANOVA models showed significant variation in the participation of both territorial and roving herbivores along the continental margin, at several spatial scales. Variance components calculated through the 'Residual Maximum Likelihood' method indicated higher variability at the larger observed spatial scale. Results presented herein provide a quantitative baseline for latitudinal comparisons of reef fish assemblages, as this is the first time that the proportional participation of herbivores in reef fish assemblages is analyzed within a broad latitudinal range contained in a single zoogeographic area. Historical, oceanographic, structural, physiological and ecological factors determining distribution ranges and the large-scale quantitative structure of herbivore fish assemblages along the Southwestern Atlantic coast are discussed.

Multi-disciplinary Spatial and Temporal Monitoring of Reef Ecosystems of the US-Affiliated Pacific Islands

*Russell E BRAINARD**, *Edward E DEMARTINI*, *Jean KENYON*, *Peter VROOM*, *Joyce E MILLER*, *Ronald HOEKE*, *John J ROONEY*, *Robert E SCHROEDER*, *Marc LAMMERS*

1125B Ala Moana Boulevard, Honolulu, Hawaii, USA, 96814 United States of America
rusty.brainard@noaa.gov

In order to better manage and conserve the coral reef ecosystems of the vast and remote U.S.-affiliated Pacific Islands, a multi-disciplinary team of scientists sponsored by NOAA's Coral Reef Conservation Program and led by the Coral Reef Ecosystem Division of the Pacific Islands Fisheries Science Center has been collaborating with other Federal, State and Territorial agencies, and non-governmental organizations to initiate a long-term, comprehensive program to assess, monitor, map, and conduct strategic research on the coral reef ecosystems of the region. Since 2000, this Pacific Reef Assessment and Monitoring Program (Pacific RAMP) has conducted baseline assessments and initiated benthic habitat mapping and multi-disciplinary spatial and temporal monitoring of the major functional components of the coral reef ecosystems of the Northwestern Hawaiian Islands, the U.S. Pacific Remote Islands Areas (Howland, Baker, and Jarvis Islands and Johnston, Palmyra, and Kingman Atolls), American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. These monitoring efforts, which were designed to observe key ecological components over a broad range of space and time scales, include: rapid ecological assessments of the corals, other invertebrates, fish, and algae using quantitative belt transects (at permanent and non-permanent sites), roving diving surveys, and stationary point counts; spatial towed diver surveys of benthic composition, and the abundance and distribution of ecologically and economically important fish and macro-invertebrate taxa; mapping of shallow and deepwater benthic habitats using single and multibeam acoustic systems, towed cameras, and satellite imagery; bioacoustic surveys of biomass in the water column; and multi-platform oceanographic monitoring using shipboard surveys, moored instrument arrays, drifters, and satellite remote sensing. Integration of repeated and concurrent observations of both the biotic and abiotic components of these ecosystems over a range of scales provides insights into the spatial and temporal scales of variability and the complex biophysical linkages controlling these reef ecosystem

Long-term Changes in Coral Community Structure and Correlations with *Acanthaster planci* Feeding Preferences on Guam

*Victor BONITO**, *Robert RICHMOND*

UOG Station, Mangilao Guam
staghorncoral@hotmail.com

Current and historical research efforts at Tanguisson Reef, Guam spanning over 30 years were combined to examine the influence of chronic *Acanthaster planci* predation on coral community structure. Previous studies at Tanguisson Reef found that the coral community recovered in terms of cover, abundance, and species composition in approximately 10 years after suffering catastrophic mortality from an outbreak of *A. planci* in the late 1960's. Since 1981, large aggregations (10's to 100's) of *A. planci* have been found at Tanguisson Reef and on other reefs along Guam's northwest coastline. We surveyed Tanguisson reef in 2001 and found considerable changes in community composition have occurred since it was last surveyed in 1981; these changes reflect current feeding preferences of *A. planci* in Guam, with preferred prey decreasing and non-preferred prey increasing in cover and abundance across most of the reef. We examined the feeding preferences of small aggregations (up to 50 starfish) of *A. planci* and the impact that larger aggregations (up to 500 starfish) had on coral communities. *Acanthaster planci* fed on *Acropora*, *Montipora*, and *Pocillopora* (preferred corals) when these corals were available. If preferred corals were not available, *A. planci* fed mainly on *Astreopora*, *Cyphastrea*, *Goniastrea*, *Pavona*, *Stylophora* (medium-preference corals). Only when preferred and medium-preference corals were relatively rare did *A. planci* feed on *Porites*, *Leptastrea*, *Favia*, and other non-preferred corals. Feeding by large aggregations of *A. planci* was found to significantly reduce the amount of preferred corals (and medium-preference corals when they were abundant) without significantly affecting the amount of non-preferred corals. We discuss the hypothesis that predation by *A. planci* has driven a phase shift from an *Acropora* and *Montipora* dominated community at Tanguisson Reef, to a community dominated by *Porites*, *Leptastrea*, and *Favia*.

Coral Reefs of the Southern Red Sea: The Effects of Extreme Seasonality on Reef Algal Community Structure and Functional Group Dynamics

*Mebrahtu ATEWEBERHAN**, *Henrich J BRUGGEMANN*, *Anneke M BREEMAN*

P.O. Box 1220, Asmara, Eritrea
m.ateweberhan@biol.rug.nl

Spatial and temporal variation in biomass of four functional groups of algae (canopy algae, foliose algae, turfs and crustose corallines) was investigated on the shallow reef flat and the fore reef at two locations in the southern Red Sea near Massawa, Eritrea. Shallow reef flats are exposed to extreme annual temperature fluctuations, with minima below 25 °C in winter and maxima above 36 °C in summer. The different functional groups vary in their distribution and seasonal abundance. Canopy and foliose algae are highly seasonal and are restricted mainly to the reef flat. Canopy algae build up a very high biomass (up to ca. 600 g ash free dry matter m⁻²) during the cold season. In the hot season, plants lose most of their vegetative parts and survive with low biomass. Foliose algae are abundant mainly in reef zones free of canopy algae or where the latter have lower density. Highest cover and biomass occurs during the cold season (up to ca. 20 g AFDM m⁻²). Most species are completely absent from all reef zones at all sites during the hot season. Turf algae and crustose corallines are less seasonal. Seasonality affects turfs directly or indirectly by influencing competition with canopy and foliose algae and by causing shifts in grazing pressure over the reef. At shallower depths, they have highest biomass in the hot season when foliose algae are completely absent and canopy algae have lowest cover. In deeper zones, they have highest biomass in the cold season. Crustose corallines have highest biomass during the cold season in all reef zones. Biomass is consistently highest on the outer reef flat in one site. Higher sedimentation levels and excessive hot season temperatures and irradiation levels negatively affect the survival and growth of adult thalli and the establishment of recruits.

A Diffuse Mutualism between Sympatric Echinoid Species: Effects on Patterns of Reef Recovery in the Caribbean

*Jamie BECHTEL**, Peter GAYLE, Les KAUFMAN

1919 m street, nw United States of America

jbechtel@conservation.org

Coral reefs along the north coast of Jamaica underwent transition in dominance from stony corals to fleshy algae following the 1980 strike by Hurricane Allen, and the 1983-84 basin-wide die-off of *Diadema antillarum*, an important herbivorous sea urchin. Now, in the same region we see signs of phase transition from an algal dominated system back to a coral dominated system. Our research suggests that this transition is contingent upon an intermediate phase characterized by bare carbonate substratum resulting from advance grazing by a second echinoid species, *Echinometra viridis*. Grazing by *E. viridis* provides bare substratum to which *D. antillarum* can recruit. Offered the choice, *D. antillarum* recruits spent twice as much time on bare as opposed to macroalgal covered substratum. These findings reveal subtle behavioral processes underlying patterns of recovery in *D. antillarum* populations, and shed light on the dynamics of reverse phase transition. The recovery of Caribbean reefs from widespread degradation may require, or at least be facilitated by, the restoration of a diverse herbivore community.

The Integrated Growth Response of Coral Reefs to Environmental Forcing: Morphometric Analysis of Reefs of the Maldives

*Abdulla NASEER**, Bruce G HATCHER

Marine Research Center, Ministry of Fisheries Agriculture & Marine Resources, H. White Waves, Male, MALDIVES

anaseer@mrc.gov.mv

Reefs of Maldives display asymmetric geomorphology in their arrangement on the atoll rims and within atoll lagoons, characteristics that reflect spatial variation in time-averaged, physical-biological control of reef growth. The hypothesis is that asymmetric ocean wave forcing interacts with antecedent reef platform structure to produce characteristic growth configurations and predictable reef morphologies. The hypothesis is tested by correlating impinging wave energy with a set of reef growth morphometrics. The methods involved the classification of eight Landsat-7 ETM+ satellite images of the Maldives, and the calculation of morphometric indices using GIS. The spatial pattern of coral reef growth, as defined by the distributions of distinct reef geomorphologies, was quantified by multiple morphometrics of well-defined geomorphic zones: reef slope, reef crest, coral rubble, sand flats, reef lagoons and reef islands. These features were delineated with an overall accuracy of 81%. Spatial gradients in environmental forcing (i.e., southern ocean swell and monsoon wind-wave fields) were characterized and quantified along the same dimensions as the reef geomorphology, and statistically related to the reef morphometrics. Non-parametric Multidimensional Scaling (MDS) and Analysis of Similarities (ANOSIM) procedures identified statistically significant differences among groups of reefs located on atoll rims that were exposed to nine differing hydrodynamic regimes. The widths of rim reef slopes, crests and flats widths were significantly correlated with incident wave power ($r > 0.42$, $p < 0.01$, $n = 9$), with the largest reef growth zones facing the major monsoon wind direction, and the smallest facing the relatively calm Maldives Inner Sea. The extensive, detailed and accurate data provided by this study for the first time on the exact numbers, sizes, shapes and areas of reef features of the entire Maldivian archipelago demonstrates the value of synoptic technologies to seascape ecology, supports the hypothesis that the spatial patterns of coral reef growth predominantly reflect recent hydrodynamic forcing.

Trapping of Fine Sediment in Mangrove-fringed Estuaries in Palau

*Steven VICTOR**, *Yimnang GOLBUU*, *Eric WOLANSKI*, *Robert H RICHMOND*

P.O.Box 7086 Koror, Palau 96940 Republic of Palau
svictor@picrc.org

Coral reefs are an integral part of the livelihood on many islanders. The reefs have for many generations provided for essential fish protein, place for reinforcing family ties and values, protection of coastline, and source of revenue generated through tourism activities. In recent years, Palau coastal coral reefs have been experiencing increase stress from soil erosion and associated runoff. Poor land management practices in watershed catchments have increased soil erosion resulting in high rates of sedimentation leading to die-off of corals and associated marine organisms. Changes in benthic habitat quality has lead to the collapse of artisanal fisheries in some areas, with resulting socio-economic problems. To resolve a potential conflict between farmers in the watershed catchment and fishermen depending on coastal coral reefs, integrated watershed management is needed. A comparative study was undertaken in 2002 on the fate of fine sediment in two mangrove-fringed estuaries in Babeldaob Island, Palau, Micronesia. The data from these two studies showed how land use change has lead to increased in sedimentation. The study also showed that mangroves are an important buffer trapping about 30% of the riverine sediment. Sedimentation has the potential to affect coral reef recovery by limiting reproductive success and recruitment of corals. Therefore, persistence of coastal coral reef resources is not possible without simultaneously reducing erosion in the watershed catchment.

Land Improvement Projects and Farmers Evaluation on Ishigaki Island, Okinawa

*Sachiho WARAI**, *Junji NAGATA*

Komaba 3-8-1, Meguro-ku, Tokyo, 153-8902, Japan
sachiho@humgeo.c.u-tokyo.ac.jp

The linkage between human activities and marine ecosystem is drawing more and more attention as red clay outflow is reported one of the main causes of coral reefs degradation in Okinawa. Particularly land improvement projects in agricultural sector are accused of one of their large destructive effects on the marine ecosystem. However, little is known about farmers evaluation to these projects. The main objective of this study is to elaborate understanding of the meaning of the projects and farmers evaluation in Ishigaki Island, Okinawa. To investigate dynamism how human perceptions evolve over time in a society where many players are acting on various strategies and the ecosystem is not perfectly understood, our analysis is based on a Complex Adaptive System framework, using key concepts such as agent, learning, interaction and evolution. Land improvement projects in Okinawa, including irrigation project and farmland consolidation, have been conducted intensively since reversion to Japanese Administration in 1972. Over the past 30 years the farmers have evolved their perception on the agriculture as follows: 1) Water is not prominently critical factor because they could cope with summer drought by selecting alternative varieties or adjusting cultivation schedule. 2) They found it hopeless both in ecological and economical sense to pursue large-scale mechanized sugarcane agriculture, based on which land improvement projects are planned and promoted. 3) For the hopeful products such as tropical fruits the farmers has found extremely important to utilize the scattered spots of good soil, rather than large-scale homogeneous farmlands which come from these projects. This indicates that farmers do not consider "improved" land indispensable to their agriculture while the Government remain emphasizing that irrigation and consolidated farmland are essential for agriculture in Okinawa. If we appreciate these evaluations, it is concluded that further promotion of these projects should be reconsidered.

Exposure of Great Barrier Reef Reefs to Land-sourced Contaminants: Changes due to Catchment Agricultural Development

*Jon E. BRODIE**, *Michelle DEVLIN*

Townsville, Queensland, 4811 Australia
jon.brodie@jcu.edu.au

Reefs of the Great Barrier Reef (GBR) have always been exposed to material discharged from the land but composition and loads have changed dramatically over the last 150 years. Changed conditions are a result of agricultural development on the catchment of the GBR, primarily beef grazing and sugarcane cropping. Loads of suspended sediments, nitrogen and phosphorus compounds have increased manyfold and some herbicides have now substantial loads. Material in river discharge is not distributed evenly throughout the GBR. Exposure of the reefs to land-sourced contaminants is dependent on proximity to rivers with large loads and reef position on the GBR shelf. Contaminants in particulate form such as suspended sediments, particulate nitrogen (PN) and particulate phosphorus (PP) are mostly deposited near the river mouth. In contrast dissolved materials are transported in the water column for hundreds of kilometres from big rivers such as the Burdekin. Increased river loads of, for example, PN may have little effect on reef exposure to increased nitrogen loading whereas increased nitrate loads may have large effects. However the form of nitrogen and phosphorus that reefs are actually exposed to may consist of substantial amounts of PN and PP as dissolved nutrient forms are converted to particulate forms by biological uptake. The initial delivery of land-sourced contaminants is during river flood events and via flood plumes. However the long-term nutrient status of inner-shelf reefs of the GBR may also be governed by the form of nutrients exported from rivers as the delivered nutrients are trapped and recycled on the shelf. Current knowledge of sediment, nutrient and pesticide loads from rivers to the GBR and the patterns of dispersal of these materials in the GBR lagoon allows us to estimate the exposure of reefs to land-sourced contaminants and how these have changed in the last 150 years.

Integrated Coastal and Ocean Management in South Florida

*Brian D. KELLER**, *Billy D. CAUSEY*

P.O. Box 500368, Marathon, Florida 33050 United States of America
brian.keller@noaa.gov

The South Florida ecosystem covers 46,600 km² and includes diverse landscapes including remaining habitats of the Everglades, agriculture, urban sprawl, and coastal waters. The ecosystem includes the Florida Reef Tract, the only system of bank-barrier coral reefs along the continental U.S. An increasing human population, combined with increasing development, agriculture, boating, and other human activities, imperils the entire South Florida ecosystem from the headwaters of the Everglades through the Florida Keys. Protection and conservation of marine ecosystems has increased over the years through the designation of National Parks, National Marine Sanctuaries, and other protected areas in the region. Designation of the Florida Keys National Marine Sanctuary (FKNMS), a 9,844-km² marine protected area that includes a network of 24 fully protected marine zones, occurred in 1990. In 1993, federal resource managers in South Florida formed the South Florida Ecosystem Restoration (SFER) Initiative, with the primary objective of "getting the water right" primarily through the Comprehensive Everglades Restoration Plan. The SFER Initiative explicitly includes South Florida coastal waters and the coral reef ecosystem of the Florida Keys (essentially the FKNMS) in the South Florida ecosystem, with attention to how restoration activities on the mainland may impact the FKNMS. In turn, FKNMS staff actively participate in the SFER Working Group to help ensure due consideration of potential negative impacts of Everglades restoration on Sanctuary resources. Implementation of the Comprehensive Everglades Restoration Plan will test the effectiveness of this bilateral approach.

Organic Matter and Nutrients in Mangrove-Intertidal Ecosystems Exposed to a Catchment Area Affected by Red Soils

*Prosper L MFILINGE**, Makoto TSUCHIYA

Senbaru 1, Nishihara, Okinawa 903-0213 Japan

mfilinge@hotmail.com

We investigated organic matter and nutrients in mangrove-intertidal ecosystem and an intertidal flat that supported no mangroves. Both of these ecosystems are exposed to a catchment area affected by red soil pollution. A similar investigation was also carried out in an intertidal flat which is unexposed to red soil pollution. All investigations were done during the rain season. Analysis of fatty acid markers of vascular plants indicated strong input of organic matter into the mangroves and the intertidal zone adjacent to the mangrove forest. A very little input of organic matter was noted in an intertidal flat directly exposed to the terrestrial coastal zone bearing the red soils. The intertidal flat sediments exposed directly to the terrestrial region bearing the red soils, was also characterized by poor organic matter and nutrients (nitrogen and phosphorus), compared to other study sites. Our results suggest that mangroves could be used to mitigate the effect of red soils on adjacent coral communities located near coastal zone areas affected by red soil.

Typological Modelling of Sediment and Nutrient Inputs to the Great Barrier Reef

*Miles J FURNAS**, Alan MITCHELL, Michele SKUZA, Margaret WRIGHT

PMB No. 3, Townsville, Queensland 4810 Australia

mfurnas@aims.gov.au

The Great Barrier Reef (GBR) receives freshwater runoff, terrestrial sediment and nutrients from a 422,000 km² catchment. This catchment contains a diverse range of landforms and vegetation communities in 35 defined drainage basins. Rainfall and associated runoff are seasonal, with most occurring during short-lived summer floods. Because of the size of the GBR catchment, it is difficult to closely monitor sediment and nutrient levels in all significant river systems. We took a typological approach to sampling materials in runoff and modelling inputs to the GBR. The drainage basins of the GBR catchment were classified as wet (ca. over 1,500 mm rainfall p.a.) or dry (ca. less than 1,500 mm rainfall p.a.). Intensive wet season sampling of representative rivers established discharge-export relationships for wet and dry catchments. These relationships can be used to estimate exports from similar, unsampled catchments. The largest loads of sediment and nutrients are carried by dry catchment rivers draining regions primarily used for cattle grazing. Smaller wet catchment rivers are characterised by lower loads, but greater losses per unit catchment area and a greater proportion of soluble nutrients. Current terrestrial sediment and nutrient (N, P) inputs to the GBR are estimated to average 10-15 x 10⁶, 43 x 10³ and 7 x 10³ tonnes per year. Annual freshwater runoff to the GBR fluctuates within a 10-fold range. Terrestrial sediment and nutrient inputs likely do the same. Estimates of sediment and nutrient inputs prior to European settlement suggest a 2- to 4-fold increase has occurred as a result of modern land-use practices. A significant initiative, the Reef Water Quality Protection Plan has recently been launched to promote adoption of runoff reducing land-use practices within the GBR catchment.

Temporal and Spatial Recruitment Patterns in Chaetodontids and Pomacanthids in the Southern Red Sea

*Zekeria A ZEKERIA**, *John J VIDELEL*

P.O.Box 1220 Eritrea
z_a_zekeria@yahoo.com

Temporal and spatial recruitment patterns were investigated by monitoring settlement of chaetodontids (*Chaetodon larvatus* and *C. semilarvatus*) and pomacanthids (*Pomacanthus* spp.) on two reefs in the southern Red Sea. Recruitment data were collected by visual census from the reefs at monthly intervals. Seasonal patterns were studied by collecting recruitment data from Resi Medri and Twalot reefs for one year while long-term temporal patterns were investigated by monitoring settlement on Resimedri reef for four years. In all surveyed reefs recruitment occurred mainly in June and July. Significant inter-annual variation in recruitment was recorded. Recruitment was reduced from 1270 to 172 recruits 1000m² from 1998 to 2001. During the same time interval live coral was decreased from 63% to 34%. The three species differed in their recruitment patterns. The two Chaetodontid species were recorded mainly from sites rich in live coral where branching *Montipora* dominate the substrate. *Pomacanthus* spp. were abundant on sites where live coral cover was low. The observed among species variation in the recruitment patterns reflects the feeding habit of the species. Newly recruited Chaetodontids feed on coral polyps whereas Pomacanthids feed on sponges and other non-coraline invertebrates.

Variability in Coral Reef Community Structure and its Implications for the Regulation of Reef Fish Populations

*Jeffrey S SHIMA**

P.O. Box 600, Wellington New Zealand
Jeff.Shima@vuw.ac.nz

Density dependence in one- or more demographic rates can regulate local reef fish populations, and may influence their resilience to habitat degradation and/or harvest. Ecological processes that underlie density dependence are varied (e.g., predation, interference competition, exploitative competition), operate over a range of spatial scales, and potentially interact. Consequently, the precise mechanisms underlying density dependence for most reef fish populations remain poorly understood, yet sufficient understanding of these mechanisms is critical for predicting the responses of fish populations to changing coral reef communities. Here, I explore patterns of variation in the strength of density dependence experienced by cohorts of newly settled six bar wrasse (*Thalassoma hardwicke*) from patch reefs of differing community composition. I examine patterns and scales of covariation among density dependence, settlement intensity, at patch reef community attributes to elucidate potential consequences of changing coral reef community structure for the regulation of local reef fish populations.

Consequences of Fluctuating Habitat on Dynamics of a Habitat-specialized Fish

*Russell J SCHMITT**, *Sally J HOLBROOK*

EEMB, UC Santa Barbara, Santa Barbara, California 93106-9610, USA
schmitt@lifesci.ucsb.edu

For fishes that are obligate microhabitat specialists, extirpation of their microhabitat results in local extinction. Beyond this boundary condition, the influence of fluctuations in microhabitat on dynamics of the fish is less clear because local populations are open and density can affect mortality rates. The fraction of a cohort that survives is related to the total effect of density (ρ) on mortality, where ρ is the per capita effect on the probability of dying and N is the size of the interacting population. When the microhabitat has dynamics, the strength of density dependence can fluctuate because of variation in (1) settlement per unit microhabitat and/or (2) the amount of microhabitat. Local dynamics will be influenced by the nature of co-variation between these determinants of N . We explored these issues using data from 26 surveys during 8.5 years at Moorea, French Polynesia, on three-spot dascyllus (*Dascyllus trimaculatus*), which shelter in sea anemones (*Heteractis magnifica*) as juveniles (when density dependence is strongest). Abundance of anemones fluctuated by a factor of 3 during the period. Using estimated parameter values, we modeled the expected fluctuation in juvenile density if (1) the number of colonists remained constant (at the mean) but anemone cover fluctuated (as observed) and (2) colonists varied but anemone cover remained constant. Although fluctuating input produced slightly greater variation in juvenile density than did fluctuating microhabitat, both effects were much smaller than the observed variation in juvenile density, indicating that anemone cover and fish settlement fluctuated somewhat asynchronously. The data for juveniles suggest that density dependence operates on this life history stage in a manner that acts to dampen fluctuations in adult populations. Indeed, the proportional fluctuation in adult numbers was exceedingly small and far lower than for either the cover of anemones or supply of colonists.

Changes in Fish Assemblage Structure after Multiple Coral Bleaching Events

*David J BOOTH**, *Giglia A BERETTA*

Westbourne Street, Gore Hill, NSW 2065 Australia
David.Booth@uts.edu.au

The recruitment of damselfishes (Pomacentridae) to sites within One Tree Island lagoon has been monitored from 1993 to 2004. High-temperature events in 1998 and 2002 along the Great Barrier Reef resulted in bleaching within OTI lagoon, reducing live coral cover significantly at some sites. Species that normally associate with live corals showed relatively lower recruitment at bleached sites, and as a result, species diversity and assemblage structure of recruits changed. In addition, adult densities changed through time, and appeared to respond to the changes in live coral cover brought about by the bleaching events. This study demonstrates that indirect effects of bleaching can include changes in assemblage structure of reef fishes.

Relationships between Live Coral Cover and Reef Fishes: Implications for Predicting Effects of Environmental Disturbances

*Sally J HOLBROOK**, Andrew J BROOKS, Russell J SCHMITT

Dept. of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, CA 93106-9610 USA
holbrook@lifesci.ucsb.edu

Predicting the effects of changes in cover of live coral on assemblages of reef fishes will require that relationships between functional or taxonomic groups of fishes and their habitats be considered in the context of spatial scale and intensity of environmental disturbances. Moderate declines in cover of coral or other key reef habitats may not result in detectable declines in local abundance or species richness of fish. Rather, fish assemblages might be relatively resistant to habitat deterioration, with major changes in population sizes or species richness occurring only at a relatively high threshold of disturbance. We explored this issue for an assemblage of reef fishes in lagoons at Moorea, French Polynesia. We conducted surveys in 500 m² plots that represented a range in cover of live coral (1-50%), and examined relationships between coral cover and species richness, taxonomic composition and population abundances. Overall species richness and total abundance of fish were related to coral cover by positive, saturating functions that rapidly decelerated with initial increases in cover of live coral from low values. However, the relationship between species richness and coral cover was not similar when the eight most speciose families of fish were examined individually; some showed positive decelerating relationships, others second order (hump-shaped) relationships, and still others exceedingly variable or no relationship with increasing coral cover. Manipulation of live coral cover across the same range (1-50%) in 1 m² experimental plots revealed qualitatively similar patterns as observed at the larger scale, although the asymptotic species richness was lower at the smaller spatial scale. These nonlinear relationships suggest that changes in assemblages of reef fish to a decline in coral cover could be subtle and hard to detect when coral is abundant, but the same proportional decline in cover could produce sizeable changes when coral is rare.

Specialisation and Extinction of Coral Reef Fishes

*Philip L MUNDAY**

Townsville Australia
philip.munday@jcu.edu.au

Predicting the risk of species extinctions due to habitat degradation is one of the most challenging tasks facing ecologists. Habitat specialists are thought to be more prone to extinction than generalists; however they may be more susceptible because 1) they are specialists *per se*, 2) because they are less abundant, or 3) both. To test the relationship between specialisation and extinction risk in reef fishes I surveyed the abundance of *Acropora* corals and associated coral-dwelling fishes (genus *Gobiodon*) in Kimbe Bay, Papua New Guinea, in 1996 and again in 2003. The period between surveys was characterised by an increased frequency of coral bleaching and elevated sedimentation that caused a dramatic decline in coral cover in Kimbe Bay. Nearshore reefs were most affected with the decline in coral abundance exceeding 80% on the reef flat and slope. Changes in the total abundance of coral-dwelling fishes closely matched changes in the total abundance of corals; however, specialist species lost proportionally more of their populations than generalist species. Thus, specialists tracked towards low population densities more rapidly than generalists. In addition, specialist species had smaller initial population sizes than generalists. These results demonstrate that habitat specialist fishes face a dual threat to extinction from human-induced changes to coral communities because their already small populations suffer the most from habitat loss. Corresponding with this elevated extinction risk I describe the local extinction of one specialist species and the near global extinction of another.

Effects of *Agaricia* Coral Death on the Demography of *Stegastes* Damsel fish in the Bahamas

*Mark A HIXON**

3029 Cordley Hall, Corvallis, OR 97331-2914 USA
hixonm@science.oregonstate.edu

Prior to 1998 near Lee Stocking Island, Bahamas, the largely planktivorous bicolor damselfish (*Stegastes partitus*) was especially abundant on living lettuce coral (*Agaricia tenuifolia*), which it used for shelter. During the 1998 mass bleaching event, following a year of detailed demographic monitoring of the damselfish, nearly all the lettuce coral in this region died. Within a year, the dead lettuce coral was overgrown by macroalgae and more aggressive damselfish species displaced bicolor damselfish from this habitat. Subsequently, storms removed much of the dead coral, thereby reducing habitat for all damselfish species. Associated with declining habitat was a steady decline in the regional population of bicolor damselfish due to both increased mortality and decreased larval settlement. These patterns suggest that mass mortality of corals can negatively affect the demography and community structure of damselfishes.

The Ecological Basis for Varied Reef Fish Responses to Extensive Coral Depletion

*Morgan S PRATCHETT**

Townsville Campus, Townsville QLD 4811 Australia
morgan.pratchett@jcu.edu.au

Coral communities are experiencing world-wide degradation due to widespread coral bleaching, outbreaks of crown-of-thorns starfish, and other large-scale disturbances. These disturbances often have major consequences for coral reef fishes, many of which depend on live coral for food and/or shelter. This study compares species-specific responses of coral reef fishes to different types and different intensities of coral disturbances. Individual responses of coral reef fishes varied greatly among taxa, among reefs, and with the type of the disturbance. Butterflyfish (family Chaetodontidae) were consistently among the most severely affected fishes on reefs subject to extensive coral depletion, probably due to their reliance on corals for food. However, even among the coral-feeding butterflyfish, effects of different disturbances were highly varied, and often very complex. *Chaetodon lunulatus*, for example, underwent significant population declines in Moorea, French Polynesia, where an outbreak of crown-of-thorns starfish and a typhoon combined to cause significant declines in the abundance of all major coral taxa. In contrast, *C. lunulatus* showed no decline in abundance following outbreaks of crown-of-thorns starfish or coral bleaching on the Great Barrier Reef, Australia. *Chaetodon lunulatus* is a generalist corallivore, able to exploit a wide range of different corals, and is unlikely therefore, to be significantly effected by disturbances, such as coral bleaching, that tend to have selective effects only a limited suite of different coral species. This study demonstrates that the individual responses of coral reef fishes to coral depletion vary with diet and habitat requirements, and are also heavily dependent on differences in their ecological versatility. Importantly, different disturbances (e.g. coral bleaching versus outbreaks of crown-of-thorns starfish) do not appear to be directly comparable due to differences in the selectivity of their effects on coral communities.

A Comparison of Fish Utilization of Simulated Coral Reef Frameworks versus Eroded Rubble Substrates off Panama, Eastern Pacific

*Peter W GLYNN**

4600 Rickenbacker Causeway, Miami, Florida 33149 United States of America
pglynn@rsmas.miami.edu

Unusually high coral mortality over the past two decades, resulting in the erosion of reef frameworks and loss of topographic complexity, may have significant effects on associated fish communities. During 2002 and 2003 at the El Nino-impacted Uva Island reef in the Gulf of Chiriqui (Panama), the effects of the transformation of topographically complex reef structures (coral frameworks) to rubble plain bottoms was assessed on associated reef assemblages. Relative abundances, densities and species richness values of reef fishes on two-dimensional dead coral rubble (DCR) substrates versus three-dimensional dead simulated reef frameworks (SRF) were compared. Ten pairs of DCR and SRF treatments, each 1 m² in area, were established at 3-5 m depth reef front sites. Sampling was performed at 6 mo intervals, and involved 3 min visual surveys of all non-cryptic fishes on each substrate type, and counts of all cryptic fishes present in collected DCR and SRF rubble. Four, 3 min visual surveys of non-cryptic fishes conducted over an 18 month period revealed densities of 12.7 ind m² on DCR bottoms and 24.5 ind m² on SRF bottoms. Species richness ranged from 4-11 on DCR and from 10-13 on SRF substrates. The DCR and SRF substrates shared several of the numerically dominant species, including labrids, serranids and tetraodontids, which together comprised 72.6% and 77.8% of all individuals tallied in DCR and SRF habitats, respectively. Three surveys conducted over a 12 month period revealed mean cryptic fish densities on DCR substrates that ranged from 0-4.4 ind m², and on SRF substrates from 41.2 to 111.2 ind m². Species richness ranged from 0-6 species and 9-14 species in DCR and SRF habitats, respectively. Results suggest that reef fish abundances and diversity would be greatly diminished following the loss of coral framework structures.

The Relationship between Changes in Habitat Characteristics and Variation in the Attributes of Reef Fish Communities

Andrew J BROOKS, Russell J SCHMITT, Sally J HOLBROOK*

Marine Science Institute, University of California, Santa Barbara, CA 93106 U.S.A.

brooks@lifesci.ucsb.edu

Communities of coral reef fishes often exhibit large fluctuations in both overall composition and the relative abundances of their component species over time. Traditionally, these temporal changes have been attributed to natural variation in the supply of new recruits to coral reef habitats or to changes in the nature or strength of biotic interactions such as interspecific competition or predation. Less studied are changes in community composition that result directly from changes that may occur over time in the amount or characteristics of the physical habitat types that influence member species. To examine the effects of changing habitat structure, complexity, and availability on the abundance and composition of the associated fish community, we surveyed 61 patch reefs composed of the mound forming coral *Porites rus* in lagoons of Moorea, French Polynesia. To explore variation in species composition and relative abundance over several temporal scales, counts were done daily, seasonally, and annually over four years. Reefs varied in initial size from 0.03 m² to 9.4 m² and in overall species richness of associated fishes from one to more than 30 species. Temporal patterns of species richness and mean abundance were not consistent, even among closely spaced reefs. The results indicate that while some large-scale temporal variation in the assemblages can be attributed to seasonal influences on the overall abundances of fishes within the lagoons of Moorea, much of the remaining variation could be attributed to small-scale effects resulting from structural changes in the attributes of the individual patch reefs arising from growth or death. This suggests that identifying the causes of temporal variation in the species composition and the relative abundances of the species comprising coral reef fish communities must include an explicit focus on changes in the quantity and quality of their associated habitats.

Temporal Variability in the Functional Structure of Three Reef Fish Assemblages from Moorea, French Polynesia

Rene GALZIN, Ambroise BRENIER, Jocelyne FERRARIS*

Universite de Perpignan, 66860 Perpignan Cedex France, Metropolitan
galzin@univ-perp.fr

A monitoring program was established in 1987 to assess the interannual variability of three reef fish assemblages and their associated habitat (outer slope, barrier reef and fringing reef) on the Tiahura transect (Moorea, French Polynesia). Here we focus on temporal changes in the structure and organisation of the three fish assemblages. Variables examined include: the number of fish (total density) and the number of species (total species richness) counted on each sampling date, the species composition and the functional structure of the fish assemblage. Structure of the assemblage is based on the number of fishes or species using the following variables: degree of mobility, social structure, trophic function, habitat, adult size, reproductive mode and activity rhythm. In general, species richness and total density increased through time. Comparative analyses of species composition of the three fish assemblages revealed that habitat had the strongest influence, followed by interannual and seasonal variabilities. Comparison of temporal variation in the functional structure of the three fish assemblages, using multiple factorial analysis, indicated that the functional structure was relatively stable on the outerslope and the fringing reef compared to the barrier reef fish assemblage. Changes in substrate cover and in the functional structure of the fish assemblages, which appeared on the barrier reef in 1992, may have been caused by cyclone Wasa in 1991. In addition, the functional structure of all three fish assemblages changed during the time periods 1987-1993 and 1994-2002, possibly as a result of fishery impacts.

Longer-term Effects of Severe Coral Bleaching on Reef Fish Assemblages of the Northwest Shelf, Australia

*Andrew R HALFORD**

PO Box 34, Al-Khod, Oman Australia

a.halford@aims.gov.au

Large-scale disturbances of coral reef communities are commonplace, yet studies on their effects are usually confined to significantly smaller scales of space and time. Moreover current models of tropical marine community dynamics focus on meta-population characteristics of marine communities and predict resilience to disturbance at larger scales. Future studies investigating large-scale disturbances therefore need to scale up to allow more rigorous testing of current population models. In this study fixed sites incorporating belt transects were established around the perimeter of a large, remote reef system off the NW coast of Australia. The fish and benthic assemblages contained therein were censused annually from 1994 to 2003. In 1998 this reef system was significantly impacted by El-Nino mediated, anomalous SSTs. Bleaching of corals was severe, with significant mortality of hard corals noticeable even below 30 m. Mean hard coral cover across all survey locations (7 locations, 3 sites, 5 transects) declined from 49% to 11% as a result of the bleaching and 5 years after the event has increased only slightly to 13%. The reef matrix has also collapsed in many areas as dead coral skeletons have been bio-eroded. The fish assemblages on the study sites have also undergone significant changes as a result of the bleaching with a decline in obligate corallivores the most obvious. The patterns of change in the fish assemblages will be discussed in the context of community resilience to large-scale disturbance on isolated reef systems.

Natural Variability in Reef Communities of the Australian Great Barrier Reef

*Hugh SWEATMAN**, *Angus THOMPSON*, *Steve DELEAN*, *Kate OSBORNE*

PMB 3, Townsville MC, Queensland 4810 Australia

h.sweatman@aims.gov.au

The AIMS Long-term Monitoring Program has surveyed assemblages of benthic organisms and reef fishes at sites on the fronts of 47 reefs on the GBR, spanning 10° of latitude, for 11 years. Four groups of reefs can be distinguished, based on the benthic communities. These have different susceptibilities to disturbance and different recovery rates, with the most dramatic changes in coral cover occurring on areas dominated by tabulate *Acropora* spp. We examine the extent of variability in the reef communities under the observed range of disturbances the relationship between benthic assemblages and fish assemblages and compare these measures of variability to values from other systems.

Changes in Reef Fish Assemblages in the Saudi Arabian Sector of the Gulf, Following the 1991 Gulf War Oil Spill and the 1998 Coral Bleaching Event

*Friedhelm KRUPP**, *Mubarak A ALMARRI*

Senckenberganlage 25, 60325 Frankfurt Federal Republic of Germany

F.Krupp@senckenberg.de

The Arabian Gulf is characterised by naturally stressful environmental conditions for tropical marine biota and many of the ca 540 fish species inhabiting this a shallow, epicontinental sea live close to their physical limits. They are particularly sensitive to human-induced and natural stressors. Since 1992, reef fish populations at nearshore and offshore reefs of the Jubail Marine Wildlife Sanctuary in the north-western part of the Gulf have been monitored by visual censuses along permanent transect lines. The sanctuary area had been severely affected by the 1991 Gulf War oil spill and in the two following years average fish species richness and population densities per transect were reduced, which is attributed to a decline in planktonic eggs and larvae caused by the oil slick and resulting in lower levels of recruitment onto the reef. Despite the oil, corals remained healthy and reef fish assemblages recovered by 1995. The 1996 and 1998 coral bleaching events resulted in the die-off of all nearshore and many offshore coral reefs, with hardly any signs of recovery by 2003. However, some offshore reef areas remained unaffected. Fish populations on healthy reefs were stable, while a shift in species composition and population sizes of several species was observed on dead reefs, with strictly coral associated species disappearing, while grazers (Acanthuridae, Siganidae) increased in relative abundance. At least one formerly common reef fish species, *Chaetodon melapterus* (Chaetodontidae), has disappeared completely from dead reefs.

Population Dynamics of Marine Mutualists: Populations of Goby and Shrimp Are Affected by Intraspecific Competition, Predation, and Recruitment

*Andrew R THOMPSON**

University of California, Santa Barbara, CA 97106 United States of America

andrew2112@yahoo.com

Although early theoretical models predicted that mutualistic populations were inherently unstable (i.e. subject to unbounded population growth or extinction), recent models demonstrate that intraspecific competition for habitat that is provided by a mutualist can check population expansion and that immigration suppresses extinction. To assess empirically these predictions, I perturbed negatively and positively the abundance of gobies (*Ctenogobius feroculus*) associated mutualistically with shrimp (*Alpheus djeddensis*) in Moorea, French Polynesia. Mutualistic gobies and shrimp are common on Indo-Pacific coral reefs and interact as follows: shrimp construct burrows in which both gobies and shrimp reside, and gobies warn shrimp of predators through touch-based signals. First, experimental addition of gobies to the field resulted in no overall change in the density of gobies because gobies competed intraspecifically for shrimp burrows and burrows were a limiting resource. Second, I experimentally increased predator densities (a potentially negative perturbation) and monitored gobies and shrimp before and after this manipulation. Although death rates of gobies increased significantly following augmentation of predators, the total density of gobies remained constant because recently killed gobies were replaced rapidly by recruits. The finding that populations were resilient to both negative and positive perturbation indicates that the goby-shrimp mutualism is stable and that intraspecific competition, predation, and recruitment are mechanisms that maintain this stability.

Spatial Variation in Density-dependence: Distinguishing Larval vs. Habitat Effects and Inferring Responses to Changes in Habitat

*Craig W OSENBURG**, *Jeffrey S SHIMA*, *Colette M ST. MARY*, *Lock ROGERS*

223 Bartram Hall, PO Box 118525, Gainesville, FL, USA 32611-8525 United States of America

osenberg@zoology.ufl.edu

Recent studies of reef fishes have demonstrated that the strength of post-settlement density-dependent and density-independent processes vary spatially. Because the strength of these processes and settlement rates can covary, resulting patterns may lead to biased estimates of the strength of density-independent and dependent processes and the relative importance of supply limitation. Two sources of spatial variation in post-settlement processes have been suggested: traits of settling fish vs. the habitats into which they settle. Here, we 1) review evidence for the importance of spatial variation in larval vs. habitat traits; 2) present data on spatial variation in larval growth rates and post-settlement body composition (lipid, protein, and carbohydrate); 3) use field data to parameterize models of recruitment dynamics to discern the likely response of fish to changes in habitat quality driven by shifts in coral composition. We conclude that spatial variation in post-settlement processes is likely to be high, but remains largely unexplored. Variation in both density-independent and density-dependent processes is likely to lead to cryptic density-dependence, suggesting that density dependence is much stronger (and possibly more heterogeneous) than indicated in the literature. Although there are few data to suggest that settler traits play an important role, this has not been well investigated; our preliminary data demonstrate no effects. Finally, our modeling efforts highlight the need to develop mechanistic understanding of the habitat features that drive variation in post-settlement survival, so that responses to shifts in habitat composition can be more accurately predicted.

Differential Effects of Habitat Complexity, Predators and Competitors on Abundance of Juvenile and Adult Coral Reef Fishes

Glenn R ALMANY*

School of Marine Biology and Aquaculture, James Cook University, Townsville 4811 QLD, Australia

Glenn.Almany@jcu.edu.au

Greater habitat complexity is often associated with greater abundance and diversity, perhaps because complex habitats reduce predation and competition. Using 16 spatially-isolated live-coral reefs in the Bahamas, I examined how abundance of juvenile (recruit) and adult (non-recruit) fishes was affected by habitat complexity, predators and interference competitors. Manipulating the abundance of low and high complexity corals created two levels of habitat complexity, which was then cross-factored with the presence or absence of resident predators (sea basses and moray eels) and interference competitors (territorial damselfishes). Over 60 days, predators and competitors greatly reduced recruit abundance regardless of habitat complexity, but did not affect adult abundance. In contrast, increased complexity had a strong positive effect on adult abundance and a weak positive effect on recruit abundance. Differential responses of recruits and adults to habitat complexity and prior residents may be related to the effects of complexity on the primary predators of each group. Sedentary recruits are likely most preyed upon by small resident piscivores that ambush prey, while larger adult fishes that forage widely and use reefs for shelter are likely most preyed upon by large transient predators that chase prey. Increased complexity may have inhibited foraging by transient predators but not resident predators. Results demonstrate the importance of habitat complexity to reef fish communities, which is of concern given the accelerated loss of structurally complex corals worldwide.

Coral Decline Threatens Fish Biodiversity in Marine Reserves

Maya SRINIVASAN*, Geoffrey P JONES, Mark I MCCORMICK

School of Marine Biology & Aquaculture, James Cook University, Townsville, Qld 4811, Australia

maya.srinivasan@jcu.edu.au

The worldwide decline in coral-cover on tropical reefs has serious implications for coral biodiversity. But if coral reefs die, what is the prognosis for coral reef fishes? Fish populations may be resilient, as their dynamics are considered to relate more to larval supply than resource availability. Also, establishing marine reserves is thought to sustain fish biodiversity, despite changing environments. Our study of a marine reserve network in Papua New Guinea showed otherwise. A devastating decline in coral cover over 7 years resulted in a dramatic decline in fish biodiversity, both in reserve reefs and on open reefs. Most reef fish species declined in abundance, half by over 50%, and some rare species became locally extinct. Only two species of surgeonfish, which are targeted in the local subsistence fishery, were afforded protection by the marine reserves. The abundance of newly settled fishes was monitored and settlement substrata were recorded during 2 of the 7 years. The decline in adult abundance was proportional to the degree to which reef fish rely on live coral when they first settle onto a reef. Species that mainly settle into live coral declined and those recruiting mostly to non-coral substrata increased in abundance. There were no differences in the number of settlers between reserve reefs and open reefs in either of the 2 years. Among the coral specialists, several species showed a decline in settlement magnitude over the 2 years, but for many of them, settlement was greater during the second year despite reduced coral cover. This indicates that for many species, post-settlement mortality due to overcrowding may lead to the decline in adult abundance. We suggest that fish biodiversity is threatened wherever permanent reef degradation occurs and warn that marine reserves will not always be sufficient to ensure their survival.

Trajectories of Recovery in Coral Reef Fish Assemblages

Fiorenza MICHELI*, Benjamin S HALPERN, Louis W BOTSFORD, Robert R WARNER

100 Oceanview Blvd, Pacific Grove, California United States of America

micheli@stanford.edu

We used meta-analyses of published data from marine reserves to address the questions of how and over what time frames coral reef fish assemblages recover from fishing and other human uses. Synthesis of studies of marine reserves spanning 1-25 years of protection showed that: (1) only species that are targeted by fishing or by aquarium trade showed overall enhanced abundances in protected areas; (2) positive effects of protection on abundances of top predators increase through time; (3) up to a third of species in different studies (19% on average) are negatively affected by protection, indicating that indirect effects of protection through competitive or predatory interactions may be common; and (4) variation and lags in species responses to protection resulted in protected assemblages diverging from reference conditions, with greater proportions of total fish biomass at top trophic levels in protected compared to fished assemblages. These results indicate that marine reserves are effective in enhancing local abundances of exploited species and restoring the structure of whole communities, though these changes occur through a series of transient states and, for some communities, over long time frames (decades). In contrast with the more predictable increases of aggregate community variables such as total abundance and biomass, individual species and community structure exhibited broad variation in their responses to protection. Marine protected areas represent multiple human-exclusion experiments, replicated in a variety of configurations and geographic locations, providing key insights on community-wide trajectories of recovery from human extraction.

Changes in Fish and Benthic Communities over Twelve Years in the British Virgin Islands

Graham FORRESTER*, Elizabeth KINTZING, Lianna JARECKI, Rachel FINLEY

Coastal Institute at Kingston United States of America

gforrester@uri.edu

We tested for relationships between the composition of the fish and benthic communities at 8 fringing reef sites (all 9-10 m deep) around Guana Island, British Virgin Islands. Divers surveyed the sites annually from 1992-2003. At each site, fish were counted along 3 transects (30 x 1.5 m) and the % cover of benthic taxa estimated on the same transects by point intercept (120 points per transect). Pooling data across sites, live coral cover increased over the first 3 years of the study and then leveled off for the remaining 9 years, whereas macroalgal cover increased steadily throughout. The density of most functional groupings of fish showed no obvious temporal trends, except non-territorial herbivores whose density increased over time. Much more striking than these temporal trends in community composition were the consistent spatial relationships between fish and benthic community composition. Within each year, differences among sites in live coral cover were positively correlated with the density of most fish functional groups (territorial herbivores, diurnal planktivores, small piscivores, benthic microcarnivores). The density of these fish groups and live coral cover were all negatively correlated with macroalgal cover. Differences among sites in the density of non-territorial herbivores were weakly, but positively, correlated with live coral cover and showed a weak negative association with macroalgal cover. Any interpretation of the increased abundance over time of roving herbivores as being causally linked to increased macroalgal cover requires an explanation of the fact that these groups covary negatively in space. In general, increased macroalgal cover over time at these sites was not associated with changes in live coral cover and, perhaps as a result, fish community composition changed little.

Interactions between Herbivorous Fishes and Shifting Coral Reef Ecosystems

*Michelle J PADDACK**, *Su SPONAUGLE*, *Robert K COWEN*

RSMAS MBF 4600 Rickenbacker Causeway, Miami, Florida 33149 United States of America

mpaddack@rsmas.miami.edu

Grazing by macro-herbivores (fishes and urchins) can exert a notable “top-down” force on coral reefs, greatly moderating algal biomass and community structure. However, the majority of evidence for this was gathered close to thirty years ago, and in the decades since many reefs within the Caribbean region have experienced dramatic declines in coral cover and have shifted to an algal-dominated state. Additionally, the community structure of grazers in this region has been substantially altered by disease and overfishing, resulting in a guild of grazers now dominated by herbivorous fishes and rare in urchins. Remaining herbivores are thus confronted with a considerably altered grazing landscape and the extent to which they are capable of continuing to exert a strong top-down impact may be affected by these changes. Recent findings suggest that fish grazing rates may decline in areas of high percent cover and/or biomass of macroalgae. In order to examine this, we collected data on size and species-specific densities, diets, and bite rates of parrotfishes, surgeonfishes, and damselfishes on several reefs in Florida and the Caribbean. We used this information to calculate algal consumption rates of these herbivores (total algae removed per unit area per day). Our preliminary data show significant spatial variation in grazing rates on both local and regional scales, with decreased bite rates in areas of high macroalgal cover and low coral cover. In this talk, we will explore the factors that moderate grazing rates of parrotfishes and surgeonfishes and describe how these moderations may affect both the metabolic needs of the fish as well as the community structure of the benthos.

Role of Invertebrates in Surrounding Sandy Habitats as Forage for Reef Fishes

Ralph C DEFELICE, *James D PARRISH**

661 S. Lake Ave., Pasadena, California United States of America

defelice@bishopmuseum.org

The invertebrate fauna of open, sandy substrate adjacent to coral reefs may provide an important food source for reef fishes. Because this potential interaction has been little studied in most of the tropical Pacific, including Hawaii, we examined it in Hanalei Bay, Hawaii, identifying and quantifying the major invertebrate fauna in sands that we had thoroughly described near the shallow fringing reefs. We also identified the fish species that seemed to make significant use of these sand habitats, estimated their density there, determined the times, locations and types of fish activity there, and sampled the gut contents of the fishes to determine trophic links with the sand habitat. Small polychaetes, crustaceans (e.g. amphipods, isopods, ostracods and small shrimp), mollusks (especially bivalves), and small echinoids were important in the samples. Fish guts examined contained ~77% of the total number of benthic taxa collected, including nearly all the above. However, the larger shrimps, crabs and small cryptic fishes were dominant in the diets of most of the numerous predator taxa. Diets of benthic feeding fishes showed relatively low specific overlap. The fish fauna in this area included substrate-indifferent pelagics, species with various degrees of reef relatedness, reef-restricted species, and (at the other extreme) permanent cryptic sand dwellers. Occurrence and movements of fishes indicated that a band of sandy substrate several tens of meters wide next to the reef was an active area for fishes, with diel variability in activity. These results imply an important trophic role for the benthos in these near-reef habitats by providing forage to reef-associated fishes.

Interannual and Decadal Variability of the Western Pacific Sea Surface Condition for the Last Two Centuries: Reconstruction Based on Oxygen Isotope Records from a Guam Coral

*Ryuji ASAMI**, *Tsutomu YAMADA*, *Yasufumi IRYU*, *Terrence M QUINN*, *Christopher P MEYER*, *Gustav PAULAY*

Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Aobayama, Sendai 980-8578 Japan

ryuji@dges.tohoku.ac.jp

Reconstruction of changes in a tropical ocean-atmosphere system for the period prior to instrumental records requires the use of climatic and oceanographic proxies such as corals and tree rings. Oxygen isotope composition (^{18}O) in modern massive coral skeletons has been used as a powerful tool for reconstructing past continuous variations in thermal and hydrologic conditions of the tropical and subtropical sea surface waters because coral ^{18}O varies with sea surface temperature (SST) and seawater ^{18}O (related to salinity). We present 213-year time series records of coral ^{18}O at monthly resolution from a Guam coral (13° N, 145° E) in the northern part of the Western Pacific Warm Pool. The coral ^{18}O shows seasonal, interannual, and decadal variability, which documents significant oceanographic changes related to ENSO (El Niño/Southern Oscillation) and PDO (Pacific Decadal Oscillation). We detected 36 ENSO warm and 31 cool phases from the entire record of this coral, which are consistent well with those reconstructed by previous ENSO investigations and Darwin Sea Level Pressure. Spectral analysis of the coral ^{18}O records for the years 1790-1999 identified the significant peaks around 4- to 8-year and found a periodicity centered at 3.6-year for the last 50 years. These results indicate that the Guam coral has been influenced by global ENSO periodicities and that recurrence of ENSO phases has been more frequent since ~1950. An accumulative ~0.35 per mil decrease in the long-term trend may imply <-1.3 °C warming of SST and/or >~0.1 per mil freshening of seawater ^{18}O , corresponding to >~0.33 depletion in salinity, in the north region of the western equatorial Pacific for the last 2 centuries.

Stable Carbon and Oxygen Isotope Records in a Palau Sclerosponge

*Andrea G GROTTOLE**, *Olivia GIBB*

240 South 33rd Street, Philadelphia, PA 19104-6316 United States of America
grottoli@sas.upenn.edu

The calcium carbonate in sclerosponge skeletons appears to incorporate stable carbon (^{13}C) and oxygen isotopes (^{18}O) in isotopic equilibrium with seawater dissolved inorganic carbon (DI- ^{13}C) and seawater oxygen isotopes, respectively, thus faithfully archiving the isotopic composition of seawater over time at a given site. Here, a high-resolution (0.1 mm) ^{13}C and ^{18}O record for a 7.7 cm long *Acanthocheatetes wellsi* sclerosponge collected in 2001 from Palau (7°N, 134°W) in the northwestern region of the Western Pacific Warm Pool (WPWP) is presented. Radiocarbon and stable isotope analyses reveal that the sclerosponge is 52 years old with an annual growth rate of 1.48 mm/year. Thus our sampling rate yields an average of ~15 samples/year. Distinct horizontal skeletal features appear to be annual. The sclerosponge ^{13}C record shows a significant Seuss Effect with a decrease of 0.2 permil/decade for the period of 1970-1990, which is equivalent to the instrumentally measured decrease in the tropical Pacific DI- ^{13}C for the same time period. Thus, sclerosponge ^{13}C seems to accurately record seawater DI- ^{13}C variability. The detrended sclerosponge ^{18}O record is inversely correlated with the Southern Oscillation Index and Trade Wind Index anomalies on interannual timescales indicating that the WPWP is cooler/saltier (warmer/fresher) during El Niño (La Niña). This is consistent with model and available instrumental data for the WPWP. These results show that sclerosponge ^{13}C and ^{18}O records may be valuable tools for reconstructing DI- ^{13}C and ENSO variability, respectively, on century or longer timescales. This research represents the first sub-annually resolved, multi-decadal long paleoceanographic record for the northwestern equatorial Pacific region of the WPWP.

A Coral Record of Northwestern Pacific Climate Variability from 27 Degrees North

*Thomas FELIS**, *Atsushi SUZUKI*, *Hodaka KAWAHATA*

Klagenfurter Str., 28359 Bremen Federal Republic of Germany
tfelis@allgeo.uni-bremen.de

Most climate reconstructions based on annually banded corals are from locations throughout the tropics, providing information about past variations of the ENSO phenomenon and its teleconnections. Recent studies from the northernmost Red Sea (28-29 degrees North) have shown that *Porites* corals from subtropical sites can provide proxy records of atmospheric variability over the extratropics of the Northern Hemisphere, providing information about past variations of the Arctic Oscillation/North Atlantic Oscillation phenomenon. Here we present a new coral record obtained from a *Porites* colony from the islands of southern Japan, in the subtropical western North Pacific (27 degrees North). The coral oxygen isotope record has a bimonthly resolution and extends back into the late 19th century. Analyses of instrumental climate data reveal that decadal variations of sea surface temperature in this region are related to atmospheric variability over the mid to high latitudes of the Northern Hemisphere during the winter season. We therefore expect that our new coral record will provide information about past atmospheric variability over the Pacific sector of the Northern Hemisphere extratropics, complementing climatic information obtained from other rare subtropical sites of coral growth, e.g., the northernmost Red Sea or the Bermudas in the subtropical North Atlantic.

$\delta^{18}\text{O}$ Record of Sesoko Island, Okinawa, Japan *Porites* spp. Corals during the 1998-Bleaching Event

*Michael ROSENFELD**, *Aldo SHEMESH*, *Kazuhiko SAKAI*, *Yossi LOYA*

Tel Aviv 69978, ISRAEL
roz@post.tau.ac.il

Oxygen isotope composition has been used to examine the effect of the 1998 bleaching event on the skeletal record of six *Porites* spp. colonies from Sesoko Island, Okinawa, Japan. Growth and calcification rates were found to change significantly during the bleaching event and its manifestation in skeletal ^{18}O masked the temperature signal. A ten year long coral record was used to calibrate the local $^{18}\text{O}_c$ to SST, dependency of 0.18 permil/°C, well within the acceptable calibrations for *Porites* corals. Surprisingly, the skeleton portion that had been accreted during 1998 exhibited a 0.3permil enrichment which contrasts the $^{18}\text{O}_c$ depleted values expected in abnormally high SST conditions that initiated the bleaching. The variance of $^{18}\text{O}_c$ among six neighboring *Porites* spp. colonies was relatively high during 1998, in comparison with 1997 and 1999. A residual analysis conducted on the 10 year record revealed that 75% of the residual inter-annual ^{18}O variation is explained by variability in annual extension rate along the maximal growth axis. The increase in the variance of *Porites* among the six colonies during 1998 suggests that each colony is responding differently to the elevated SST. These results imply that the variance in $^{18}\text{O}_c$ from a number of neighboring colonies may be a more reliable tool for establishing the presence of stressful environmental conditions.

Stable Isotopic Changes in the Skeletons of Corals Around the Island of Tobago Relative to the Outflow of the Orinoco

*Peter SWART**, *Chris MOSES*

4600 Rickenbacker Causeway United States of America
pswart@rsmas.miami.edu

The island of Tobago is situated off the north-east coast of South America and is seasonally influenced by the outflow of the Orinoco. In conjunction with the Amazon, these two rivers contribute 10% of the global flux of freshwater discharge into the oceans. Despite the influence of the Orinoco, there are luxuriant reefs at several locations surrounding the island. In order to investigate the possibility that the coral contain a record of discharge in the stable oxygen and carbon isotopic composition of the skeleton, we collected 24 corals (*Montastraea faveolata*, *M. franksii*, and *Siderastrea siderea*) from various locations around the island (Bucco Reef, Colluden, and Spey side) and analyzed the skeletons of four of these for their fluorescence and stable isotopic composition (O & C). All corals showed distinct density banding and *Montastraea faveolata* exhibited relatively high growth rates (in excess of 1 cm/yr) compared to specimens of the same species from other areas in the Caribbean. A distinct, but narrow band of high fluorescence, was observed in all corals, presumably related to the peak discharge of the Orinoco, which occurs in August/September of every year. The stable O isotopic composition of all corals exhibited a larger range in isotopic composition than could be accounted for by temperature alone, but the mean annual values showed no relationship to the volume of freshwater discharge derived from the Orinoco. The explanation for the absence of a relationship is suggested to be a result of a complex combination of atmospheric steering controlled by the position of the Inter-Tropical Convergence zone (ITCZ) and the absolute discharge. If the ITCZ is positioned at a southerly location, the ITCZ deflects water from the Orinoco into the Atlantic, while a more northerly position allows a greater influence of the freshwaters on the island.

Temporal/Spatial Relationships between Skeletal Density, Carbon, and Oxygen Records in the Reef-building Coral *Montastraea faveolata*

*Kevin P HELMLE**, *Peter K SWART*, *Richard E DODGE*

8000 N Ocean Drive, Dania, Florida 33004 United States of America
kevinh@nsu.nova.edu

Reef coral skeletons commonly contain annual signals as variations in bulk density and chemistry. These records have been used extensively to determine coral growth and proxy data for water temperature, precipitation, and other environmental parameters. Often, time relationships are assigned by declaration of signal peaks and valleys to an annual framework. Independent relationships in the same time and space scale of these signals have been understudied and potentially can provide key understanding about how the coral skeleton stores (and how to best extract) environmental/climatic information. In this study, skeletal bulk density, ^{13}C , and ^{18}O were measured along a common transect on a *Montastraea faveolata* core from Biscayne National Park in Southeast Florida. The three datasets were aligned by distance along the transect over the 130 year skeletal record dating from 1856 to 1986. The three records exhibited strong correlation due to the annual signals. Additional information was provided by absence of particular annual features and distance offset of annual signals along the transect. Comparisons addressed the following issues: degree to which the annual signals in bulk density, carbon, and oxygen consistently occurred; meaning of absent specific annual peaks or valleys; consistency of the timing relationship between annual signals; timing and environmental cues of density banding; and the consistency of estimating linear extension from the annual signals of each parameter.

Coral Growth (Annual Linear Extension) Chronologies from High-latitude Reefs of Southeast Florida: Correlations within and between Sites, Species, and Environmental Records

*Richard E DODGE**, *Kevin P HELMLE*

8000 N Ocean Drive, Dania, Florida 33004 United States of America
dodge@nova.edu

Scleractinian reef-building corals can be long-lived (hundreds of years), and their skeletons contain records of growth via annual density bands. The degree to which growth is similar between corals at the same and spatially separated sites can help to identify the nature and degree of common responses to environmental forcing functions. In this study we measured the annual skeletal extension of 154 corals. Specimens of two coral species, *Montastraea faveolata* and *Diploria labyrinthiformis*, were collected from 8 sites divided into two depths (9 m and 18 m). North-South distance between farthest sites spanned approximately 30-miles along reefs of Southeast (Broward County) Florida. Medial coral slabs were X-radiographed to reveal annual density bands that were measured along two separate transects per colony. Annual extension measurements were divided by the transect means to normalize the data. Normalized transect data were averaged by year into coral chronologies. Coral chronologies were ensemble averaged into site and depth master chronologies for each species. Correlation analysis was used to assess variability between different corals, sites, and depths over 16 common years (1985-1970) as well as to compare growth and environmental records. Environmental records were water temperature and density (salinity), rainfall, canal discharge, and six prior beach renourishment projects. Results showed stronger correlation between site master chronologies than between coral chronologies within a given site. Correlations were found between both depth and species master chronologies. Correlations of master chronologies with environmental records (water temperature, salinity, rainfall, and canal discharge) were positive for water density (salinity), negative for rain and canal discharge, and not significant for beach renourishment events.

Sclerochronology and Geochemical Evidence of Natural and Anthropogenic Influences on Coral Growth in a Stressed Environment, Belize

*Lila GERALD**, *Lisa GREER*, *H Allen CURRAN*

137 Nyac Ave., Pelham, NY 10803 United States of America
lgerald@smith.alumnae.net

The aragonite skeletons of scleractinian corals can provide a chronology of environmental conditions during growth. Temporal changes in growth rate and the stable isotopic composition of coral carbonate may reflect variations in the isotopic composition of surrounding waters as influenced by hurricane activity, El Nino events, and sediment flux in the reef environment. Growth rate and geochemical analyses of a Belizean patch reef coral provide an excellent chronology of natural events and recent water quality degradation during growth. Several cores of *Montastraea faveolata* corals were collected in June 2002 from south-central Belize. Sclerochronological analysis reveals distinct seasonal banding punctuated by anomalous high-density stress bands. These stress bands formed contemporaneously between corals and correlate with well-documented environmental perturbations. Stable carbon and oxygen isotopic data collected from the most recent 40 years of one shallow-water coral show mean annual carbon isotopic depletion and oxygen isotopic enrichment over the 40-year time period, with significantly accelerated rates during the last decade. The depletion in carbon is interpreted to represent an increased flushing of light terrestrial carbon onto the reef tract, likely due to forest clear-cutting. The oxygen isotopic enrichment may be attributed to a freshwater starving effect due to decreased rainfall or coastal water usage which increased dramatically over the most recent decades. All coral cores display intense stress banding and a significant decrease in coral growth that correlates with the extreme 1997-1998 El Nino event. The seasonal cycles of carbon and oxygen isotopic data are poorly represented during these years, indicating adverse conditions and possible coral growth cessation or bleaching. Hurricane Mitch (1998) likely exacerbated stress conditions and may be recorded as a dramatic depletion in carbon isotopic composition due to the influx of terrestrial matter onto the reef.

Human Impacts and Global Changes on Western South Atlantic Coral Reefs: The Case of Abrolhos Reefs

*Ruy K P KIKUCHI**, Zelinda M A N LEAO, Altair J MACHADO, Francisco A R SANTOS, Roberto M ARGOLLO, Helisangela A NASCIMENTO, Paulino P OLIVEIRA, Leo X C DUTRA, Augusto M NETO, Marilia D M OLIVEIRA

Institute of Geosciences, Barao de Geremoabo St., Salvador, Bahia Federative Republic of Brazil

rkikuchi@cpgg.ufba.br

The Eastern Coast of Brazil was one of the most impacted areas during the 20th century. Tropical rainforest area of occurrence was reduced to 4% of its original size. This resulted from roads construction, extensive cattle raising and culture of Eucalyptus. Urbanization and tourism also increased resulting in a greater discharge of sewage to rivers and to the coast. Petroleum exploration occurs, mainly offshore. This happened close to the most important reef areas in the Southern Atlantic, including reefs of Abrolhos, Corumbau-Porto Seguro and Tinhare-Boipeba. Anecdotal informations point to an increase of turbidity in reefs. Fisheries of carnivores decreased and catches of herbivores (parrotfishes), are increasing. Three episodes of coral bleaching associated with ENSO events were assessed in the reefs, since 1993. During the year of 2003, sediment (60cm long) and coral (up to 1m long) cores were collected in five stations in Abrolhos reef complex with the aim to assess the impacts, natural and human induced, imposed on coral reefs. The content of foraminifera, spores, CaCO₃, and siliciclastics is studied in sediment cores. Coral banding studies are under development. Studies of oxygen, calcium, strontium and barium isotopes will be made. Sedimentation rate was measured with sediment traps and based on the concentration and radioactive decay of ²¹⁰Pb. Both indicate sedimentation rates of 5 to 10 mg.cm⁻².day, averaged for the last 70 years. Preliminary results of foraminiferal content show that in some cores the planktonic foraminifera concentration reduced significantly in the last century. This may be interpreted as an increase in the influence of continental processes on the reefs. Spores of arbustive plants were found in some cores, but the variation of its concentration was not thoroughly evaluated. Studies of historical data, though, show a general decrease in river discharge and sediment runoff in the last 20 years.

Global Warming and Coral Range Expansions: Real or Imagined?

*William F PRECHT**, Richard B ARONSON

2001 NW 107th Avenue, Miami FL 33172 United States of America

wprecht@pbsj.com

The fingerprint of global climate change can be mapped via the response of species to changes in their physiographic environmental settings. We report the first known example of poleward expansion of a Caribbean coral genus in response to recent patterns of climatic warming. Reef-coral assemblages dominated by the staghorn coral *Acropora cervicornis* were discovered off Fort Lauderdale, Florida in 1998, where they had not been observed previously. In addition, the elkhorn coral *A. palmata* was observed for the first time in 2002 on reefs of the Flower Garden Banks in the northern Gulf of Mexico. The appearance of acroporid corals north of their previously known range is associated with a decadal-scale increase in annual sea-surface temperature. Significantly, the present northward expansion of acroporids has a historical precedent that can be used to model the response of these corals. During the early to middle Holocene (9-4 ka), oceanic conditions favored the growth and accumulation of acroporid corals along the shelf margin of the Florida reef tract. Reefs up to 10 m thick ranged as far as 150 km north of their present limit in response to a millennial-scale, high-amplitude climate flicker. The climate flicker also correlates with the northernmost expansion of coral reefs in the Pacific. As temperatures cooled after the mid-Holocene, the northern limit of acroporid reef growth in the Atlantic regressed south to the northern Florida Keys. The northward expansion and then southward contraction of framework-building corals implicates climate change as an important forcing mechanism in the distribution of reef systems. Under current scenarios of global warming, the continued northward expansion of *Acropora*-dominated reefs is a strong possibility, mimicking the geographic distribution of reefs in the mid-Holocene.

Application of Paleoclimatology to Monitoring Areas of Management Concern

*C Mark EAKIN**, Peter K SWART, Terrence M QUINN, Richard E DODGE, Jennifer M SMITH, Kevin P HELMLE

325 Broadway, E/CC23, Boulder, CO 80305-3328 United States of America

mark.eakin@noaa.gov

The skeletons of reef-building corals are valuable archives of information on the climatic and environmental milieu during the life of the corals. Paleoclimatic data chiefly have been generated in areas that may show past global or wide-spatial climatic variability. Such paleoclimatic records can provide valuable information of the anthropogenic influences and hence provide guidance for management activities. The Coral Reef Watch of the U.S. National Oceanic and Atmospheric Administration funds observations of current and past coral reef health in or near marine protected areas through satellites, *in situ* sensor platforms, and paleoclimatic analyses. Such paleoclimatic data provide retrospective monitoring through multi-century records of past climate near existing or newly installed monitoring platforms. Hence, areas of management concern can take advantage of the powerful tools developed through sclerochronology and geochemistry. This presentation will describe the results of the first sites to benefit from the full suite of Coral Reef Watch data near Looe Key and Key Largo in the Florida Keys National Marine Sanctuary. Data from coral cores include direct measurements of ¹⁸O, ¹³C, Sr/Ca, and coral skeletal growth (extension, density, and calcification). Because the network of SeaKeys buoys has existed in the area for over a decade, temperature and salinity data from SeaKeys buoys will be compared against geochemical and growth data from the corals and used to reconstruct temperature and salinity from the cores. Additional work at these sites includes skeletal growth measurements on additional cores from the Florida Keys National Marine Sanctuary and Biscayne National Park and a comparison among nearby cores sampled at high temporal resolution to assess the degree to which the cores used are representative. Other paleoclimatic aspects of Coral Reef Watch, including planned updates of the CoralXDS program to process geochemical data and plans for future paleoclimatic sites, will be introduced.

Climatological Context for Large-scale Coral Bleaching Observed since 1979

*Andrew D BARTON**, *Kenneth S CASEY*

NOAA/NESDIS/NODC, E/OC1, 1315 East West Hwy, Silver Spring, MD 20010, USA

andrew.barton@noaa.gov

Coral bleaching is a pan-tropical phenomenon with serious ecological and economical impacts that has become increasingly frequent since 1979. Despite the extensive scientific research and increased public awareness of coral bleaching, it is not known if large-scale coral bleaching occurred prior to the recent observational record. This study uses three 132-year historical SST data sets, ERSST, HadISST1, and GISST 2.3b to identify persistent warm periods during the past 132 years. The results of this study show that while coral bleaching and anomalously warm SSTs have occurred over much of the world in recent decades, conditions favorable for thermally induced coral bleaching may have existed in the Caribbean and Northwest Hawaiian Islands prior to 1979.

Remote Measuring of Coral Reef Ecosystem Stimulus and Response

*James C HENDEE**

4301 Rickenbacker Causeway; Miami, FL 33149-1026 United States of America

jim.hendee@noaa.gov

Corals and other reef organisms may respond to a variety of environmental stimuli differently during various periods of the day, or during each of the four seasons. These organisms may also experience a cumulative effect from persistent stresses or influences during these periods. A suite of expert systems (artificial intelligence software) and other tools were engineered to process daily raw data and images received from regularly maintained and calibrated meteorological and oceanographic monitoring stations situated at remote coral reefs, and to model and report in near real-time select permutations of such environmental stimuli. Timely field observations and a pulse amplitude modulating fluorometer were utilized in concert with the near real-time modeling reports to validate the predictions of organismal and zooxanthellae response to the modeled environmental conditions. Thus, environmental stimuli thought responsible for coral bleaching, coral growth and coral larval recruitment health were measured and modeled with the instrument/software system, with varying degrees of success in predictive capabilities, at various locations. Feedback from these trials gives researchers a better understanding of how the physical environment influences coral reef ecosystem response.

A Re-evaluation of Expert System Coral Bleaching Thresholds Based on Data during the Partial Bleaching Event in St. Croix, US Virgin Islands 2003

*Derek MANZELLO**

4301 Rickenbacker Cswy., Miami, Florida United States of America

derek.manzello@noaa.gov

A computer expert system, termed the Coral Reef Early Warning System (CREWS), was employed at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami, Florida, USA, to provide interpretations of near real-time acquired combinations of meteorological and oceanographic data, thought to be conducive to coral bleaching. These data are collected continuously from the CREWS station at Salt River Bay, St. Croix, U.S. Virgin Islands, broadcast via satellite to a data download facility at Wallups Island, Virginia, USA, and acquired via automated procedures for processing at AOML. In September 2003, coral bleaching was reported at Salt River Bay, yet no CREWS bleaching alert was produced. This finding highlights the variability of bleaching thresholds between sites and elucidates the need to reconfigure the system so that bleaching alerts can be accurately produced in the future for St. Croix. The parameters cited in the literature as being most important in eliciting the bleaching response (high sea surface temperature (SST), low winds, increased irradiance) were examined for June through September 2003. Bleaching was first noted after SSTs reached an average of 29.6 °C over a period of 3 days. SSTs for the 30 days preceding the bleaching event averaged 28.9 °C, whereas during the month of bleaching SSTs averaged 29.5 °C. The penetration of ultraviolet B (UVB, 280-320 nm) radiation into the water column increased at the start and stayed elevated during the bleaching event. High SSTs, low wind speeds and an increase in UVB penetration into the water column occurred coincident to the time of bleaching, but it was not possible to determine if these factors were acting synergistically

Oceanographic Conditions Implicated in the 2002 Northwestern Hawaiian Islands Coral Bleaching Event

*Ron K HOEKE**, *Russell BRAINARD*, *Russell MOFFITT*, *Gang LIU*, *Alan STRONG*, *William SKIRVING*, *Jean KENYON*

1125B Ala Moana Blvd., Honolulu, HI 96714 United States of America

ronald.hoeke@noaa.gov

Beginning in late July 2002, NOAA's Coral Reef Watch program identified elevated sea surface temperature (SST) observed by both satellite and in situ observations at Midway in the Northwestern Hawaiian Islands. Based on these alerts, the focus of an ongoing coral reef ecosystem assessment and monitoring two-ship expedition aboard the NOAA ship *Townsend Cromwell* and *M/V Rapture* was modified to better document the predicted bleaching. Extensive data from these cruises confirmed widespread massive coral bleaching, particularly at Kure, Midway, and Pearl and Hermes Atolls at the northern end of the Hawaiian Archipelago. While details of the coral bleaching and biological impacts are presented in Kenyon et al., 2004, this work uses satellite remote sensing and in situ observations to describe the evolution of the meteorological and oceanographic conditions that are believed to have caused this event. Observed regional SST around these northern atolls not only reached warmer temperatures than any observed in the last 20 years, but also the duration of anomalously high SST lasted much longer than any previously observed events. This event was primarily related to exceptionally quiescent wind and wave energy across a large portion of the subtropical central Pacific. In situ observations indicate that local SSTs within lagoonal and backreef areas of the atolls were further elevated over the already anomalous regional SST. The quiescent conditions, atoll morphology, and inferred circulations patterns all help explain possible reasons for elevating local SST and possibly increasing UV penetration, thereby increasing the severity of bleaching described at the northern atolls. The spatial extent and temporal duration of this exceptional warm and quiescent period are described and compared to previous events. Underlying factors for its cause are examined, including links to El Niño/Southern Oscillation multivariate indices and potential links to Pacific Decadal Oscillation.

Spatial Heterogeneity of Photosynthesis in Light and Temperature Stressed Corals

*Ross HILL**, Peter J RALPH, Ulrich SCHREIBER, Rolf GADEMANN, Anthony W LARKUM, Michael KUHL

Westbourne St, Gore Hill, NSW, 2065, Australia

Ross.Hill@uts.edu.au

High resolution imaging of chlorophyll *a* fluorescence emission was used to identify 2-dimensional heterogeneity of photosynthetic activity across the surface of corals. In comparison to earlier studies with fibre-optic microprobes for fluorescence analysis, the Imaging-PAM enables greater accuracy by allowing different tissues to be better defined and by providing many more data points within a given time. Both the impact of exposure to varying light regimes and exposure to bleaching conditions was investigated in these experiments. Images of fluorescence emission indicated that the photosynthetic activity of coenosarc and polyp tissues responded differently to changing light and diel fluctuations in *Acropora nobilis*, *Goniastrea australiensis*, and *Pavona decussate*. In *P. damicornis*, *A. nobilis* and *Cyphastrea serailia* the Imaging-PAM was used to map the impact of bleaching stress. The effect of bleaching conditions (33°C vs 27°C) was studied over a period of 8 h. Marked changes in fluorescence parameters were observed for all three species. Although a decline in EQY (effective quantum yield) was observed, *P. damicornis* showed no visual signs of bleaching on the Imaging-PAM after this time. In *A. nobilis* and *C. serailia*, visual signs of bleaching over the 8 h period were accompanied by marked changes in F_v (light-adapted fluorescence yield), NPQ (non-photochemical quenching) and EQY. These changes were most marked over the first 5 h. The most sensitive species was *A. nobilis*, which after 8 h at 33°C had reached an EQY value of almost zero across its whole surface. Differential bleaching responses between polyps and coenosarc tissue were found in *P. damicornis*, but not in *Acropora nobilis* and *Cyphastrea serailia*. Spatial variability of photosynthetic performance from the tip to the distal parts was revealed in one species of branching coral, *A. nobilis*.

Light-generated Reactive Oxygen Species in Reefal Waters and their Impact on Coral Photosynthesis

*Ron SZYMCZAK**, Anya SALIH

PMB 1, Menai, NSW 2234 Australia

rsx@ansto.gov.au

Photo-ionisation of natural organic matter (DOM) in seawater induces rapid reduction of oxygen to superoxide and other transient radical species (hydroxyls, peroxides, etc) which, when produced intracellularly, directly impact on photosynthetic processes and contribute to photoinhibition in zooxanthellae and bleaching of corals. The incident concentrations of hydrogen peroxide were recently measured at several locations in the vicinity of Osprey Reef (Coral Sea) and within the Heron Island (Great Barrier Reef) coral lagoon. Diel cycling of photogeneration and decay was evident and highly elevated concentrations were observed in seawater localised in pools on the reef flat and lagoon shallows. Controlled-aquaria experiments were undertaken exposing corals to similarly elevated levels of hydrogen peroxide and their photosynthetic efficiency monitored using pulse amplitude modulated (PAM) fluorometry. Differences observed in the corals' responses to combinations of direct and indirect light-induced stresses provide valuable mechanistic insights to the impact of varying light regimes during global climate change.

Temporal Patterns in Zooxanthellae Expulsion during Bleaching Conditions

*Peter J RALPH**, Tony LARKUM, Michael KUHL

westbourne st gore hill nsw 2065 Australia

peter.ralph@uts.edu.au

Bleaching conditions result in the expulsion of zooxanthellae. It has been assumed that expelled zooxanthellae were dead; however we have found cells that have effective quantum yields (PSII) > 0.65 after 8 h of bleaching conditions (500 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$, 33°C). The population of expelled zooxanthellae from *Cyphastrea serailia* and *Pocillopora damicornis* showed distinct patterns in the frequency distribution of PSII over time and between locations within a colony. During the first 4 h exposure to bleaching conditions only 5% of expelled cells from *P. damicornis* were photosynthetically non-viable (PSII < 0.05), whereas for *C. serailia* this was 30%. The overall photosynthetic health of expelled zooxanthellae from *C. serailia* was greater than *P. damicornis* (0.53 and 0.38 after 8 h, respectively). This was generally reflected by in hospite measurement of the coral, yet in hospite cells always had higher PSII than expelled, suggesting host tissue availed added photoprotection for the zooxanthellae.

Symbiosis Induced Thermotolerance in Mediterranean Sea Anemone *Anemonia viridis*

*Sophie RICHIER**, Paola FURLA, Amandine PLANTIVAUX, Pierre-Laurent MERLE, Denis ALLEMAND

aculte des Sciences, Parc Valrose, BP71, 06108 Nice Cedex 02 France, Metropolitan

srichier@unice.fr

Cnidarians in symbiosis with photosynthetic Dinoflagellates (zooxanthellae) are daily submitted to oxygen variation in their tissue. As consequence of the photosynthetic process, high concentration of oxygen leads to reactive oxygen species (ROS) production and to endogenous hyperoxia state (60% O_2) in animal cells. Because such oxygen variations commonly lead to cell death, origin of adaptation has been investigated in the symbiotic model *Anemonia viridis*. Comparative studies between symbiotic (*Anemonia viridis*) and non symbiotic (*Actinia equina*) Mediterranean sea anemones have been carried out to highlight differences in antioxidant defense and cell integrity maintaining in control and stress conditions. Thermal stress, one factor or involve in symbiosis disruption during bleaching phenomenon was tested during time. Biomarkers of cellular damages (lipid peroxidation, protein oxidation and caspase activation) and biomarkers of antioxidant defense (superoxide dismutase (SOD) and total oxygen scavenging capacity (TOSC)) were followed during thermal stress (+7°C). These results were discussed on the basis of symbiosis effect on thermotolerance. These data suggested that endogenous hyperoxia, induced by the presence of the photosynthetic symbiont, would constitute a preconditioning step necessary for the animal host cell to resist to environmental stress such as thermal increase.

Pigmentation as a Strategy to Reduce Solar Damage in Reef-building Corals

*Anke KLUETER**, *Sophie DOVE*, *Ove HOEGH-GULDBERG*

PMB No 3, Townsville MC, QLD 4810 Australia

a.klueter@aims.gov.au

The pigmentation of reef-building corals is a striking feature of coral reefs. Many coral pigments have been identified as homologs of the Green Fluorescent Protein (GFP) of the Hydrozoan jellyfish *Aequorea victoria*. Preliminary studies suggest that the presence of fluorescent pigments is related to light stress, and that these pigments may have an important role in photo-protection and coral bleaching. Understanding the function of compounds associated with the photobiology of coral symbiosis is important to evaluating the full impact of their ability to protect shallow water corals and hence how corals survive successfully in an extreme environment. We explored the physiological and ecological significance of GFP-homologs in reef-building corals and particularly those that are green fluorescent. While the abundance of green fluorescing corals varied significantly, the total content of GFP-like proteins within corals was constant. The consistent presence of GFP-like proteins across species in all parts of the reef (Heron Island Reef, GBR) suggests that all corals contain a pool of fluorescent and/or non-fluorescent GFP-like proteins. The response of GFP-like proteins to different wavelengths of light varied significantly between coral species and colour morphs. The findings of our study indicate a main role of coral host pigments in regulating the solar flux that reaches the dinoflagellate partner of the coral-algal association. By regulating the flux in the ultraviolet and photosynthetically active spectra, host pigments show the potential to be a critical element in determining how and where corals are found within the extreme light gradients that are characteristic for the shallow tropical sea that they inhabit.

The Role of Coral Host-based Fluorescent Pigments in Reducing Bleaching Stress

*Anya SALIH**

Electron Microscope Unit F09, University of Sydney, NSW 2006, Australia

anya@emu.usyd.edu.au

Coral brownish colors result from the photosynthetic pigments of their intercellular symbiotic dinoflagellates. Corals also have bright purple-blue and fluorescent colors. We have explored the photoprotective function of these pigments and show that they reduce the photoinhibitive effects of sunlight by screening the intra-cellular photosynthetic dinoflagellates of corals. We also showed that these pigments can influence the survival capacity of corals following mass bleaching events on reefs. In 2002, severe bleaching occurred on reefs of the Great Barrier Reef and Coral Sea, Australia. We examined the degree of bleaching damage by comparing the photosynthetic impairment and degradation of symbiotic dinoflagellates during bleaching as well as the degree of post-bleaching colony tissue die-off between the highly fluorescent and non-fluorescent color-morphs. We found that non-fluorescent color-morphs had significantly higher degrees of damage of their symbionts and higher levels of impairment of photosynthesis as well as higher degree of partial colony mortality than highly fluorescent color-morphs. These results further substantiate the results of earlier studies that showed higher bleaching resistance of fluorescent compared to non-fluorescent corals.

Ecosystem-based Management in US Fisheries: Challenges and Opportunities

*Kitty M SIMONDS, Jarad L MAKAI/AU**

1164 Bishop Street, Suite 1400 United States of America

Kitty.Simonds@noaa.gov

A comprehensive ecosystem-based fisheries management approach requires managers to consider all interactions and linkages that a target fish stock has with predators, competitors, and prey species, the relationship between fishes and their habitats, the effects of fishing on fish stocks and their habitat and the effects of weather and climate on fisheries biology and ecology. Fishery managers recognize that identifying and understanding these processes for the purpose of fisheries management is highly complicated and will require a great deal of time, resources and information. Therefore, most have recognized that implementation of ecosystem-based fisheries management is an incremental and adaptive process, which at minimum, should begin with a precautionary and adaptive management approach. The Western Pacific Regional Fishery Management Council (Council) has developed the first ecosystem-based fishery management plan in the U.S. governing the coral reef ecosystems and associated habitats in the Exclusive Economic Zone (EEZ) around American Samoa, Guam, Hawaii, the Northern Mariana Islands (3-200 nautical miles only) and the US Pacific Remote Island Areas. This plan incorporates many of the basic principles of ecosystem-based management and represents the first step in developing Fishery Ecosystem Plans for each discrete ecosystem within the Council jurisdiction. A description of the Fishery Management Plan for Coral Reef Ecosystems of the Western Pacific Region will be presented, including ecosystem approaches for analyzing coral reef fishery data for monitoring reef ecosystem health, barriers and challenges encountered implementing comprehensive ecosystem-based fisheries management plans as well as future ecosystem-based management initiatives and opportunities.

Components for an Ecosystem Approach to Coral Reef Fisheries Management in the United States

*Thomas F HOURIGAN**

1315 East-West Hwy., Silver Spring, Maryland United States of America

Tom.Hourigan@noaa.gov

Coral reef ecosystems in the United States provide important commercial, recreational and subsistence fishery benefits to local communities. These benefits and the health of the ecosystems are increasingly threatened by overfishing and associated fishing impacts. The U.S. Coral Reef Task Force has initiated a series of coral reef workshops and broad-based stakeholder consultations that have identified consistent concerns and a variety of management responses. By nesting traditional and novel management approaches in a place-based scheme, the glimmer of what might constitute an ecosystem approach to coral reef fisheries management is beginning to take shape. Key components of such an approach will likely include: 1) eliminating the most destructive fishing techniques, e.g., the use of large gill nets; 2) regulating or eliminating highly efficient techniques, such as night spearfishing with scuba, that have led to selective overharvesting; 3) incorporating representative protection of both target species and their habitats in a network of no-take reserves; 4) enhancing fisheries enforcement; and 5) explicitly linking management of coastal development and land-based pollution to fisheries management approaches as they may impact reefs or other habitats important for the life-history of certain reef species. Managing these components in an integrated fashion can be facilitated by GIS tools that overlay fisheries species distributions over comprehensive maps of coral reef habitats, and by incorporating fisheries-independent and fisheries-dependent monitoring of key indicator species reflecting a range of trophic levels and potential ecosystem effects. The goal is to maintain the integrity of ecological processes in a patchwork of exploited and protected habitats. While all these components are being tried, their actual mix and form of implementation is richly varied among U.S. jurisdictions, reflecting a social and cultural diversity nearly as great as the biological diversity of the reefs themselves.

Using Species and Trophic Group Analysis and Size at Maturity Estimates to Examine the Ecological Pressures Exerted by Different Artisanal Fishing Methods on a Reef-Fish Community

Andrew B GILL, Julian CLIFTON*

Institute of Water and Environment, Cranfield University, Silsoe, Bedfordshire, MK45 4DT United Kingdom of Great Britain and Northern Ireland

a.b.gill@cranfield.ac.uk

We undertook an assessment of the fish species caught in a variety of nearshore coral reef environments by different fishing methods in an artisanal fishery in S.E. Sulawesi, Indonesia. The aim was to determine the current status of the fishery and specifically examine any potential consequences to the fish community of using each method. The bulk of fishing activity used the line fishing method, with nylon gill net and spear fishing also being practiced. Our analysis found significant differences between the three methods in the fishing pressure they exerted on different species, on different sizes of fish and trophic groups. We conducted an analysis of the length at first maturity of each species which showed that a large proportion of the fishery was being caught at sizes below the expected size at maturity. We consider the ecological implications of these findings with regard to the future status of the fishery.

An Unconventional Method of Assessing MSY of Reef Fisheries, Applied to the Gulf of Mexico

*Ernesto A CHAVEZ**

Av. IPN s/n Col. Santa Rita, Playa El Conchalito, La Paz Baja California Sur, c.p. 23070 United Mexican States

echavez@ipn.mx

Diversity of coral reefs imposes particular difficulties when informed decisions are required to manage exploited fish and invertebrate stocks where lacking of catch records is the normal rule. Given growth parameter values, stock density, and the reef area, the method of cohort dynamics applied to 36 stocks allowed determining fishing mortality values and age of first catch required for an estimate of maximum potential yield or MSY as a reference point. By assuming that stocks share the same densities in different reefs, the MSY and 0.75MSY values were determined for each stock at six coral reef systems of the south Gulf of Mexico. Adoption a Fishing Mortality value equivalent to the 75% of the MSY, is suggested here as the maximum fishing intensity or precautionary catch limit. Given the relative abundance of the stocks considered in the analysis, it was found that the thirteen most abundant ones account to at least 95% of total exploited biomass; this apparent pattern may be valuable as additional reference point for optimizing resources on planning of sampling programs in these ecosystems, implying a significant reduction of costs with consistent efficiency when management of exploited stocks is the goal.

Community and Trophic Structure of Reef Fish Fauna in the Philippines at Varying Levels of Fishing Pressure

*Cleto L NANOLA**, *Porfirio M ALINO*

Bago Oshiro, Tugbok District, Davao City 8000, Republic of the Philippines
tingnanola@yahoo.com

Underwater fish visual census data derived from more than 500 transects was utilized to investigate the relationship between the community structure of reef fishes and their differential levels of fishing pressure. Initial results indicate that trophic structures vary among different reef types and at various levels of fishing pressure. In general, dominant planktivore biomass such as those for the Acanthuridae represented by *Naso* spp. are indicative of offshore reefs and atolls or more exposed reefs. The parrotfishes (Scaridae), represented roving herbivores more indicative of fringing reefs. Trophic shifts are apparent in the highly fished areas. Fringing reefs were found to be more susceptible to fishing pressure than offshore reefs and atolls. In heavily fished fringing reefs, non-denuding herbivores represented by the damselfish, *Plectroglyphidodon lacrymatus* (Pomacentridae) are remnants of the overexploitation. A considerable number of carnivores were present in areas that were less fished or with some level of protection. Indications of a lag in phase shifts to algal dominated communities may be indicative of the intuitive logic of the importance biodiversity conservation and top-down control mechanisms in reefs. Understanding the interaction of intensity of fishing pressure on the trophic structure of reef fishes reef together with their reef types are important considerations in the management of reef fishes. These considerations (e.g. levels of acceptable vis-a-vis trophic resilience, reef zoning classification and size) are important in improving the design of management conservation efforts.

Ecopath as a Means to an End: Modeling Fishing Dynamics and Marine Reserves in an Ecosystem Context

*Ronald L HILL**, *Richard S APPELDOORN*, *Omar J GUERRA*

4700 Ave. U, Galveston, Texas United States of America
ron.hill@noaa.gov

Tropical coral reef fisheries are difficult to manage using conventional, data-intensive, fishery management techniques. Infrastructure is typically lacking and data are generally poor or unavailable. One alternative means for evaluating management effectiveness is ecologically based modeling, incorporating the relationships between species and characterizing fishing removals as higher trophic-level predators. An Ecopath with Ecosim (and Ecospace) model has been constructed representing a generalized PR-USVI-type Caribbean reef ecosystem to examine sustainability of management policies. Simulations have examined the efficacy of marine reserves and the variability in productivity caused by incorporating different habitats (e.g., seagrass beds, mangroves) within the marine reserve boundaries. Species-specific effects in abundance and biomass resulting from marine reserve establishment are predicted and will be validated through continued monitoring as the reserve develops.

Implications of Natural Variation of Fish Assemblages to Coral Reef Management

*Lance K B JORDAN**, *Richard E SPIELER*

8000 N. Ocean Dr., Dania Beach, Florida United States of America
spielerr@nova.edu

The ability to detect anthropogenic change in fish assemblages requires, at a minimum, knowledge of both the initial state prior to the change, and the natural variation within the assemblages. Whereas the former is often acquired as baseline data, the latter is not. A measure of understanding of natural spatial variation at a given point in time is readily obtained by examining the variation within a baseline data set. However, coral reef fishes often exhibit substantial temporal variability, in terms of both species richness and abundance. We examined variation of coral reef fish assemblages on the nearshore hardbottom of Broward County, Florida, USA twice in three years prior to an anticipated beach renourishment project. In the summer of 2001, we made 176 visual fish counts along a 13km stretch of coastline as part of a larger study. Eighty-eight 30x1x2m transects were run at 152m intervals, and DGPS coordinates of each were recorded. Each transect ran west to east across the north-south oriented hardbottom, beginning at the nearshore edge. We alternated between a 15m diameter point-count or 20min rover-diver count, 20m north of each transect. With the rover-diver counts, only the species present were recorded. With transect and point-counts each species, its abundance, and lengths (TL) were recorded. In the summer of 2003 we returned to the sites (using the DGPS coordinates) and repeated the same census methods. A comparison of the two data sets yields a measure of annual variation in the fish assemblage that we can incorporate into evaluations of any future anthropogenic changes.

Method to Evaluate Sustainability of Fisheries Management Systems with Reference to Additional Management Objectives

*Joshua Sladek NOWLIS**

9721 Executive Center Drive North, Saint Petersburg, FL 33702 United States of America
joshua.nowlis@noaa.gov

Great uncertainties surround the management of all renewable natural resources, but these challenges are especially severe in marine fisheries—particularly those in developing countries. Despite recent substantial progress in addressing uncertainty within assessments, management decisions for most coral reef fisheries are still mired in great uncertainty. As an alternate approach, I have developed the concept of an index of resiliency, which measures the capacity of a management alternative to meet management objectives even if information is incorrect or lacking. When presented with indices representing other important management objectives (e.g., high sustained catch levels), the resiliency index can lead to better-informed and more transparent decision-making in coral reef fisheries management. These techniques were applied to the evaluation of various rebuilding strategies for vermilion snapper (*Rhomboplites aurorubens*) in the United States' Gulf of Mexico. The resulting analyses demonstrated fundamental trade offs between short-term catch reductions and resiliency, average catch levels throughout rebuilding, and manageability of this fishery through rebuilding. As a consequence, it provided the decision-makers with clearer advice about the potential negative consequences associated with the choice of least political resistance. This approach has been applied elsewhere (e.g., Alaskan groundfish) and offers especially great promise for coral reef fisheries, where data are sparse and ecosystems are complex.

Defining and Mapping Essential Fish Habitat for Management of Western Pacific Coral Reef Fishes

*Mark H TUPPER**

UOG Station, Mangilao, Guam 96923, USA Guam
mtupper@guam.uog.edu

Essential spawning and nursery habitat for Western Pacific reef fishes is virtually unknown. In order to effectively manage these fishes, information is needed on their habitat associations and ecological processes that control their abundance and distribution in different habitats. This is particularly true if management is to involve the use of marine protected areas or other ecosystem-based approaches. Among the most desirable and most vulnerable nearshore reef fishes in the U.S. Western Pacific Islands are the larger species such as humphead or Napoleon wrasse (*Cheilinus undulatus*) and commercially important groupers (genus *Epinephelus*, *Plectropomus*, and *Variola*). The objective of our research is to identify essential nursery habitats and ontogenetic habitat shifts for Napoleon wrasse and groupers in Guam and Palau. We quantified settlement, growth, movement and mortality in a range of habitats. Preliminary results indicate that Napoleon wrasse actively select for branching hard and soft corals and macroalgae at settlement. Survival appears to be highest in shallow nearshore habitats combining branching hard corals and macroalgae. The groupers *Plectropomus areolatus* and *Variola louti* settled primarily in rubble areas along the slopes of channels. In order for fisheries management to incorporate essential fish habitat, information on the location and extent of such habitat must be available to managers in a format that is intuitive and readily accessible. Digital habitat maps created in a Geographic Information System (GIS) format are particularly useful in that they allow the merging of habitat data with other thematic layers, such as fish or coral abundance and distribution, fishery catch and effort, pollution sources, etc. Such maps can be used to support a wide range of coastal management and research activities in addition to fisheries management.

Eco-Social System Supported by Multifaceted Marine Industry- Example Analysis of Utilization and Conservation of Coral Reef -

*Izumi SEKI**, Akira NAGANO, Atsumi FURUYA

1-14-10, Uchikanda, Chiyoda-ku, Tokyo Japan
tama@jific.or.jp

In Okinawa, offshore fishing such as single-hook bonito fishing or long-line tuna fishing, and coastal fishing such as submerge fishing or drive-in fishing utilizing coral reef as fishing grounds take place. Also for its distinctive culture and natural environment, Okinawa is known as a tourist Mecca. However, social and environmental causes such as marine pollution, dwindling resources, fall in fish price, decrease and aging of fishery operators, constrict the promotion of fishing industry, which is the major industry in this area. It is notable that environmental pollution gives the serious damage also to the tourism. Under these conditions, efforts are made to perceive fishing industry from diversified viewpoints, or multifaceted marine industry. Examples are to shift from "catch-only" fishing to cultural fishing or "show-fish" in coral reef for tourists. This paper illustrates these attempts, aiming for restoration of fishing resources and sustentation of the fishing industry, from the aspect of socio-environmental system, and then analyzes its structure. Through the case study of fishing industry and tourism in coral reef, this paper gives the structural analysis of utilization and conservation of coral reef, and finally examines the future tasks and visions.

Combining Geography, Ecology and Socio-Economy for Sustainable Management of Coral Reef Fisheries in the South Pacific

Laurent VIGLIOLA, Serge ANDREFOUET, Pascale CHABANET, Eric CLUA, Jocelyne FERRARIS, Kim FRIEDMAN, Rene GALZIN, Alison GREEN, Mecki KRONEN, Michel KULBICKI*, Pierre LABROSSE, Franck MAGRON, Gerard MOUTHAM, Samisoni SAUNI, Laurent WANTIEZ

B.P. D5 New Caledonia

laurentV@spc.int

World fisheries are in crisis and coral reef fisheries in Pacific island countries are no exception. To provide decision-makers with the necessary information for sustainable fisheries management, the Secretariat of the Pacific Community, in close partnership with several international research institutions and local governments, is conducting a European-Union funded comparative assessment of reef fisheries throughout the tropical Pacific. A total of 17 countries and territories will be covered by this program. At present, geographic, environmental, and socio-economic factors have been recorded along with biological and ecological data on coastal marine resources (vertebrates and invertebrates) in seven countries of the tropical Pacific. Two to four contrasted islands from the point of view of fishing pressure were investigated in each country. Underwater (SCUBA) fish and invertebrates counts were performed on a variety of reef formations between 0 and 15 meters. Selected reefs were chosen to represent various level of fishery pressure to evaluate the impact of the fisheries. We found that geographic, environmental, and socio-economic factors were acting at different scales to explain the level and the structure of coral reef resources. Density and biomass of marine resource varied as a function of several factors at regional and local scale, including distance to the center of biodiversity, island type and size, habitat quality, and degree of westernization-urbanization. We examine the usefulness for assessment of resource status of a multi-disciplinary approach and the methods employed to combine data from geography, ecology and socio-economy within a single framework.

Coral Reefs: The "Poster Child" for Ocean Use Planning

*John C OGDEN**

830 First Street South, St. Petersburg, Florida 33701 United States of America
jogden@marine.usf.edu

The unprecedented decline of coral reefs over the past five decades has been in concert with global deterioration in ocean health from human disturbances including fishing, land-based pollution, and global climate change. New policy approaches to stewardship of coral reefs are required, centering on comprehensive national and international programs in ocean use planning within the exclusive economic zones surrounding global reefs. The rapidly increasing interest in marine protected areas, particularly marine reserves fully protected from all extractive human use, arises largely from field research on coral reef fishes, which are only one component of the reef ecosystem. More theoretical research suggests that networks of marine reserves strategically located within larger marine managed areas may help to protect coral reef biological diversity. However, little progress has been made in spite of exemplary management plans including the Great Barrier Reef Marine Park and the Florida Keys National Marine Sanctuary. The past three decades of coral reef oceanography and remote sensing surveys, fisheries science, and in situ surveys have provided much information about reef distribution, connections to land, linkage by currents, the distribution and abundance of both benthic and planktonic biological diversity, and key human uses. Assembled in georeferenced formats, this information will provide stakeholders easily visualized scientific and social rationales for implementation of ocean use plans, which include marine reserve networks. Emphasis on sustainable use rather than only protection may help to develop the political will for action, which has been sadly lacking. Once established, ocean use plans will be refined by monitoring and social science studies and several key areas of research including connectivity or seascape ecology at large geographic scales, ecological resilience and the functioning of biological diversity, and global climate change. Research and management will be supported by ocean observing systems currently under development by national and international agencies.

From Ocean to Aquarium: The Global Trade in Marine Ornamental Species

Colette C WABNITZ, Michelle TAYLOR, Edmund GREEN*, Tries RAZAK
2250 Lower Mall, Vancouver, BC V6T 1Z4 Canada
c.wabnitz@fisheries.ubc.ca

In the main, debate over the marine aquarium trade has taken place without access to impartial and quantitative data and so achieving consensus has been difficult. The Global Marine Aquarium Database (GMAD), a collaborative effort between UNEP WCMC, MAC and members of aquarium trade associations was established in 2000 to address this need (<http://unep-wcmc.org/marine/GMAD>). GMAD now contains 102,928 trade records (representing 7.7 million imported and 9.4 million exported animals) for 2,393 species of fish, corals and invertebrates from 1988 to 2003 provided by 58 companies, and four government management authorities. A total of 1,471 species of fish are traded worldwide. The best estimate of annual global trade is between 20-24 million individuals, with a few families dominating. The most traded species are the blue-green damselfish (*Chromis viridis*), the clown anemonefish (*Amphiprion ocellaris*), the whitetail dascyllus (*Dascyllus aruanus*), the sapphire devil (*Chrysiptera cyanea*) and the threespot dascyllus (*Dascyllus trimaculatus*). The ten most traded species account for about 36% of all fish traded for the years 1997 to 2002. Data, correlated with aquarium suitability information, indicate that two species, the bluestreak cleaner wrasse (*Labroides dimidiatus*) and the mandarin fish (*Synchiropus splendidus*) known not to acclimatize well to aquarium conditions are nonetheless very commonly traded. Species characterized as "truly unsuitable", mainly due to their restricted dietary requirements, such as the foureye butterflyfish (*Chaetodon capistratus*), the harlequin filefish (*Oxymonacanthus longirostris*) and the Hawaiian cleaner wrasse (*Labroides phthiophagus*), also appear to be commonly traded, albeit in lower numbers. Similar data for corals and other invertebrates exist and will be presented. Overall, there is a pressing need for basic information on the population dynamics and life history characteristics of the organisms in the ornamental trade. Combined with accurate trade data, such information is essential for making more informed decisions regarding the sustainable collection of marine ornamentals.

A Review of the Maldivian Aquarium Fishery

Mariyam R SALEEM*, Zaha WAHEED

H. White Waves, Male' Republic of Maldives
msaleem@mrc.gov.mv

The aquarium fishery of the Maldives began around 1979 and is predominantly export oriented. Previously the fishery was concentrated in the vicinity of Male but has spread to atolls further north and south. Aquarium fish collection is allowed in all areas except the "housesreefs" of tourist resorts and the 25 protected dive sites. About 120 species of fish are exported of which 22 species makes up about 70% of the exports. In 2002 there were 6 licensed companies of which 3 were operational. The largest market is in Europe followed by Sri Lanka. In 2002, more than 175800 fish and invertebrates were exported from the Maldives, deriving about 6.5 million rufiyaa (~US\$ 500,000) and making up 0.91% of total marine exports. There was a sharp decline in exports since 1997, probably due to the lower number of active companies involved in the trade. The Ministry of Fisheries set a blanket quota of 100,000 fish for 1988 and 1989 but this was not properly implemented. In 1997, a species based quota system was adopted and this system appears to be working more effectively. The trade in live tropical fish exploits many species sought after by tourist divers and thus there is a potential conflict of interest between these two stakeholders. This study reviews the status of the tropical live fish industry of the Maldives and discusses the management and monitoring issues of the fishery including the effectiveness of the present quota system.

Maqtrac and the Development of Resource Assessment Models for the Sustainability of Marine Ornamental Trade

Domingo G OCHAVILLO*, Gregor HODGSON, Craig SHUMAN, Renante RUZ
1362 Hershey Hall, Box 951496, LA, CA 90095-1496, USA
ochavill@yahoo.com

The global marine aquarium industry trades around 15 to 36 million fishes annually. The industry started since the 1950's and at present the Philippines and Indonesia, countries that comprise the center of coral reef fish species diversity, are the major sources. In spite of its potential significant impact on coral reef resources, there have been no monitoring protocols and resource assessment models developed for the long-term sustainability of the trade. Reef Check, the global coral reef health monitoring program and in partnership with the Marine Aquarium Council, has developed a survey protocol for the ornamental trade (Marine Aquarium Trade Coral Reef Monitoring Protocol or MAQTRAC). We present how the generated data of this protocol are utilized in standard fisheries stock assessment models (e.g. yield-per-recruit analysis). We also evaluate the applicability of these assessment models and the other management strategies (e.g. total allowable catch) for the sustainability of coral reef resources for the marine ornamental trade.

A Stock Assessment of Ornamental Corals at Several Locations in Indonesia

Johan O. SUKARNO*

Jl. K.S Tubun Petamburan VI Republic of Indonesia
ofrijohan@telkom.net

This research was conducted at nine sites in three provinces of Indonesia: the research area located on Rembang with two sites (Central Java province), Lampung province with three sites and Kendari with fourth sites. The assessments were carried out in July, August and October 2002. The primary purpose of this study was to collect information related to ornamental corals, especially existing stock, distribution, habitat, abundance and recruitment rate. The methods used to assess the ornamental corals were belt transect to obtain diversity, distribution and abundance of coral species as coral trade targets, and pointnet transect to describe both the type and condition of the habitat. In addition, the research aimed to determine the best research methods and to give information to the SA (Scientific Authority) on setting quotas for the management and monitoring of ornamental corals, supported by scientific data to reach the sustainable use principle. The research results indicated that ornamental corals are distributed as a result of survival in adapting to habitat conditions. Many factors influenced corals, in particular sedimentation, salinity and substrate type. Species *Euphyllia ancora*, *Goniopora* sp, and *Pectinia* sp were found to have a high adaptation to the factors above. These species were found at about 2 km from the mouth of the Karanggeneng river, an area which has high sedimentation and low salinity. In contrast, the collecting area in Lampung demonstrates a dominance of ornamental corals such as *Euphyllia* sp, *Trachyphyllia geoffroyi*, *Goniopora* sp, *Blastomussa* sp, *Caulastrea* sp etc. that are more diverse than the Rembang site. The collection area in Kendari has a low occurrence of dominant species of ornamental corals, but one location in Padea was found to have a very high diversity of *Catalaphyllia jardinei* compared to others species.

Management Dynamics in a World Heritage Area - The Coral Collection Fishery in the Great Barrier Reef Marine Park

*Margie ATKINSON**, *Randall OWENS*

O Box 1379, Townsville, QLD 4810 Australia

margiea@gbmpa.gov.au

Aquarium fisheries, worldwide, have been the focus of increasing debate because of concerns over unsustainable management and collection practices and conflict of use with other reef stakeholders. The Queensland Coral Harvest Fishery operates within the Great Barrier Reef World Heritage Area Marine Park (GBRMP). Over the last five years, the future of this industry looked bleak as it bore the brunt of misunderstanding about the nature of the industry, poor public perception regarding its relevance, and outdated/inappropriate management practices. A recent rezoning initiative, the Representative Areas Program (undertaken by the Great Barrier Reef Marine Park Authority), to ensure the long-term protection of biodiversity within the marine park will result in a significant increase (from 5% to 33%) in 'No-take' areas; some of these will remove access to traditional coral harvesting grounds. This, together with a statutory need to demonstrate that fishing activities within the GBRMP are ecologically sustainable and aligned with world heritage values has helped to drive a review of the coral fishery management arrangements. Marine Park managers, Fisheries managers and industry collaboratively have developed innovative management arrangements that will significantly restructure the industry. The resulting package should enable industry to operate sustainably, minimise conflict with other Marine Park users, meet the CITES non-detriment principle and therefore gain access to export markets. Key features of the management arrangements include: a capped number of zonally-based operators; a unitised component-based transferable quota; with a strong focus on quota tracking and compliance. Achieving this outcome for a small, diverse industry within a multi-use, multi-jurisdiction Marine Park presented many challenges, but also generated solutions that could be relevant to, or adapted for, other tropical regions.

Evaluating Problems and Prospects for the Trades in Live Reef Fishes for Ornamental Display and Food

Yvonne J SADOVY, *Amanda C J VINCENT**

Pok Fu Lam Road, Hong Kong SAR Hong Kong

yvsadovy@hkusua.hku.hk

We found tremendous commonalities in the fisheries for live food and display animals, both of which are centred on coral reefs. Our research analyses show that managing such fisheries for long-term persistence of populations will be a challenge: the target species are largely unstudied; their life history characteristics tend to make them ill suited for heavy exploitation; the fisheries are not well served by existing management models; juveniles are heavily targeted; the trades effectively go unrecorded; and the commodities are usually valuable but nonessential. These fisheries are already exacting their toll on some wild populations, with demand projected to increase. Successful management of live fish fisheries for sustainability will require a creative and interdisciplinary mix of management measures. In theory, well-managed fisheries for live food and ornamental use could support high-value and relatively low-volume trades, potentially employing many fishers without damaging wild populations. Also in theory, mariculture might help support local people, were it practised in an ecologically sound manner, with attention to economic viability and social implications. The luxury nature of the fishes means that consumers have some flexibility in their purchases, so could exert considerable market pressure on suppliers to conform to agreed ecological standards. On the other hand, however, the nonessential nature of these luxury items might make it more difficult to foster stewardship of the resource and more likely that populations will be heavily overfished.

Tankers or Fish Tanks: What Brought Non-native Marine Fishes to Florida Waters?

Brice X SEMMENS, *Eric R BUHLE*, *Anne K SALOMON*, *Christy V*

*PATTENGL-SEMMENS**

Box 351800, Seattle, Washington 98195-1800

semmens@u.washington.edu

Invasions of non-native species in marine ecosystems can be ecologically damaging and economically costly. Identifying "hot-spots" of non-native species and their sources of introduction is necessary to maximize the effectiveness of invasion quarantine programs. We use a large spatially-explicit marine fish database to show that there are a surprising number of non-native fishes on the reefs of southeast Florida, USA. Two likely sources explain the occurrence of non-native marine fishes in this region: introductions through ballast-water exchange, and introductions from aquaria. Data on international shipping patterns and marine fish imports were used to evaluate the culpability of these two vectors. Our results suggest that the introductions are most likely the result of aquarium releases. Prevention of further releases and invasions will require education, outreach, and enforcement efforts directed at marine aquarists and the aquarium industry.

Feasibility Study for Mac Certification in Seribu Islands Indonesia 2003

*Yunaldi YAHYA**, *Jan H STEFFEN*

14 Blimbing St, Kemang Timur, Jakarta Republic of Indonesia

yunaldi@terangi.or.id

The people of Pulau Panggang has been dealing with ornamental fishes since late of 1960, and grow up after in Jakarta was established in Aritha Trading Company (1968). Aritha was the first company from Indonesia to export live marine fish to Europe in 1970. When it was decided to expand the company in 1972 they built the new company PT Vivaria Indonesia in anticipation of the increased demand in Live Tropical Fish and related products from Indonesia. which all this period ornamental fishing activities used net only. In period of 80th the cyanide was introduced as an alternative catching technique. Fishermen in Pulau Panggang can be categorized in two groups: those catching fish for human consumption or larger fish such as snappers, jack, sardines, fusilier, etc. and those catching ornamental fish. The most common fishing gears in use are line fishing, net and fish traps. Other gears used include muroami, Poison, potassium cyanide, is frequently used for catching ornamental fish. Another illegal, non-sustainable method. The fisheries structure can be grouped into three levels. The highest level involves the bosses the boat owners; then come the boat captains; finally, the lowest level englobes the ships crews. Generally, fishermen in Pangang Island will catch fish only in the waters of the area. However, since the region was proclaimed a Marine National Park, they can no longer fish freely within the park, thereby limiting their fishing area. Consequently, their incomes are depressed. Some Pulau Seribu fishermen now go to catch fish outside their home area, in the waters of Lampung province, Bangka and around the Sunda Straits. Fishing activities can damage the environment

Lombok Frags- The First Sustainable Coral Cultivation in Indonesia for Trade and Reef Conservation

*Christiane SCHMIDT**, *Frederic AMBLARD*, *Vincent CHALIAS*
20, avenue de la chevaliere, F-81200 Mazamet, France, Metropolitan
overseas@amblard.fr

For several years now the demand for live corals has increased together with conservational concerns about coral reefs. Since 1990 all Scleractinia spp. and some other corals, all together more than 2000 species, are subject to CITES-regulations. In this situation of growing demand and decreasing and uncertain supply, Amblard Overseas Trading S.A. decided in 1999 to create its first Indonesian coral farm with marine cultivation. The aim is to produce corals, independent from wild resources, for reef aquarium keeping, scientific research and transplantation in damaged reefs and thus to sustain the trade but also to offer an alternative livelihood to local people. In a first step parent colonies are established. These colonies come from corals rejected by the exporters because of damage. Thus unnecessary extraction can be avoided and the cultivation is self-sufficient. After 10-30 days of acclimatization to a carefully selected site, production can be initiated. If the site is appropriate to the species, a transplantation board is installed, fragments are cut from the parent colony and attached to patented supports. The supports with the fragments are then placed at the board. A period of maintenance follows. After 3-4 months soft coral fragments, after 5-6 months most SPS corals and after 2-3 years LBS corals can be harvested. 20-40% of the fragments (depending on the growth rate) serve to produce additional parent colonies while the rest is traded or used for reef reconstruction in tourist regions. Guided snorkelling tours are planned to increase ecological awareness. The project gives a livelihood to former fishermen now responsible for the manufacture of supports and the monitoring and harvest of the fragments. The farming concentrates now on the production of soft corals and multi-species fragments (2-3 species on the same support), which are especially attractive to our customers.

Coral Farming, Learning from Past Mistakes

*Dana RIDDLE**
77-6497 Alii Drive, Kailua-Kona Hawaii, 96740 United States of America
riddlelabs@compuserve.com

Captive coral propagation for the international pet trade is often viewed as an ecologically friendly means for preservation of natural coral reefs. However, harsh financial realities paint a bleak picture for commercially successful endeavors. This presentation will discuss the challenges facing coral farmers, and will explain why most commercial coral propagation facilities will fail. The most commonly propagated corals are often those most easily cultured and ultimately in least demand. The future of successful facilities will depend upon a multi-faceted approach and will depend upon development of innovative culture techniques. This presentation will focus on those lessons learned during a two-year operation of a 16,000 gallon inland mariculture facility, and will include a brief discussion of successful, and not so successful, endeavors.

Towards a Sustainable Aquaculture of Giant Clams (Tridacnidae) in the Jordanian Sector of the Gulf of Aqaba

*Hilly Ann ROA-QUIAOIT**, *Claudio RICHTER*, *Mohammad ZIBDAH*
PO Box 195, Marine Science Station, Aqaba, Jordan Federal Republic of
Germany
rhamq@yahoo.com

The extensive use of giant clams for food, shellcraft and in the live aquarium trade has led to severe depletion of natural stocks throughout their geographical range. A pilot study on the culture of the two Red Sea species, *Tridacna maxima* and *T. squamosa*, has been initiated at the culture facilities of the Marine Science Station in Aqaba, Jordan. Clam culture methods developed in the tropical Pacific have been adapted and modified to the conditions and climate at their northwestern limit of distribution. Artificial induction of wild broodstock, larval to post-metamorphic rearing, and land-based nursery culture have been attempted over a yearly cycle, showing pronounced seasonality in reproductive success. Combined heat- and serotonin-induced winter spawnings showed protracted larval development and total mortality during pre- and post-metamorphosis. Summer spawnings were partially successful yielding clam juveniles ranging from 2-20mm shell lengths after 3-6 months for both species. Growth rates are continuously monitored. Current research focusses on (1) conditioning of broodstock to extend production of giant clams during the cold season, (2) the use of through-flow systems to decrease larval and post-larval mortalities and (3) the use of giant clams as biofilters in an integrated recirculation system for the polyculture of reef ornamental species, as a show-case for the production of high-valued commodities without harming the environment.

Phylogeographic Patterns in Reef Fishes: Indo-Pacific versus Atlantic*Brian W BOWEN**, *Luiz A ROCHA*, *D Ross ROBERTSON*

P.O. Box 1346, Kaneohe, Hawaii United States of America

bbowen@hawaii.edu

The primary biogeographic partitions for reef organisms in the Indo-Pacific are 1) the land barriers between Indian and Pacific Oceans, and 2) the 5,400 km oceanic gap between central and eastern Pacific. In the phylogeographic surveys to date, the first barrier is associated with strong genetic partitions in reef fish and a variety of invertebrates. The second barrier is less influential, with high connectivity observed between populations of the tropical Americas and Hawaii. A contrasting pattern is apparent in the Atlantic, where the primary biogeographic barriers are 1) the freshwater outflow of the Amazon, between Brazilian and Caribbean Provinces, and 2) the oceanic gap of 4,000 km between eastern and western Atlantic. In the phylogeographic surveys to date, both barriers are associated with strong genetic partitions in reef fish and invertebrates. Hence the shorter oceanic gap in the Atlantic is associated with greater genetic partitions than the corresponding gap in the Pacific. Since the observed genetic partitions are likely harbingers of evolutionary separations, resolving the differences between oceans will likely reveal the factors that are generating biodiversity in both hemispheres.

Physical Oceanography as a Creative Evolutionary Force in Indo-West Pacific Marine Biodiversity*Paul H BARBER**

7 MBL Street United States of America

pbarber@bu.edu

The creation of biodiversity in marine environments is often considered paradoxical as geographic isolation may be overcome by planktonic larval dispersal, limiting the opportunity for vicariant speciation. Pleistocene vicariance in the Indo-Pacific has been frequently implicated as a cause of high biodiversity in this region as biogeographic and phylogeographic patterns often match regional oceanographic isolation associated with low sea levels. This study compares patterns of genetic structure in 13 coral reef associated stomatopods with populations spanning the Maluku Sea, a deep basin that remained open during all Pleistocene low sea level stands. In all species examined, significant genetic breaks in mitochondrial cytochrome oxidase-I are observed. Nuclear data from myosin also demonstrates concordant patterns, suggesting that these intraspecific genetic breaks may represent cryptic species. Although these results indicate that the Maluku Sea is a barrier to dispersal and gene flow the timing of these genetic breaks is highly variable, indicating an absence of shared origin, downplaying the role of Pleistocene low sea level stands in their creation. Rather, it is proposed that the limited exchange of water from the Pacific South Equatorial Current associated with the Halmahera Eddy limits larval dispersal across this region, indicating that specific physical oceanographic processes may be important in the creation of marine biodiversity in the Indo-West Pacific.

Peripatric Speciation and Evolutionary Radiation of *Mastigias* (Scyphozoa) in Marine Lakes During the Holocene: An Island Biogeography for the Seas?*Michael N DAWSON**, *William M HAMNER*, *Laura E MARTIN*

University of New South Wales Australia

mndawson@unsw.edu.au

Exceptions to the long-held belief that marine species are widespread and well-mixed are commonplace but still explained vaguely, often in terms of limited dispersal ability and hard-to-see barriers to gene flow that are poorly quantified. In many marine contexts it is difficult to ascertain a priori the likely connectivity between populations over evolutionary time. Consequently, extreme cases may illustrate particularly well the potential of evolution in marine organisms. Golden jellyfish (*Mastigias*) inhabiting land-locked marine lakes for approximately 10,000 years are behaviorally, genetically, and morphologically distinct; their population dynamics also differ as do their physiologies. Thus, in physical isolation and novel habitats, marine taxa can evolve extremely rapidly, an heterodox finding that is more typically associated with the evolution of terrestrial taxa on oceanic islands. This suggests the rich theory of island biogeography and associated disciplines, such as metapopulation dynamics, apply to marine taxa and have much to contribute to our understanding of patterns of and influences on marine biodiversity including methods of conservation - particularly marine protected areas.

Phylogeography of the South China Sea: Evolutionary Concordance and Conservation Implications*Allen C CHEN**, *Menchie ABLAN*, *Jay M YANG*, *Ho-I LIN*, *Sakanan PLATHOG*, *Chang-Po CHEN*, *Shen HWANG*, *Pei-Jun LIAO*, *Padermsak JARAYABHAND*, *Kwang-Tsao SHAO*

128, 2nd Section, Academia Road, Nankang, Taipei Taiwan

cac@gate.sinica.edu.tw

The South China Sea, extending 2800 km north from the Equator to the Tropic of Cancer and averaging 1000 km in width, encompass the highest diversity of marine species anywhere on Earth. Over 450 out of 800 reef-building coral species, 23 out of 50 species of seagrasses, and 51 species of mangroves are found in the nearshore areas of the South China Sea. These founders provide the shallow water ecosystems, including, coral reefs, mangroves, and seagrass, the capacity to accommodate high marine biota diversity in the region. Concordant phylogeography among these founders and associated organisms may elucidate the common background for the evolution of marine biodiversity in the South China Sea. In this study, genetic structure of several marine organisms, including reef fishes, reef-building corals, mangroves, and horseshoe crabs, examined by mitochondrial and nuclear markers were reviewed. Although these studies were limited by the number of sites surveyed, all the preliminary results, however, tend to suggest four major biogeographic groups in the South China Sea. The groups identified were: (I) a West Pacific group to the east of the Philippines and southeast of Taiwan; (II) a north-central group encompassing northwestern Taiwan, northern Vietnam, and the northwestern Philippines; (III) a southwestern group comprised of southern Vietnam, Gulf of Thailand and the eastern coast of mainland Malaysia; and (VI) a southern group including the southern and central Philippines, eastern Malaysia, and central Indonesia. Evolutionary and ecological forces, including collision of tectonic plates, sea-level changes, and present-day current circulation are highlighted and the implications towards the marine biodiversity conservation in the South China Sea are discussed.

Comparative Phylogeography of Several Unicornfish Species (*Naso*), and their Modes of Speciation

Selma O KLANTEN*

Townsville, Queensland 4811 Australia
selma.klanten@jcu.edu.au

Population genetic structure and phylogeography was examined in three reef fish species of surgeonfish, *Naso lituratus* (Pacific Ocean), *N. elegans* (Indian Ocean) and *N. vlamingii* (distributed throughout the Indo-Pacific). The first two species are sister taxa that diverged from a common ancestor in the Miocene. The control region (dloop) of mitochondrial DNA was sequenced. Genetic differentiation between sub-populations, were very low ($F_{ST} = -0.001$ to 0.005) indicating high levels of gene flow. Diversity indices, haplotype ($h=0.90$ to 1.0) and nucleotide ($\pi = 9.0\%$ to 15.1%), were extremely high, indicating that a large proportion of individuals have unique haplotypes. The extremely high nucleotide diversity indices indicate deep divergences among individuals within populations. This was particularly true for *N. vlamingii*, which has the highest nucleotide diversity so far reported for any reef fish species. Values for diversity indices obtained for *Naso* species appear to resemble those typical of pelagic fishes rather than of other reef fish species. Several factors probably contribute to this: life history traits such as an extensive pelagic larval duration; the ability of larvae to swim for extended periods; the extended evolutionary history of *Naso* species; the long life-span of *Naso* species coupled with their early maturation and overlapping generations. During the mid-late Miocene, when these species diverged, extreme sea level fluctuations occurred over extended periods with resulting cycles of isolation and mixing (secondary contact). This is reflected by the lack of geographic sub-division within each species. However, populations of the common ancestor of *N. lituratus* and *N. elegans* were isolated for sufficiently long periods to permit allopatric speciation. This was not the case with *N. vlamingii*, which has the greatest dispersal capacity of the three species studied, a fact that may be attributed to the semi-pelagic lifestyle of adults of this species in addition to the extended larval duration.

Mushroom Corals (Fungiidae) and Associated Gastropods: Phylogenies and Distributions

Adriaan GITTENBERGER*, Edmund GITTENBERGER, Bert W HOEKSEMA
P.O. Box 9517, NL-2300 RA Leiden Kingdom of the Netherlands
Gittenbergera@naturalis.nnm.nl

Corals are known to harbour various symbionts. Host-parasite associations are therefore important in evolutionary studies related to species diversity. Mushroom corals (Fungiidae) and their parasitic snails (Epitoniidae and Leptoconchus spp.) are ideal model taxa for such studies. A morphology-based phylogeny reconstruction is available for the Fungiidae, but not for their gastropod parasites. We use DNA-sequencing to obtain reliable phylogenies for both the coral and the snail taxa. For this purpose, the snails and their hosts were collected at various Indo-Pacific localities. While doing so, the their habitats were also studied. The DNA-analyses show that there are far more separate gene-pools among the gastropod parasites than had been distinguished as species on the basis of only their morphology. This was most obvious in the endoparasitic *Leptoconchus* species, which do not show much interspecific differences in shell morphology. Nevertheless, their conchological characters were used in the literature to characterize nine morpho-species. However, the molecular data on *Leptoconchus* (c. 150 sequences of CO-1, ITS-1 and ITS-2), indicate that there are at least 18 species, each restricted to its own host coral species. A similar pattern was found for the ectoparasitic wentletraps (Epitoniidae) on mushroom corals. Molecular analyses (c. 200 sequences of CO-1 and ITS-1) suggest that there are at least 12 epitoniids, each associated with its own host species, among the seven that were recognized in the most recent morphological studies. Both morphological data and the DNA-analyses indicate that several species have Indo-West Pacific ranges, being distributed from the Red Sea and the Indian Ocean to the central Pacific Ocean.

Larval Ecology and Speciation in Five *Phestilla* spp. (Gastropoda: Opisthobranchia)

Raphael D RITSON-WILLIAMS*, Sonia SHJEGSTAD, Valerie J PAUL
701 Seaway Dr., Fort Pierce, Florida, 34949 United States of America
williams@sms.si.edu

Cryptic speciation is common in the marine environment, however the processes that lead to speciation remain poorly studied. On the islands of Guam and Palau we found three described and two undescribed species of *Phestilla* feeding on different host corals. The larvae of these nudibranchs show a range of host specificity. *Phestilla melanobranchia* have planktotrophic larvae that require at least 10 days to reach metamorphic competency. Adult *P. melanobranchia* are known to eat several genera of corals within the Dendrophyllidae. *Phestilla sibogae* has lecithotrophic larvae that reach metamorphic competency 4 days after hatching. *P. sibogae* larvae settle and metamorphose in response to most species of *Porites* corals. *Phestilla* sp. 2 has similar larval traits as *P. sibogae* but metamorphoses in response to *Goniopora* spp. The larvae of *Phestilla minor* can spontaneously metamorphose, but the adults are only found on *Porites lutea* and *P. annae*. *Phestilla* sp. 1 has similar larval traits as *P. minor* and is only found on *Porites rus* and *P. cylindrica*. Since *P. melanobranchia* larvae can disperse widely and can feed on different genera of corals we would predict high genetic exchange throughout its range in the Indo-Pacific. *P. minor* has a short larval dispersal phase and specificity to only two coral species. Their larval traits make *Phestilla minor* and *P. sp. 1* likely candidates for cryptic speciation. These nudibranchs illustrate the importance of larval ecology as a process of speciation in the marine environment.

Comparative Fertilization and Morphological Studies of the Genetically Diverged Species of Pacific Sea Urchins (Genus, *Echinometra*) on the Okinawan and Hawaiian Coral Reefs

M Aminur RAHMAN*, Yuji ARAKAKI, Yuji HIRATSUKA, M Saifur RAHMAN, Tsuyoshi UEHARA
Department of Chemistry, Biology and Marine Science, faculty of Science, University of the Ryukyus, 1 Senbaru, Nishihara-cho, Okinawa 903-0213, japan
arahman1963@yahoo.com

The Indo-pacific (IP) tropical sea urchins belonging to the genus *Echinometra* composed of at least four or five independent gene pools. Among them, two sympatric *Echinometra* sp. C (Ec) and *Echinometra oblonga* (Eo) inhabiting on the Okinawan reef margins and one, *Echinometra* sp. E (Ee) commonly occurred on the Hawaiian reef flats were examined through a series of cross-fertilization and morphological studies. Cross-fertilization rates between sympatric Ec and Eo in either directions were higher compared to those between Ec and allopatric Ee under limited and lower concentration of sperm, whereas these values were very low with the eggs of Eo and sperm of Ee and vice versa. The lower fertilization success between the Hawaiian and Okinawan black urchins (Ee and Eo) indicated that gamete recognition molecules have recently been evolved. Such a system might eventually lead to gametic incompatibility and speciation process between these species. Morphological characteristics of gametes, spines, pedicellaria valve length, Aristotle's lantern and spicules of gonad and tube feet of Ee were differed from Eo but showed closer relations to Ec, while other characteristics such as test sizes and pore pair ratios of Ee were closer to Eo. The closer affinity of majority of the characteristics of Ee to those of Ec indicated the possibility that they were recently evolved into distinct species in the Indo-pacific.

Phylogeography and Conservation of the Horseshoe Crab, *Tachypleus tridentatus*, in the South China Sea

Ming Jay YANG*, Chaolun Allen CHEN, Sakanan PLATHOG, Hwey-Lian HSIEH, Padersak JARAYABHAND, Chang-Po CHEN
128 Academia Rd. Sec.2, Nankang, Taipei, Taiwan 11529 Taiwan
ymt@gate.sinica.edu.tw

The Indo-West-Pacific region (IWP) hosts the highest marine biodiversity on Earth. Diversified habitats, including coral reefs, mangroves, seagrasses, mud flats, and the deepsea, play an important role in the formation of biodiversity in the IWP. Amongst them, coral reef and reef-associated organisms are the examples to describe the IWP biodiversity and studied in detail for their evolutionary histories. Whether the none reef-associated marine organisms share the concordant evolutionary patterns of coral reefs in the IWP is worthy for the further investigation. The concordance among different habitats can be used to deduce the common mechanism that forms the IWP marine biodiversity. In this study, genetic variation of mitochondrial (mt) AT-rich region in the "living-fossil" horseshoe crab, *Tachypleus tridentatus*, were revealed for 82 individuals collected from 4 populations in the South China Sea, including Kinmen (KT) and Penghu Islands (PT) in Taiwan, Angsila in Thailand (AT), and Kawthaung of Burma (KB). Pairwise difference (*Fst*) indicated a significantly deep divergence between KB and the rest Pacific populations, suggesting a concordant pattern of Indian-Pacific tectonic plate divergence revealed in the previous studies of reef-associated invertebrates (giant clams and starfishes) in the IWP. Haplotype phylogeny constructed by neighbor-joining algorithm and the network derived from the nested clade analysis (NCA) demonstrated that KT and PT formed a significantly different clade from AT in the South China Sea, indicating that sea-level changes and present-day current circulations may play an important role in retarding gene flow between Gulf of Thailand and the populations of northern South China Sea. The implications towards the *Tachypleus tridentatus* conservation in the South China Sea are also highlighted.

Phylogeography and Connectivity of Zebra Coral, *Oulastrea crispata* (Scleractinia; Faviidae) in the West Pacific

Ho-E LIN*, Yi Ting LIEN, Katherine K LAM, Hironobu FUKAMI, Nancy KNOWLTON, Padersak JARAYABHAND, Chaolun Allen CHEN
R403, Center for Biodiversity Research & Institute of Zoology, Academia Sinica, Nankang, Taipei, Taiwan
queenone@gate.sinica.edu.tw

The West Pacific is rich by the high diversity of scleractinian corals. The scleractinian corals may have connectivity through ocean currents, such as the Kuroshio Current or the South China Sea Current. We quantified the genetic variability within and among populations of the widespread scleractinian coral, *Oulastrea crispata*, along the temperate Japan, subtropical Ryukyu Archipelago and the Penghu Islands, Taiwan, and Hong Kong, Weichou Islands, tropical Hainan Island, southern China, Gulf of Thailand using sequences of internal transcribed spacers (ITS1-2) from ribosomal DNA. Geographic patterns in genetic variability were deduced from a nested clade analysis (NCA) performed on a parsimony network haplotype and an analysis of molecular variance (AMOVA). Among 109 individuals distributed across 13 populations, 27 unique haplotypes were detected that encompassed the range of *O. crispata*. Although high haplotypic but low nucleotide diversity is detected for *O. crispata* ITS, Tajima D and Fu and Li's tests support the scenario of ranging expansion followed by population growth. In addition, NCA suggested that the population differentiation among Gulf of Thailand and the rest of populations can be best explained by restricted gene flow due to isolation by distance. AMOVA analysis revealed the pattern of restricted genetic flow among population of *O. crispata* on Japan, the Penghu Islands, Taiwan, and Gulf of Thailand seems to be associated with the present surface ocean current on this side of the West Pacific.

Diversity and Distribution of Species in Marine Lakes, Palau: Testing Island Biogeographic Hypotheses in Marine Taxa

Michael N DAWSON, Lori J BELL, Laura E MARTIN*
Sydney, NSW 2052, Australia Australia
mndawson@unsw.edu.au

Increasing evidence of limited gene flow among populations of marine species demonstrates marine ecosystems are more isolated than once assumed. Yet our understanding of the processes that generate, and the results of, isolation in marine taxa remains poor, at least in part because it is often difficult to ascertain a priori the likely connectivity between populations over evolutionary time. Consequently, extreme cases, such as land-locked marine lakes, may illustrate particularly well the patterns and processes of evolution in marine organisms in the same way that oceanic islands and freshwater lakes elucidate patterns of evolution in terrestrial and aquatic taxa. Here we describe the distribution and diversity of Indo-West Pacific coastal marine species in land-locked marine lakes in Palau. These lakes harbour many species new to science, peculiarly high abundances of normally rare species, novel species interactions, and show considerable variation in species diversity. We use these data to test key island biogeographic hypotheses including, for example, relationships between species diversity and area, distance from the 'mainland', local and regional diversity, and time since isolation. These approaches will increase our knowledge of patterns of, and influences on, marine biodiversity in marine lakes and a wide range of other potentially island-like situations, including hydrothermal vents, seamounts, atolls, ocean islands, and estuaries. The approach is also pertinent to conservation biology, particularly management of invasive species and marine protected areas.

Behavioral Variation in *Octopus aculeatus* on Sulawesi, Indonesia

Christine L HUFFARD*
Department of Integrative Biology, 3060 VLSB, University of California, Berkeley, CA, USA
chuffard@socrates.berkeley.edu

For widely distributed, behaviorally complex animals such as octopuses, geographic variation in the behavioral repertoire may indicate site-specific responses to the environment. *Octopus (Abdopus) aculeatus* is a small, well-camouflaged diurnal octopus found on intertidal reef flats of the Philippines, Indonesia and Queensland, Australia. Males aggregate around females and encounter each other frequently, establishing a size-based dominance hierarchy for mates. Large guarding males are dominant over smaller satellite males that either guard opportunistically or sneak matings. Mating and aggressive behavior were studied at naturally occurring high and low small-scale population densities in North and Southeast Sulawesi to help determine the plasticity of intraspecific interactions and mating strategies. Reproductively active males and females formed holes adjacent to each other at both high and low densities, however aggression and mate guarding behaviors were reduced at low densities. The relative copulation rates of dominant and non-dominant males at varying densities are discussed.

Feeding Apparatus Specialization and Ecological Diversification in Angelfishes (Pisces: Pomacanthidae): The Implications of a Novel Feeding Mode?

*Nicolai KONOW**, David R BELLWOOD

Douglas Campus QLD 4811 Townsville Australia

Nicolai.konow@jcu.edu.au

We examined functional morphology, linkage kinematics and performance characteristics of feeding apparatus types in representative Indo-Pacific pomacanthid fishes. Three linkages appear of major importance in pomacanthid food procurement: An intra-mandibular (I-M) articulation, of modified construction and function to previously described examples, facilitates jaw closure with the mandible depressed. Hyomandibular rotation facilitates anteroposteriorly movement of the suspensorium (previously identified in cichlid and chaetodontid genera). The interopercular-articular linkage appears of importance in mandible depression (previously only suggested for larval teleosts). Kinematics of these linkages, and novel patterns of onset, duration, and magnitude of movement in cranial, and sternohyoid linkages, characterise a pomacanthid grab-and-tearing feeding mode with performance characteristics distinct from previously described teleost feeding modes. A variety of manipulation feeding, grab-and-tearing involves a high degree of morphological and biomechanical complexity, yet appears most important in basal pomacanthids, enabling large, robustly built and omnivorous taxa to prey on attached and structurally resilient prey in confined microhabitats where large size would otherwise obstruct foraging. Contrary, in derived pomacanthid taxa, feeding apparatus architecture remains largely unaltered, while reductions in linkage robustness and specimen size, combined with altered kinematic profiles correspond with a radiation in diversification of feeding ecology. The implications of the grab-and-tearing feeding mode on patterns of ecological diversification in Indo-Pacific pomacanthids are discussed in an evolutionary context.

Indo-Pacific Coral Reefs: A Test to the Neutral Theory

*Maria DORNELAS**, Sean R CONNOLLY, Terence P HUGHES

School of Marine Biology and Aquaculture, James Cook University, Townsville, 4811 QLD AUSTRALIA Australia

Maria.Dornelas@jcu.edu.au

It has been proposed that the neutral theory can explain the structure of coral assemblages. Here we compare neutral model species abundance distributions to a multi-scale coral dataset. We fitted the neutral model to species abundance distributions across three spatial scales (site, island and region), three reef habitats (flat, crest and slope), and five regions across the Indo-Pacific biodiversity gradient. The shape of the species abundance distribution is almost invariant across spatial scales. Estimates of the fundamental biodiversity number vary predictably across the biodiversity gradient. Estimates of immigration rate are consistently high. The neutral model has consistent and significant deviations from our data. Consequently, the neutral theory, in its present form, is inconsistent with the species abundance distributions observed in coral assemblages.

Marine Biodiversity Hotspots in the Indo-Pacific Ocean

*Fabio MORETZSOHN**

1525 Bernice St., Honolulu, Hawaii 96817, USA

fabio@bishopmuseum.org

In order to prioritize regions for conservation, the marine biodiversity hotspots of the Indo-Pacific region were studied. Biodiversity hotspots are here defined as regions with high diversity and high endemism, which coincide with some of the areas most threatened by anthropogenic changes, habitat loss and climate changes. The goals of this project are to: 1) produce comprehensive Indo-Pacific diversity datasets for marine invertebrates (mollusks, crustaceans and corals) and fishes; 2) map the distribution of these species and 3) make a composite map of the Indo-Pacific invertebrates and fishes, to understand the patterns of diversity and recognize diversity hotspots to make recommendations for conservation and planning. Distributional data from the taxonomic literature have been used to compile a large database of some 30,000 records, representing more than 2,100 species. More data are being added in this ongoing project. Coordinates for each location have been established using the literature, gazetteers, maps and specimen labels. Analyses are being done in ArcGIS, producing maps of distribution for each species, and then overlaying them for biodiversity analysis. Preliminary results based on the distributions mapped thus far show that patterns of diversity are congruent with previous studies, with high diversity centers in the Malayan peninsula, Philippines, Eastern and Western Australia, New Zealand, Hawaii, southern Japan, and to a lesser degree, Tanzania, Red Sea, Arabian Gulf, and the Northeast Pacific. A discussion of the patterns of diversity per group of organism, hotspots of diversity and centers of endemism will be discussed, as well as recommendations for conservation.

Distribution Patterns of Benthic Marine Algae: Hotspots of Generic Richness and Endemism

*Ailsa P KERSWELL**, Terry P HUGHES

Townsville 4811, Queensland Australia

ailsa.kerswell@jcu.edu.au

Consistent patterns are evident in the global distribution of many marine organisms, such as corals and reef fish. For these organisms, biodiversity hotspots occur in the Indo-Australian Archipelago (IAA) and are generated primarily by the overlap of wide ranging species. Analyses of marine algal distributions have not extended beyond a regional scale. Consequently, broad scale biogeographic patterns of benthic marine algae are largely unknown. This study forms the first comprehensive examination of global patterns in marine algal biogeography. Over 300 literature-based checklists were used to generate global-scale geographic ranges for all currently recognised algal genera. Algal biodiversity hotspots were identified by overlaying generic ranges in a GIS and contours of generic richness interpolated from points of known richness. Areas of highest algal generic diversity occur in the Caribbean, the Mediterranean Sea, Japan, southern Australia and the IAA. With the exception of the IAA, the above areas represent hotspots outside of regions traditionally known to be rich in marine diversity and are situated in both tropical and temperate seas. This is in contrast to corals and reef fish, for which diversity drops off steeply towards temperate regions. High algal diversity is a result of different patterns in tropical versus temperate locations. In the IAA and the Caribbean endemism is low and diversity is generated by the overlap of wide-ranging genera. In the temperate regions, however, endemism is as high as 70% in some groups, suggesting diversity is generated by the concentration of many small ranging species in a restricted area. Identifying areas of high algal generic richness and endemism is an important first step in understanding the processes underlying the distribution of benthic marine algae.

Causes of Latitudinal Gradients in Species Richness: A Test with Shorefishes in the Tropical Eastern Pacific*Camilo MORA**, *Ross ROBERTSON*

401 Sunset Winsor On Canada N9B 3P4 Canada

moracamilo@hotmail.com

The inverse relationship between species richness and latitude is a well known, but poorly understood, macroecological pattern. Using a comprehensive database on the fish fauna of the Tropical Eastern Pacific, we delineated latitudinal diversity patterns for species with differently sized ranges, and assessed how those patterns relate to the Mid-Domain effect, and to proxies for energy input, environmental variability and habitat availability. The Mid-Domain effect is the strongest determinant of the regional pattern of species richness of the entire fauna. This largely reflects its strength as the determinant of the distribution of widespread species, which are strongly represented in that entire-fauna pattern. In contrast, the only predictors of the diversity of small-range species (habitat variables), had no effect on the entire-fauna pattern. There were no indications that energy supply or environmental stability were important determinants at any level within the fauna. Latitudinal (Rapoport) trends in range-size in this fauna, although present, were shown to arise as corollaries of the Mid-Domain effect. Our results demonstrate the failure of conventional analyses based on entire faunas to adequately represent all faunal components, especially small-range species, which often are the more threatened members of a biota.

Nonindigenous Marine Species on Coral Reefs in the Main Hawaiian Islands: Limited by Reef Biodiversity?*Steve L. COLES**, *Frederique KANDEL*, *Pakki REATH*, *Kenneth LONGENECKER*

1525 Bernice St. United States of America

slcoles@bishopmuseum.org

Rapid assessments for nonindigenous (introduced) and cryptogenic (of uncertain origin) marine organisms were conducted in 2002-2003 at 41 coral reefs sites on the islands of Kaua'i, O'ahu, Moloka'i, Maui and Hawai'i using timed searches on areas of 312 m² at each of the sites. Only 26 nonindigenous or cryptogenic species (collectively termed NIS), comprised of three species of algae, 19 invertebrates, and four fishes, were recorded from a total of 486 taxa identified on the entire study, and 17 of the 26 NIS occurred at only one or two sites. The most NIS that occurred at any site was six, and 21 of the sites had less than three. If the three species of fish that were introduced in the 1950s and known to occur throughout Hawai'i are excluded, over half the sites had less than two NIS. Invertebrate NIS usually occurred cryptically within recesses of the reef, and none were abundant or dominant at any reef site. These low numbers of introduced or cryptogenic species on reefs contrast strongly with the large numbers of NIS that occur in Hawaiian harbors. Best subsets regression analysis compared the numbers of NIS occurring at each site against values measured or assigned to a number of factors that may influence the spreading and proliferation of introduced marine species. Over 65% of the variance in numbers of NIS was explained by a highly significant relationship of NIS increasing from open coastlines to embayments to semi-protected harbors, and by a highly significant interaction between ocean non-exposure and native species richness. This analysis suggests that, in embayments and semi-enclosed environments, higher native species diversity may limit the opportunities for introduced species to establish themselves.

Sponge Beta Diversity in the Spermonde Archipelago, Indonesia*Nicole J DE VOOGD**, *Rob W M VAN SOEST*Mauritskade 57, Box 94766, 1090 GT, Amsterdam, The Netherlands Kingdom of the Netherlands
voogd@science.uva.nl

Sponges are the most basal of all metazoans, important structural components of reefs from the tropics to the (ant)-arctic, and repositories of diverse secondary metabolites with considerable pharmaceutical potential. Very little, however, is known about sponge diversity and how this is related to spatial and environmental processes. In this study we use remotely sensed and locally measured data to show that spatial patterns of sponge similarity among sites in the Spermonde archipelago, Indonesia was significantly related to remotely sensed habitat heterogeneity, the degree of human settlement and depth, but not to the distance between sites. Sponge species richness was significantly related to depth and the degree of human settlement between sampling sites. In contrast to our expectations, oviparous and viviparous species groups responded to the same set of environmental constraints and differences in similarity were unrelated to the distance between sites. The degree of human settlement had a significantly negative impact on species richness and had the greatest effect on the most common species. Our results demonstrate the utility of remotely sensed data in predicting the spatial turnover of diverse species assemblages such as sponges and show that patterns of human settlement in the Spermonde archipelago are already associated with reduced sponge species richness and shifts in community composition. These results should heighten the need to assess and protect marine areas in biodiversity hotspots such as Indonesia.

In Situ Uptake of Ultraplankton by Red Sea Cavity-dwelling and Epi-reefal Sponges*Iris KOETTER**, *Claudio RICHTER*, *Mark WUNSCH*, *Dominique MARIE*Fahrenheitstrasse 6 Federal Republic of Germany
ikoetter@zmt.uni-bremen.de

Sponges abound in Red Sea coral reef crevices, yet how these filter feeders manage to meet their nutritional requirements in plankton-depleted waters remains enigmatic. We carried out comparative in situ measurements of ultraplancton (<10 μ m) uptake rates in nine species of Red Sea sponges, belonging to three ecologically distinct groups: obligate coelobites (OC), living exclusively in coral reef crevices; facultative coelobites (FC), occurring both, inside crevices and on the outer reef surface; and epi-reefal sponges (ER), dwelling only on the exposed reef surface. Retention efficiencies, derived from comparisons of inhalant and exhalant waters taken with microsamplers from 2.9 \pm 1.1 mm (median \pm MAD) diameter oscula, differed between plankton groups: the larger eukaryotic algae were retained less efficiently (around 60%) than the smaller autotrophic prokaryotes *Prochlorococcus* and *Synechococcus* (>90%), with no marked differences between sponge groups. The most abundant but smallest plankton fraction, the heterotrophic bacteria, were retained most efficiently by OC (83 \pm 6%, median \pm MAD), albeit at eight-fold lower pumping rates corresponding to the replacement of an equivalent of their body volume once every 7.2 \pm 2.6 s (median \pm MAD). Low volume throughput and high retention efficiency appear as adaptations of OC to the limited supply of plankton in framework crevices. OC and FC community uptake amounted to 0.60 \pm 0.36 g C d⁻¹ per projected m² of reef, equivalent to one sixth of the gross productivity of the entire reef. ER community uptake was more than one order of magnitude lower, compounding the importance of coelobite filter feeders in harnessing pelagic material for the reef benthos.

Reef Sponges as a Hot Spot of Biodiversity*Carlo CERRANO*, *Barbara CALCINAI*, *Silvia PINCA**, *Giorgio BAVESTRELLO*C.so Europa 26, Genova Italian Republic
cerrano@dipteris.unige.it

Biodiversity management is among the most important challenges of the new century. Recently, new species assemblages in novel marine habitats have been described, contributing to the discovery of new genomes. Scientists and media play high attention to these new science frontiers. Indonesian coral reefs are considered among the richest hot spots regarding marine biodiversity but are still little investigated. Sponges are often described as living hotels, hosting numerous organisms, from protists to fishes. From this point of view Indonesian sponges can be considered a hot spot into a hot spot, representing a key-stone *phylum* that has to be included *in toto* in future conservation programs. At present we are studying the associations between sponges and macroalgae, octocorals and polychaetes in the Bunaken National Park (Indonesia, North Sulawesi). Concerning sponge and macroalgae we recorded a very strict association between the coralline algae *Amphiroa* sp. and the sponge *Mycale* sp. In this case the sponge tissue is confined to a thin layer covering the algae and influencing algae growth pattern. The association between two invasive species coming from the Caribbean is also unusual; the species involved are the octocoral *Carijoa riisei* and the sponge *Desmapsamma anchorata*. *C. riisei* was probably introduced by vessels and the sponge could have been transported attached to the coral. *D. anchorata* covers *C. riisei* completely, so that only coral polyps are visible. Also in this case the sponge affects the growth pattern of its living substratum. The sponge *Achantosstrongylophora ashmorica* can host different organisms. The commonest is the polychaete *Aplosyllis spongicola*, that can reach density of more than 180 individuals/cm³. The same species of polychaete can colonize also the small sponge *Stelletta clavosa*.

Morphological Strategies of Coral Reefs Sponges: Trade-offs between Prevention and Cure*Janie L WULFF**Florida State University, Tallahassee, Florida 32306-1100 United States of America
wulff@bio.fsu.edu

The extreme homogeneity and simplicity of design of sponges allows them to achieve virtually any shape, from thin crusts to enormous barrels to branching arrays of tubes, and everything in between. Skeletal materials with properties as divergent as siliceous spicules and spongin fibers further increase the variety of possible morphological strategies. Sponge species harboring photosynthetic symbionts are constrained to overall growth forms conducive to collection of adequate sunlight, and wave-swept zones are not hospitable to most upright forms. But the wide range of shapes represented among sponges in most habitats indicate that a variety of different combinations of shape, materials, and other characteristics can be successful under the same environmental conditions. Patterns of sponge mortality caused by an assortment of challenges, including hurricanes, diseases, and sedimentation, suggest a strong dichotomy between groups of morphological traits that promote resistance to damage vs. groups of traits that promote efficient recovery from damage. One result of this dichotomous pattern that may be important as conservation issues loom more critically is that species with traits that promote resistance are not good at recovery, and their resistance can be overwhelmed by multiple simultaneous challenges.

Friction and Turbulence on Coral Reefs; Roughness, Waves and Heterogeneity

Clifford J HEARN*

University of South Florida , USGS, 600 Fourth Street South, St Petersburg, Florida, FL 33701 United States of America
cjhearn@usgs.gov

Numerical models need the value of a “roughness length” to describe the friction which a reef offers to the flow of current. Models can only reasonably predict the currents that flow over reefs if this roughness length is taken to be a fraction of a meter which is in marked contrast to the sandy bottom of the ocean which has roughness lengths of order, or less, than one millimeter. The extreme roughness of reefs is clearly due to the height of the roughness elements but the roughness is also increased by the effects of waves via the formation of an exceptionally thick “wave boundary layer”. Without this roughness, the effect of waves breaking on the fore-reef would be to drive currents of many meters per second over the reef and the energy released by the waves would be transported into the lagoon as kinetic energy. Instead, that energy is converted by friction into turbulent eddies and eventually dissipated as heat. The same effect is seen for seagrass meadows (*F.I.M. Thomas, C. Cornelisen, J. Zande. Ecol, 81: 2704, 2000*). According to the Uptake Dissipation Law (*Hearn C. J., Atkinson M. J., and Falter J. L., 2001, A physical derivation of nutrient-uptake rates in coral reefs: effects of roughness and waves. Coral Reefs, 20, 347-356*), turbulent dissipation favors nutrient uptake. Coral reefs are composed of many different types of surface apart from coral and at high currents this turbulence is transported from zones of high production (the roughest parts of the reef) to other areas. This heterogeneity produces some interesting, and important, effects on the dynamics of roughness, water flow and nutrient uptake.

Coral Reef Roughness and its Effects on Wave Boundary Layers

Geno PAWLAK*, Marion BANDET, Vasco NUNES

2540 Dole St., Holmes Hall 402 United States of America
pawlak@hawaii.edu

The turbulent motions generated along the seabed by surface waves play a fundamental role in physical and biochemical processes in coral reef environments through their effects on wave dissipation, sediment transport and suspension, and transport of nutrients. The nature of this turbulent boundary layer over the very rough bathymetry characteristic of coral reefs is not well understood, although this type of inhomogeneous roughness is pervasive in natural settings. In addition, while it is generally accepted that coral reefs present a rough boundary, quantitative measurements of reef roughness are lacking, particularly from the turbulence dynamics perspective. We are carrying out field observations on a coral reef on the south shore of Oahu examining the effects of reef roughness on the physical environment at a number of spatial scales. An acoustic current profiler is used to obtain a high resolution, two-dimensional view of the wave boundary layer in a phase-averaged sense over a wave orbital amplitude (~2 m). These measurements are used to discern turbulent structure and to estimate the associated boundary stress. An array of directional wave gauges is used to determine the integral effect of reef roughness over a larger scale. These observations are used in conjunction with high resolution boat-based measurements of the reef roughness that resolve scales down to 10-20 cm. Field observations of the wave field are compared to results from numerical modeling using roughness maps from the boat-based surveys. Various roughness measures are compared to the equivalent friction roughness scales obtained from boundary layer and wave field observations. The boat-based measurements are validated by diver surveys and are compared to traditional quantities such as rugosity. These field observations are forming the core of a nearshore observatory presently under development that will allow real-time observations of the coral reef in a dynamic, tide and wave influenced environment.

Mass Transfer Limits to Nutrient Uptake by a Wave-dominated Reef Flat

James L FALTER*, Marlin J ATKINSON, Mark A MERRIFIELD

PO Box 1346, Kaneohe, Hawaii, USA, 96744 United States of America
falter@hawaii.edu

Maximum rates of phosphate, nitrate, and ammonium uptake by a reef flat community were estimated based on the attenuation in wave heights across the community and the rate of frictional dissipation these changes represented. Time-averaged flow speeds varied between 0.08 and 0.22 m s⁻¹ across the entire study area and over all days sampled. Observed differences in wave energy fluxes and near-bottom orbital velocities gave an estimate for the bottom friction coefficient (c_b) of 0.22 ± 0.03 which compares well with other estimates of wave friction factors for other reefs (0.28 ± 0.05 and 0.15 ± 0.02). These results were used to estimate nutrient mass transfer coefficients for the reef flat of between 5 and 9 m day⁻¹ for phosphate and between 9 and 16 m day⁻¹ for ammonium and nitrate based on experimental mass transfer relationships and evidence of enhanced mass transfer rates under oscillatory versus steady flow. Significant wave heights just offshore of Kaneohe Bay on one of the sampling days was close to the mean significant wave height over a two-year period (1.9 versus 2.0 m). Therefore, spatially averaged data from this day was taken to give an average value for the phosphate mass transfer coefficient of 8 ± 2 m day⁻¹ for the entire reef flat community over an annual cycle. This value is similar in magnitude to an annually averaged net phosphate uptake rate coefficient of 9 ± 2 m day⁻¹ previously measured for the Kaneohe Bay Barrier Reef flat indicating that phosphate uptake by the reef flat community is occurring near the limits of mass transfer.

Kinetics of Nutrient Uptake in Corals: Bridging the Gap between Biology and Engineering

Fred LIPSCHULTZ*, Kenneth SEBENS

Biological Lane, St. George's, Bermuda
fred@bbsr.edu

Studies of solute transport to corals have focused on two divergent scales, the colony or the community scale while generally ignoring the polyp scale. Depending on the scale choice, the mass flux to a surface can vary by orders of magnitude. Another conceptual difference is that studies generally employ a kinetic transport model for the colony scale, and a diffusive transport model for the community scale, even though they lead to divergent predictions. A final complication is that these studies have utilized concentrations far in excess of ambient reef concentrations and must be extended to submicromolar concentrations where both mechanisms predict uptake rate to be linearly related to concentration. This review highlights these distinctions and discusses recent data for uptake of ammonium and nitrate by corals at concentrations down to 15 nM over a realistic range of flow conditions. The different approaches can be reconciled by considering the flow fields within the experimental apparatus and in the field. We suggest that flow and concentration are often sufficiently low that even coral colonies isolated on an unobstructed reef surface are diffusion limited. Kinetic control is possible under conditions of high flow, such as under waves or in areas of strong currents, and at high nutrient concentrations.

Modelling of Nutrient Gradients in Three-dimensional Images - and Simulated Morphologies of a Branching Coral

Jaap A KAANDORP*, Rolf P M BAK, Mark J A VERMEIJ

Kruislaan 403, 1098 SJ Amsterdam Kingdom of the Netherlands
jaapk@science.uva.nl

Understanding morphogenesis of scleractinian corals is crucial to obtain insight into their susceptibility to changes in the external physical environment. Using simulation models we studied the three-dimensional flow pattern and distribution of nutrients for the scleractinian *Madracis mirabilis*. Three-dimensional images of *M. mirabilis* were obtained using X-ray (Computed Tomography) scanning techniques and simulated morphogenetic models. The three-dimensional morphogenetic model is based on an accretive growth model in which the coral growth process is simulated by a surface normal deposition process (representing the light-dependent calcification process) and where the thickness of new growth layers is determined by the local availability of (simulated) nutrients. To model the advection-diffusion of nutrients in the complex-shaped coral morphologies, a particle-based technique (the lattice Boltzmann method) was used. The simulation experiments showed that in branching corals, relatively large boundary layers and stagnant zones are formed between the branches. Such regions, where mass-transfer is diffusion-limited, play a crucial role in the morphogenesis of *M. mirabilis*. Furthermore the flow patterns and the spatial and temporal dispersion of nutrients in simulated and actual morphologies of *M. mirabilis* is compared and discussed.

Water Flow and its Effects on Coral Nutrition across a Broad Range of Reef Habitats in Bermuda

Kenneth P SEBENS*, Fredric LIPSCHULTZ

100 Morrissey Blvd, Boston, MA 02125

United States of America

Kenneth.Sebens@umb.edu

Water movement over reef corals modulates nearly all processes of coral biology. On a scale of meters or less, flow microhabitats differ substantially, causing measurable differences in coral growth rate in field experiments. At the polyp to colony scale, flow affects the processes of photosynthesis and suspension feeding by corals, uptake of dissolved nutrients, the escape behavior of zooplankton encountering corals, and the ultimate success of phototrophy, heterotrophy and calcification. At larger scales, there is a characteristic range of flow regimes on reefs, from high velocity oscillatory (wave-induced) flow in shallow reef zones, to unidirectional flows of low velocity in some deep reef and lagoonal habitats. We conducted three years of field measurements on a range of reef habitats in Bermuda to quantify the flow environment over a range of spatial scales. Most habitats had oscillatory flow with velocities less than 5 cm.s⁻¹. Shallow reefs at wave exposed locations, and very shallow mid platform reefs, experienced oscillatory and unidirectional flows over 10 cm.s⁻¹. The effects of flow on coral biology were then integrated using a model that combines flow effects on the contributions of zooxanthellae (photosynthesis), nutrient uptake and suspension feeding to coral energetics and growth. Each source of energy and nutrients is affected differentially by the type and magnitude of flow, which in turn depends on reef location and local conditions. Dissolved inorganic and organic compounds can be important sources of limiting nutrients in all habitat types, although under low flow conditions and low nutrient concentrations common on Bermuda's reef platform, corals would frequently find it difficult to acquire sufficient nutrients. Under most reef conditions, increased flow could improve nutrient uptake rates, particle capture, and gas exchange resulting in higher coral growth rates.

Exposure to Multiple Physical Stressors Explain Spatial Patchiness in Coral Bleaching: Results of a Manipulative Field Experiment

Hunter S LENIHAN*

Bren School, UCSB, Santa Barbara, CA 93106-5131 United States of America
Lenihan@bren.ucsb.edu

Spatial patchiness in coral bleaching and associated mortality is a perplexing feature of coral reef ecosystems. Species and genotype specific resistance and/or resilience to heat stress of both corals and zooxanthellae are factors commonly used to explain spatial variation in bleaching responses. Using a meso-scale manipulative field experiment I tested whether bleaching and the subsequent mortality of corals varied across a lagoon in response to combinations of flow speed, sedimentation, and increased sea surface temperature (SST). Small colonies of *Pocillopora eydouxi* (5 cm in diameter; n=20; total=180) and *Acropora eleyi* (6 cm tall; n=20; total=180) were transplanted to experimental reefs constructed at a low-sedimentation site near the reef crest and a relatively high sedimentation site on the fringing reef of Moorea, French Polynesia. A third site in the mid-lagoon allowed for experimental reef treatments with moderate sedimentation rates. Reef height (5-cm, 25-cm, and 1-m tall) was used to control local flow speed and sedimentation rates around transplanted corals. Variation in reef height, a time series of coral response data, and an unanticipated two-week period of low wind velocity and subsequent high water temperature provided insight into the single and combined effects of routine environmental constraints on coral bleaching dynamics. Regardless of location, only corals exposed to a combination of high SST, low flow, and high sedimentation had a high percent of tissue that bleached and subsequently died. Corals exposed to high temperature but low sedimentation experienced bleaching but low rates of mortality (i.e., high rates of recovery). *P. eydouxi* displayed a greater resistance and resilience to the combination of stressors than did *A. eleyi*. Results of this field experiment indicate that multiple stressors combine to enhance the impact of elevated SST on coral demographics, that effects are species and microhabitat specific, and that hydrodynamic conditions are critically important.

Connecting the US Florida Keys Coral Reef Ecosystem to the Hydrodynamics: A Numerical Model Study

Villy KOURAFALOU*, Roland BALOTRO, Tom LEE

4600 Rickenbacker Causeway, Miami, FL 33149 United States of America

villy@rsmas.miami.edu

A comprehensive, three-dimensional hydrodynamic model of the coastal seas adjacent to the U.S. Florida Keys has been developed. The study goal is to link the shallow coastal regions that encompass the Florida Keys Reef Tract to adjacent oceanic and shelf flows that play an important role in the water circulation and exchange. It has been shown through physical and biogeochemical observations that the coral reef ecosystem in the Florida Keys is greatly influenced by wind and eddy induced upwelling. Moreover, frontal eddies that travel along the Florida Current play an important role in the replenishment of coral reef organisms in the Florida Keys. The modeling strategy is to follow a nested approach, where the regional model around the Florida Keys is nested within a larger scale Atlantic Ocean and Gulf of Mexico hydrodynamic model. Both regional and large scale models are implementations of the HYCOM (Hybrid Coordinate Ocean Model, <http://hycom.rsmas.miami.edu>), a finite-difference hybrid isopycnal/sigma/z-level model. HYCOM behaves like a conventional sigma model in very shallow and/or unstratified oceanic regions, like a z-level coordinate model in the mixed layer or other unstratified regions, and like an isopycnic-coordinate model in stratified regions. This flexibility makes HYCOM an excellent choice for the simulation of the oceanic hydrodynamic interactions around reef systems, as it can be easily coupled with a range of ecosystem models that focus on reef processes. Furthermore, the nesting approach ensures the connectivity of the Florida Keys reefs with the Caribbean coral reef system at large.

Hydrodynamic Controls on the Recovery of an Isolated Coral Reef System Following Mass Coral Bleaching

Richard BRINKMAN*, Luke SMITH, James GILMOUR, Craig STEINBERG
PMB 3 Townsville MC, QLD, 4810 Australia
r.brinkman@aims.gov.au

The Scott Reef system is an isolated group of reefs located approximately 270 km off the northwestern Australian mainland. The distance to the nearest reefs is in excess of 240 km. In 1998, the coral communities at Scott Reef suffered a catastrophic mortality episode resulting from thermal stress. The bleaching event killed the vast majority of corals to a depth of 30 metres across all habitats, leaving few surviving corals across the entire Scott Reef system. There has since been virtually no recovery of the coral communities at Scott Reef, due to complete recruitment failure. Recovery of communities devastated by major disturbances is usually facilitated by the arrival of new individuals onto the reef via sexual recruitment. This study contrasts the larval competency periods for local coral species with regional estimates of larval transport times determined from satellite-tracked, current-driven drogues, in order to quantify the systems reproductive isolation and assess the ecological timescale of recovery.

Water Flow Suppresses Photoinhibition of the Reef-building Coral *Acropora digitifera*

Takashi NAKAMURA*, Hideo YAMASAKI
Nishihara, Okinawa 903-0213, Japan
takasuken@yahoo.co.jp

Water motion is an environmental factor crucial for reef-building corals. We have recently reported that water flow potentially suppresses coral bleaching induced by high seawater temperature. However, its mode of action has remained unclear. Here we show that water flow mitigates the light-induced inhibition of photosynthetic activity (i.e. photoinhibition) in symbiotic algae. Using PAM chlorophyll *a* fluorometer, we investigated effects of artificial water flow on photoinhibition of zooxanthellae within *A. digitifera*. We conducted series of laboratory experiments under combinations of various light intensity, water temperature, and water flow velocity. In short-term experiments, F_v/F_m value, a measure for photoinhibition of PSII, was always greater in high flow-treated samples than those in low water-flow treatment. The suppressive effect strongly depended on water flow velocity. Similar results were obtained in long-term outdoor experiments. Visible bleaching was pronounced in the corals treated with flow-limitation compared to those treated with faster flow. Based on these short and long-term observations we suggest that water flow is required to avoid photoinhibition of coral *A. digitifera*.

References Nakamura T., Van Woesik R. (2001). *Mar. Ecol. Prog. Ser.* 212: 301-304 Nakamura T., Van Woesik R., Yamasaki H. (2003). *Mar. Ecol. Prog. Ser.* 256: 287-291

Coral Bleaching Limitations by Wave-induced Vertical Mixing at He Reef Front

Mal L HERON*, William J SKIRVING, Scott F HERON
James Cook University, Townsville, Australia 4811 Australia
mal.heron@jcu.edu.au

Elevated water temperature near the surface is the main physical cause of coral bleaching. To get an elevation in sea surface temperature there has to be a consistent high input of heat from insolation, and there has to be a decrease in the cooling of the surface water by mixing through the vertical water column. Several mechanisms have been discussed for such heat transfer in the context of coral bleaching, including current shears and wind waves. Here we make a first-order estimate of the effects of swell in mitigating the stratification of the water column near the reef front. The calculation uses linear wave theory to estimate the energy in the swell wave as it approaches the reef front. This energy is partitioned at the abrupt reef encounter (assumed to occur within a wavelength), into reflection, conversion to turbulent kinetic energy, and into a breaking bore which crosses the reef front. The partition of energy into turbulence at the reef front is used to estimate the vertical mixing parameters for an initially stratified layer. Using a reasonable range of parameters, it is shown that a swell of a mere 20 cm will generally cause sufficient mixing to limit stratification and coral bleaching at the reef front. Under conditions of calm wind and low currents, it is shown that swell from a distant energy source may be the only physical limit to bleaching. One consequence of this result is that, on a statistical level, we can expect diminished bleaching on the side of a reef which is open to prevailing swell.

Hydrodynamics Affects Photodamage and Bleaching Stress in *Porites divaricata*

Sean W KINANE*, Florence I M THOMAS
4202 E. Fowler Ave., Tampa, FL 33620 United States of America
skinane@helios.acomp.usf.edu

Porites divaricata is often found in very shallow areas with high solar irradiance, temperature, and water velocity, yet does not commonly bleach, which suggests that water motion may play a role in alleviating bleaching in this species. We tested the hypothesis that increased water motion reduces bleaching stress using paired flume experiments with different water velocities under conditions of high temperature and / or high solar irradiance. We examined whether water motion affected dynamic photoinhibition or chronic photoinhibition (photodamage). Minimal fluorescence, F_o , increases more rapidly in low-velocity flow than in high-velocity flow, which is consistent with an increase in chronic photoinhibition (photodamage) of the zooxanthellae photosynthetic apparatus. Bleaching stress, measured as a decrease in photochemical efficiency of PSII (F_v/F_m), is diminished in high-velocity flow compared to low-velocity flow even after only one day of exposure to bleaching conditions.

Effects Water Flow on the Sediment Tolerance of Corals

*Jeremy J SOFONIA**, *Kenneth ANTHONY*, *Bette L WILLIS*

Townsville, Queensland 4811 Australia

jeremy@sofonia.com

Sedimentation is an important disturbance factor on coastal coral reefs worldwide. However, little is known about the interactions between sedimentation stress and other physical factors, such as water flow. Here we test the hypothesis that high water flow alleviates the stress effect of high sediment concentrations by preventing tissue smothering, using the coral *Turbinaria mesenterina* as a case study. In a controlled laboratory experiment, 100 colonies were exposed to three sediment treatments: low ($0.8 \pm 0.3 \text{ mg cm}^{-2}$), moderate ($16.2 \pm 4.4 \text{ mg cm}^{-2}$), and high ($110.7 \pm 27.4 \text{ mg cm}^{-2}$) under two turbulent flow velocities: low ($0.73 \pm 0.01 \text{ cm s}^{-1}$) and high ($23.7 \pm 6.7 \text{ cm s}^{-1}$) for a period of 30 days. Sediment levels refer to sediment availability (for resuspension) per unit surface area of the tank floor. As a measure of physiological stress, we compared growth rates, lipid concentrations, and photosynthetic efficiency between treatments over time. Surprisingly, there were no significant differences between any of the treatments, indicating that *T. mesenterina* is highly robust to sediment concentrations $>100 \text{ mg cm}^{-2}$, regardless of hydrodynamic conditions. This exceptional sediment tolerance of *T. mesenterina* explains, in part, its dominance on many high-turbidity reefs in inshore areas of the Great Barrier Reef lagoon.

An Integrated Study of Fine Suspended Sediment Transport in a Coral Reef Lagoon, New-Caledonia

*Sylvain OUILLOIN**, *Pascal DOUILLET*, *Loys SCHMIED*, *Serge ANDREFOUET*, *Christophe CHEVILLON*, *Aymeric JOUON*, *Renaud FICHEZ*

BP A5, 98848 NOUMEA New Caledonia

ouillon@noumea.ird.nc

We present results on the integrated study of fine sediment dynamics in the southwest lagoon of New Caledonia, involving in situ measurements, numerical modelling and remote sensing. Coral reef lagoons of New Caledonia cover a total area of $23,400 \text{ km}^2$. The study area extended over an area of $2,000 \text{ km}^2$. Wind, currents, CTD and turbidity profiles, water and sediment sampling, and hyperspectral reflectance have been regularly recorded so as to support the analysis of hydrodynamics and sediment transport, calibration and validation of the models, and satellite data inversion. The numerical models include a 3D hydrodynamic model, the wave model Wavewatch III and a classical 3D numerical model for cohesive sediment transport. A 500-m grid size is used in the models. The fine sediment transport is modelled by use of several equations of transport, one per grain-size class. It involves the formulations of Krone and Partheniades for the exchange rates of particles through deposition and erosion, respectively. As bathymetry and sedimentology are highly variable throughout the lagoon, it was not efficient to calibrate the sediment transport model through local time-series. We calibrated the model using sedimentological characteristics and maps of turbidity obtained from OBS measurements and from Landsat7 ETM+ data. Parameters involved in the model are described and discussed. Turbidity distribution and its variability were analyzed from data collected during 20 field campaigns (1997-2001) under non-storm conditions. Its temporal and spatial variations were analyzed against river discharges, wind stress and direction. It was shown that interannual variability in turbidity apply both to the mean turbidity level and to its vertical distribution. Sediment inputs by rivers were likely expected during La Nina or neutral periods. An increase in stratification in turbidity was observed during La Nina. Resuspension was enhanced by stronger winds during El Nino.

Field Measurements and Analysis of Currents and Fine Sediment, Thermal and Coral Larvae Transport in Sekisei Lagoon, Okinawa

*Jun MITSUI**, *Kazuo NADAOKA*, *Katsuya HAMASAKI*, *Mitsuhiro UENO*, *Tadashi KIMURA*, *Saki HARII*, *Enrico C PARINGIT*, *Hitoshi TAMURA*, *Youichi SUZUKI*, *Wataru KUMAGAI*, *Nina YASUDA*, *Kenji ISHIGAMI*, *Hiroyasu IIZUKA*

2-12-1, O-okayama, Meguro-ku, Tokyo 152-8552, Japan

mitsui@wv.mei.titech.ac.jp

Coral reefs in the Ryukyu Islands are prone to various threats, such as outbreaks of crown-of-thorns starfish, red silt pollution, and coral bleaching by high water temperature. Sekisei Lagoon, which is the largest coral reef area in Japan, has a rich ecosystem and is expected to be an important source of coral larvae to supply distant reefs. Such an ecologically significant reef body requires suitable preservation measures. However, even the fundamental information about the physical environments like currents is still lacking. To capture the actual current field, fine sediment, thermal and coral larvae transport, we deployed data-logging instruments according to a multi-point moored buoy system. We also conducted surface particle tracking using GPS-installed small drifters and collected coral larvae on various points. Furthermore, we calculated the current by numerical simulation. The main conclusions are as follows: (1. current characteristics) Currents are dominated by tidal component, and it is found that the magnitude, the principal direction and the phase of velocity fluctuations changed considerably with location due to the influence of complicated topography. On the other hand, as the unidirectional or residual flow component, wind-driven current has appreciable contributions. (2. sediment transport) There is an appreciable rise in turbidity at flooding in the rivers, restricted in the areas closed to the two islands (Ishigaki and Iriomote) flanking the lagoon, and is especially high on the side of Ishigaki Island due to intensive land use activities. Moreover, during a typhoon, a remarkable rise of turbidity by re-suspension of the bottom sediments was apparent in the whole Sekisei Lagoon. (3. water temperature characteristics) The warm water mass, which may be propagated as the branch current of Kuroshio reach and intrude into the lagoon, was observed. (4. coral larvae transport) Analysis of sampled larval data and the drifters' trajectories suggest possible transport of larvae to outside the lagoon.

Wind Driven Currents in the Shiraho Coral Reef Area of Ishigaki Island, Southwest Japan

*Shak M B RAHAMAN**, *Eizo NAKAZA*, *Seikoh TSUKAYAMA*, *Yasushi KITAMURA*, *Kouji TAMASHIRO*

1 Senbaru, Nishihara-cho, Okinawa 903-0213 Japan

k008427@tec.u-ryukyu.ac.jp

Shiraho coral reef area of Ishigaki Island is characterized by very well developed blue coral reef species especially *Helipora* communities. As reef areas play important role in the ecosystems through providing habitats for fisheries and other living organisms it is important to know the water circulation pattern inside the reef and its adjacent offshore areas as it is a critical factor in determining the community structures and production rates in coral reef ecosystems. Local wind as one of the dominant forces of water circulations is found to have significant role to this areas current fields. Acoustic Doppler Current Profilers were deployed with the help of moored buoys in the offshore area just outside the reef edge for recording the time series of vertical profiles of horizontal current velocity. Electro magnetic current meters were also deployed inside the reef area for continuous measurement of current velocity. Required meteorological data were collected from Ishigaki Meteorological Observatory. The data are analyzed with a view to show the effects of local wind in inducing currents in both reef and its adjacent shallow water areas. The results show the evidence of wind driven currents in the study area. During the field observation, the average wind speed was about 5 m/s. This time maximum wind speed recorded around 19 m/s. Spectral analysis of wind and current velocity shows the existence of low frequency strong peaks both in wind and current fields at the same frequencies. Strong linear relationships between the wind and current velocity are also evident through the study showing the resultant velocity of wind induced current is about 6% of wind speed. So quantitative evidence showing the significant role of local wind in inducing currents both inside the reef and its adjacent offshore areas are established through the study.

Temperature Distributions in a Coral Reef Area and the Influences from Offshore Internal Waves

*Eizo NAKAZA**, *Shak M B RAHAMAN*, *Seikoh TSUKAYAMA*, *Yasushi KITAMURA*, *Kouji TAMASHIRO*

1 Senbaru, Nishihara-cho, Okinawa 903-0213 Japan
enakaza@tec.u-ryukyu.ac.jp

Temperature sensors were deployed with the help of moored buoys inside the Shiraho reef area which is characterized by very well developed blue coral reef species especially *Helipora* communities. Depth profiles of temperature data were also collected from the offshore area adjacent to the reef area. Required meteorological data were collected from Ishigaki Meteorological Observatory. Though coral reef provides important habitat in the ecosystem beside tourism and other commercial purposes, for the last few years, this valuable resource has been subjected to mass coral bleaching. Temperature variation inside the reef area is thought to be one of the most important reasons of coral bleaching. Researchers have been given a lot of efforts to clarify this areas thermal field however, detailed explanations on the offshore area where the existence of internal wave could affect the temperature field significantly are yet to give. Current velocity inside the reef area was measured through electromagnetic current meters. Vertical profiles of horizontal current velocity inside the offshore area were collected through the deployment of Acoustic Doppler Current Profilers. Thermal structures of the reef and its adjacent shallow water areas have been analyzed under typhoon and normal atmospheric conditions. Study results show temporal and spatial variations of temperature to a significant level. Detailed distributions of reef temperature and its variation patterns in context of the influences that come both from atmospheric and offshore thermal, and hydrodynamic environments have been discussed through the present study.

Intermittent Upwelling and Subsidized Coral Growth on the Deep Forereef Slope of Discovery Bay, Jamaica

*James J LEICHTER**, *Salvatore J GENOVESE*

m/c 0227, 9500 Gilman Drive, La Jolla, CA 92093 USA
jleichter@ucsd.edu

Variations with depth in light availability and water motion on reef slopes have been long recognized as important determinants of growth rates, morphological plasticity, and zonation of scleractinian corals. Deep reefs are often viewed as areas of reduced physical variation and more constant environmental conditions relative to shallower waters. However, a suite of mechanisms associated with internal tidal upwelling can produce significant high frequency variability in temperature, salinity, nutrient concentrations, and flux of suspended particles, with the variation often increasing with depth. This study investigated the relationships between high frequency physical variability and depth-specific growth rates of *Madracis mirabilis* branch tips at 10 to 55 m depth in two sites near Discovery Bay, Jamaica. At both sites growth rates showed a bimodal response to depth, with fastest growth at 10 and 30 m depth and significantly reduced growth at 20 m. Below 30 m, growth declined from 45 to 55 m. Time series analysis of high frequency temperature data showed a distinct peak of variability at diurnal frequencies in shallow water which decreased with depth, and a weaker peak corresponding to semi-diurnal variability which increased with depth. The semi-diurnal peak likely represents internal tidal upwelling and potentially corresponding to episodic availability of subsurface inorganic nutrients and suspended particles associated with a water column thermocline and subsurface chlorophyll maximum layer impinging on the reef. The bimodal pattern of coral growth with depth is interpreted as representing the superposition of depth specific gradients in the availability of light and nutrients / suspended particles, with the intermittent input of materials associated with upwelled subsurface waters appearing to subsidize the relatively rapid coral growth at 30 m. Intermittent oceanographic forcing mechanisms may be highly significant in the productivity of deep coral reefs.

Upwelling of the Equatorial Undercurrent near Jarvis Island: Implications for Local Ecosystem Processes

*Jamison GOVE**, *Ron HOEKE*, *Robert SCHROEDER*, *Russell BRAINARD*, *Mark MERRIFIELD*

1125B Ala Moana Blvd., Honolulu, HI 96714 United States of America
jamison.gove@noaa.gov

A series of biological and oceanographic surveys was conducted by NOAA Fisheries near Jarvis Island during February or March in 2000, 2001, and 2002. Jarvis is a small island (approximately 4.5 km²) located in the central equatorial Pacific at 0°22.5'S, 160°01.0'W. This location is in the mean path of the high velocity core of the subsurface eastward flowing Equatorial Undercurrent (EUC), which typically lies just below the westward surface flowing South Equatorial Current. The overall strength and structure of the EUC modulates greatly with variations in El Nino/Southern Oscillation and other shorter timescale processes. In situ hydrographic measurements, including conductivity, temperature, depth profiles, and shipboard acoustic Doppler current profiles, show evidence of an upwelling region of cold water stemming from the EUC on the western slope of the island. Temperatures measured were up to 2°C colder on the western side of Jarvis compared to equal-depth temperatures in surrounding waters, and overall surface temperatures were up to 4°C different between the surveys. Biological surveys included rapid ecological assessments of corals, other invertebrates, fish, and algae and towed-diver surveys of benthic composition, abundance, and invertebrate taxa. Relating hydrographic measurements with concurrent biological data shows a significant impact of upwelling on the coral reef ecosystem surrounding Jarvis. Fish surveys show increased planktivore densities up to 1 or 2 orders of magnitude greater in the upwelled waters compared to the surrounding waters and large differences in overall densities and spatial distribution between the yearly surveys. This injection of cold waters stemming from the EUC and the presumed increase in nutrients are likely altering the trophic structure near Jarvis Island, creating a unique and isolated ecosystem relatively free of fishing pressures, and thus modulated primarily by oceanographic changes.

Unlithified Magnesium Calcite Mud-Matrix in Branching Coral Framework of Open Lagoons in Belize and Panama: Equivalent to Precipitates of Lithified Crusts and Infillings Found in Fore-reef Frameworks

*Ian G MACINTYRE**, *Richard B ARONSON*

P.O. Box 37012, NMNH, MRC 121, Washington, DC 20013-7012 United States of America
macintyre.ian@nmnh.si.edu

The mud matrix in push cores collected from branching-framework accumulations in open lagoons of Belize and Panama contain large quantities of Mg-calcite. The *Acropora cervicornis* deposits of the Rhomboid Cays in Belize and the branching *Porites* spp. deposits of Almirante Bay, Panama, both contain 12 -13 mole % MgCO₃, which is concentrated in the clay-size fractions. This clay-size Mg-calcite consists of anhedral equant crystals and shows no relationship to the well preserved coarser skeletal grains, which suggests that the Mg-calcite is a precipitate. This evidence of Mg-calcite precipitates in reefal settings is further supported by the documentation of Mg-calcite of identical composition found in surface sediments of shallow waters in Belize, Florida, and the Bahamas and in deeper (30m) sediments of the fore reef in Belize. It was a long time before carbonate sedimentologists recognized extensive Mg-calcite lithification in fore-reef coral framework. Now it appears that micritic Mg-calcite precipitates throughout the tropical reef environment but remains unlithified when trapped in sediments, particularly the sedimentary matrix of branching-coral lagoonal deposits.

A New Global 4 km Sea Surface Temperature Data Set for Coral Reefs

Kenneth S CASEY*

1315 East-West Highway, Silver Spring MD, 20910 United States of America
Kenneth.Casey@noaa.gov

Satellite-based time series from the Advanced Very High Resolution Radiometer (AVHRR) on board NOAA polar-orbiting satellites are exceeding 20 years in length and have been shown to provide accurate and useful sea surface temperature (SST) observations. However, many previously available satellite SST data sets were not well-suited for highly-variable coastal and coral reef environments due to coarse spatial and temporal resolutions, poor land masking procedures, and inconsistent retrieval algorithms. A new reprocessing based on an improved Pathfinder algorithm by the University of Miami and the NOAA National Oceanographic Data Center has resulted in a twice-daily, global time series of SST at 4 km resolution dating back to 1985. This new SST data set provides observations at over 98% of the coral reef locations identified in ReefBase, a substantial improvement over the previously best available AVHRR SST collection which covered only 61%. The details of this new global SST data set and how to access it will be presented along with some example applications.

Overview of NOAA Coral Reef Watch Program's Near-Real-Time Global Satellite Coral Bleaching Monitoring Activity

Gang LIU*, Alan E STRONG, William SKIRVING, Felipe ARZAYUS

E/RA31, SSMC1, Rm 5307, 1335 East-West HWY, Silver Spring, Maryland United States of America
gang.liu@noaa.gov

Coral bleaching has been considered as one of the major contributors to the increased deterioration of coral reef ecosystems worldwide being reported over the past few decades. The need for an improved understanding, monitoring, and prediction of coral bleaching becomes imperative. With the capability of providing synoptic views of the global oceans in near-real-time and the ability to monitor remote reef areas previously known only to wildlife, satellite remote sensing has become a key tool for coral reef managers and scientists. As early as 1997, NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) began producing near-real-time, Web-accessible, satellite-derived sea surface temperature (SST) products to monitor conditions conducive to coral bleaching from thermal stress around the globe. This activity evolved into a crucial part of NOAA's Coral Reef Watch (CRW) Program in 2000. Recently, most of its key products, including SST anomalies, bleaching HotSpot anomalies, Degree Heating Weeks (DHW), and Tropical Ocean Coral Bleaching Indices have become "operational" products after successfully providing early warnings of coral bleaching to the global coral reef community as "experimental" products for several years. Currently, several new near-real-time products, including Short-Term Trends of Thermal Stress, Duration of Thermal Stress, Number of Stress Days, and an automated email alert system, are in the final stages of development and should become available soon. As we attempt to improve the accuracy of the monitoring products and develop prediction capabilities, NOAA is seeking to develop these products at higher spatial resolutions, monitor other related environmental parameters (such as surface wind, solar radiation, and wave field), incorporate simulations of numerical models, and develop new and more accurate algorithms. CRW's mission is to provide the domestic and international coral reef community with timely and accurate information for understanding, monitoring, and preserving these "rainforests of the sea."

Quick-Query GIS Coral Bleaching Reference for Park Managers and Stakeholders

L Felipe ARZAYUS*, Chunying LIU, Alan E STRONG

1335 East-West Hwy # 5313, Silver Spring, Maryland United States of America
felipe.arzayus@noaa.gov

Often times, coral reef managers and stakeholders need to make key conservation decisions within a short time span. These decisions may affect great expanses of marine parks and sanctuaries, and impact local economies possibly restricting tourist trade and fisheries. NOAA's Coral Reef Watch (CRW) is developing the Quick Query information system (Quick-Query), aimed at providing a rapid nowcast of the potential for coral bleaching to occur in an area, given existing environmental conditions. Managers and stakeholders will be able to access a database composed of currently available CRW products (Bleaching HotSpots, Degree Heating Weeks, and SST anomalies), as well as locally reported bleaching reports, all arranged within a Geographical Information System (GIS). Two types of queries will be available: (1) by location, where the user simply clicks on the coral location of interest; and (2) by in-situ water temperature, adding local measurements to a coral location of interest. Given this information, the GIS will provide a time and location-specific output of the likelihood for bleaching. Output information will be based on near-real-time information, and the previous 5-year data points for the same time and location. Local bleaching reports for that time and location will be presented as supporting information. As Quick-Query will be served on a GIS, it will offer field and remote location accessibility, requiring only an Internet connection and a web browser. Quick-Query will provide preliminary information regarding the potential for bleaching based on historical data and current conditions. As the suite of CRW products is expanded (e.g., ocean color and scatterometry data), databases to Quick-Query will be added, however, as with any GIS, the user will have the ability to select which databases to query and in what capacity, thus allowing for faster download times and ease of use in field applications.

Oceanographic Atlas of the Pacific: An Accessible Interface to Marine Environmental Data

Russell A MOFFITT*, Russell E BRAINARD, Ronald HOEKE, Alan E STRONG, William SKIRVING, John SIBERT, David FOLEY

2570 Dole St., Honolulu, Hawaii 96822-2396 United States of America
Russell.Moffitt@noaa.gov

Coral reef ecosystems are influenced by a broad range of oceanographic conditions and processes. These processes affect temperature, sedimentation, larval supply, transport, recruitment, and the habitats of both small and large scale reef systems. Resource managers tasked with developing and implementing broad-based ecosystem approaches are hindered by the large amount of unsynthesized oceanographic data currently available. The Oceanographic Atlas of the Pacific is designed to provide a single point of access to environmental data from a variety of platforms (satellite, shipboard, moorings, and numerical models) in forms that are useful and accessible to both non-expert and expert users. Data coverage is provided at Pacific basin-wide and regional scales as well as for various biogeophysical sub-regions and, contingent upon data availability, individual banks or reefs. The Atlas enables straightforward visualization of numerous data products in formats such as climatologies, anomalies, time series, animations, and data snapshots and facilitates the retrieval of specific source data. It provides a means for understanding trends and patterns of spatial and temporal variation in environmental parameters influencing reef conditions, offering researchers, resource managers, policy makers, and other stakeholders a valuable source of information on the conditions influencing particular ecosystems. As an example, users might choose to view SST anomalies overlaid with wind fields while concurrently exploring available in-situ observational time series from moorings located near a particular reef. Basic categories of data include sea surface temperature and height, ocean color, salinity, oxygen, wind, storm tracks, currents, waves, bathymetry, and other derived data products such as HotSpot or Degree Heating Weeks maps for investigating thermal stress associated with coral bleaching. Distribution via an interactive website application allows users to customize aspects of data selection and display.

Interannual Variability of Sea Surface Temperatures in the Western South Pacific and on Great Barrier Reef: 1982 to 2004

*Andrew M FISCHER**, Bruce C MONGER, Charles H GREENE

1007 Del Monte Blvd, Pacific Grove, California, 93950 United States of America

amf26@cornell.edu

Climate change is a particularly potent threat to coral reefs. Warming sea surface temperatures (SSTs) associated with global climatic events (e.g. El Nino and Pacific Decadal Oscillation) can cause extensive physiological changes in corals, leading to widespread bleaching and coral mortality. Mass bleaching events in the tropical South Pacific have been strongly linked to the physical stress of elevated SSTs and these events have increased in frequency and severity over the last two decades. However, the bleaching response can be patchy and the intensity of bleaching does not always closely correlate with SST anomalies. To further understand the role of climate change on coral bleaching events and the role of SST variability on the spatiotemporal patterns of mass bleaching, sea surface temperatures on the scale of tropical coral seas should be examined more closely. We use remotely sensed imagery from the Advance Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) to analyze summer averaged SST anomalies between 1982 and 2004. We use Empirical Orthogonal Function (EOF) statistics to describe spatial and temporal modes of SST variability in the western South Pacific and on the Great Barrier Reef. Cross-correlation analyses are conducted to understand significant, concurrent and time-lagged correlation of SST variability with large-scale climatic events. These analyses present a baseline description of interannual SST variability against which the effects of global climate events on mass bleaching can be measured. They also provide a mechanism of discerning global climatic impacts from local and anthropogenic impacts in coral reef ecosystems.

Satellite-based Monitoring of Water Quality in the Great Barrier Reef Region: Algorithm Validation and Product Development

*Andrew D L STEVEN**, Vittorio BRANDO, Arnold DEKKER, Jonathan HODGE, Ben LONGSTAFF, Kadija OUBELKHEIR, Alan MARKS

80 Meiers Rd, Indooroopilly, Queensland 4068 Australia

andy.steven@epa.qld.gov.au

The development of sophisticated satellite sensors such as the MODIS and MERIS systems, covering a large swath (1500 to 2000 km) with a high overpass rate (twice daily) at moderate spatial resolution (300 to 1200 m pixels), provides the capability to deliver routine, comprehensive and cost-effective monitoring of the status of water quality in the Great Barrier Reef region. Despite these advances, environmental managers have been reticent to adopt remote-sensing for routine monitoring of water quality, in part because of prevailing perceptions of poor algorithm resolution and also because derived management products remain largely undeveloped. Physics-based field validation of inshore areas along the Great Barrier Reef is being undertaken to refine algorithm resolution for both MODIS and MERIS sensors. Validation results will be presented for rivers and coastal waters of the GBR. A time series of water quality products derived from the January 2003 Fitzroy River flood demonstrates the capability for estimating the sediment fate. Another example is presented for nutrients and suspended matter compliance monitoring in the Douglas Shire Coastal waters. An overview will be given of progress in the development of products such as maps of chlorophyll-a and total suspended matter compliance with defined water quality criteria, and a web-based delivery infrastructure being built to deliver these products to management in near real-time.

Global Mapping of Factors Controlling Reef-Island Formation and Maintenance

*Hiroyo SHIMAZAKI**, Hiroya YAMANO, Hiromune YOKOKI, Toru YAMAGUCHI, Masashi CHIKAMORI, Masayuki TAMURA, Hajime KAYANNE

16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan

hyamano@nies.go.jp

Reef islands established on shallow reef flats have significantly high vulnerability to projected environmental changes, and understanding the primary factor controlling the formation and maintenance is of critical importance. Reef islands are regarded as a combined product of geological, biological, and physical factors. Of the factors, late Holocene sea-level history and modification of reef-building organisms and depositional environment have been considered to be important. However, we should note that reef islands have diversity in size, structure and component both regionally (e.g., within an atoll) and globally, which is expected to be a result of difference in the significant factor(s). Thus both global and regional assessment of factors-islands relationship is needed. We develop a Geographical Information System that include Holocene sea-level history, biogeography of reef-building organisms, and climate, in order to understand the formation and maintenance mechanisms of reef islands. We conduct on the zoning of regions and present initial results relating reef-island structure and the controlling factors. This approach should also be applicable to understand the diversity of coral reefs worldwide.

Mapping Shallow-Water Coral Reef Structure from Space

*Kristine HOLDERIED**, Richard P STUMPF

1305 East West Highway ms N/SC11, Silver Spring, MD 20910 United States of America

kris.holderied@noaa.gov

Water depth information is required to characterize shallow marine regions at global to local scales, particularly for those habitats with complicated morphology, such as coral reefs. Mapping shallow water depths at coarser scales can improve reef location information, while mapping at fine scales can improve reef characterization. The availability of data from a variety of satellite sensors, with a range of spatial resolutions, provides a capability to examine and map shallow water habitat at all these scales. A new method has been developed to simplify depth determination in clear water from satellite data. This method efficiently provides detail on bottom structure independent of variations in bottom cover, and can be applied to multi-spectral satellite sensors such as SeaWiFS (Sea-viewing Wide Field-of-view Sensor), Landsat, and IKONOS, as well as to digital photography from the International Space Station (ISS). Data from SeaWiFS provides a capability for global mapping with 1-km pixels, which is comparable to the accuracy of many maps on which the current global coral reef map is based. A global composite of depth derived from SeaWiFS, using this method, can be found at <http://seawifs.gsfc.nasa.gov/reefs/>. Landsat, with 30-m pixels, can provide regional information useful for locating banks and characterizing massive coral atolls. IKONOS, with 4-m pixels, provides the detailed information necessary to characterize smaller reef features, such as patch reefs. Water depth and coral habitat maps derived from IKONOS for the northwest Hawaiian Islands can be found at <http://ccma.nos.noaa.gov/rsd/products.html>. Space Station photography, with 5-10 m pixels, could provide repetitive imagery for cloud removal and habitat change analysis. Ongoing work with these data sets will provide information that can be incorporated into an integrated database for improved understanding of coral habitats.

Integrating Land Cover and Reef Mapping to Improve Risk Assessment: Using Landsat to Improve the Reefs at Risk Assessment for the Antilles

*Jennifer L GEBELEIN**, Julie ROBINSON, Laretta BURKE, Jon MAIDENS
FIU, University Park Campus, International Relations Dept., DM 434, Miami, Florida, 33199 United States of America
gebelein@fiu.edu

Utilizing Landsat imagery, land cover / land use maps have been created of all Greater and Lesser Antilles islands in the Caribbean Sea. According to the World Resources Institute (WRI), over half of the Greater and Lesser Antilles reefs are severely threatened due to anthropogenic influences. These influences include coastal population increase, urban expansion, intensified agricultural production, deforestation, and sewage outflow. These detailed maps have a fifteen-class categorization of the landscape that highlights the most important land cover classes that could negatively influence reef health. These land cover maps will be integrated with WRI's reefs at risk models. A comparison of the risk models, utilizing the Landsat derived maps versus the AVHRR derived maps, will be discussed. Additionally, a comparison using WRI's risk model with three landcover maps (IGBP, Gebelein et al, and GeoCover) for three island nations will also be discussed. These maps can provide policy-makers and scientists with useful information about land use and land cover adjacent to reef locations and shallow reef features. These maps will not only aid tropical marine resources research and management, but would also improve our ability to analyze the status and trends of coral reef health, productivity, and threats on a regional and potentially global scale. Maps derived from remote sensing technologies are of particular interest to resource managers because they can provide a basis for coastal planning and for the conservation, management, monitoring and valuation of these resources. Ultimately, such information will strengthen our ability to better assess anthropogenic impacts of coral reefs. This mapping effort is part of a larger project to combine both reef and land maps, yielding the first reef/land mapping project in this region. This dataset will be available for public use and evaluation as a GIS product through the online ReefBase website.

Reefbase: A Global Geographic Information System (GIS) on Coral Reefs

*Marco NOORDELOOS**, Nasir Bin NAYAN, James K OLIVER
PO BOX 500, Bayan Lepas, 11680 Penang Malaysia
m.noordeloos@cgiar.org

ReefBase (<http://www.reefbase.org>) is a global information system on coral reefs. It is the central database of the Global Coral Reef Monitoring Network (GCRMN), and serves as a key source of data and information for the development of GCRMN coral reef status reports. ReefBase had taken a major step forward in providing key information services to coral reef professionals, by implementing a state-of-the-art Geographic Information System (GIS). It allows unprecedented access to a wide range of coral reef related datasets from multiple sources on interactive maps. Through collaboration in a NASA-funded, multi-partner project on remote sensing of coral reefs, a new generation of base maps are now becoming available for use in ReefBase's GIS. These new datasets allow for better integration with reef monitoring data and information at scales more relevant to reef managers. In this way, remote sensing products are helping ReefBase, GCRMN, and its numerous partners to develop coral reef information products with a far greater potential for practical applications. As such, the NASA-sponsored partnership between remote sensing scientists, international agencies and NGOs (<http://eol.jsc.nasa.gov/reefs/>) is providing an important vehicle for establishing the best possible knowledge base for informed management of coral reef resources.

Partnerships for Global Coral Reef Mapping and Data Distribution

*Julie A ROBINSON**, Serge ANDREFOUET, Laretta BURKE, Gene FELDMAN, Jennifer GEBELEIN, Edmund P GREEN, Christine KRANENBURG, Frank E MULLER-KARGER, Norman KURING, Marco NOORDELOOS, Steve ROHMANN, Alan SPRAGGINS, Richard P STUMPF, Damaris TORRES-PULLIZA
2400 NASA Road 1, C23, Houston, Texas 77058 United States of America
julie.a.robinson1@jsc.nasa.gov

The current level of global knowledge about locations and status of coral reefs is not sufficient for many regional applications. For instance, regional studies attempting to identify coral reef risk factors or to prioritize conservation areas are faced with inadequate maps of reefs and adjacent land uses for most areas of the world. In a NASA-sponsored partnership between remote sensing scientists, international agencies and NGOs, efforts have been made to complete the first consistent high-resolution global reef map. The basis of this partnership was the Millennium Global Coral Reef Mapping project developed at the Institute for Marine Remote Sensing at University of South Florida in collaboration with many scientific international institutions. This new global data set systematically identifies the reef geomorphologic units visible in Landsat images of oceanic and continental shelf reefs. Linkages with NASA, IRD, UNEP-WCMC, ReefBase (World Fish Center), and the World Resources Institute have been built to promote the distribution of the maps and data. We discuss the tradeoffs between different mapping techniques and abilities in meeting various user needs. We also discuss the challenges faced in developing GIS-based distribution networks, and discuss how cooperation with USF, IRD, NASA, UNEP-WCMC and ReefBase will support future activities of international agencies and local resource managers. The talk will serve as the summary for activities and collaborations discussed in the session.

Effects of Tectonic, Oceanographic and Climatic Settings and History on the Diversity of the Coral Triangle

Donald C POTTS*

A316 Earth & Marine Sciences Building, University of California, Santa Cruz, California, USA 95064 United States of America
potts@biology.ucsc.edu

The extremely high biodiversity of the “coral triangle” (southern Philippines, eastern Indonesia, northern New Guinea) is superimposed on one of the most complex and dynamic tectonic regions on Earth, a region created and maintained by continuing collisions of the Australian, Asian and Pacific crustal plates (plus smaller units). At least since the early Miocene, the tectonics have produced rapidly changing locations of terranes (10^4 - 10^8 yr; 10^2 - 10^{3+4} km); extreme topography (mountains) and bathymetry (trenches) (10^2 - 10^{+6} yr; 10^2 - 10^4 m); extensive terrestrial and submarine volcanism; and high erosion, sedimentation and reefal growth rates. Climatically, much of the region has high rainfall, equatorial regimes dominated by seasonal alternation of trade winds with Asian monsoons (which have intensified since the late Miocene, due to uplift of the Tibetan Plateau). Oceanographically, surface circulations are poorly known, while understanding of vertical circulation remains largely conjectural. During the last 2.3×10^6 yr, the climatic, oceanographic, shallow bathymetric and sedimentation regimes were modified by sea-level fluctuations (10^3 - 10^5 yr; 10^2 - 10^3 m) and by other consequences of Plio-Pleistocene glaciations. Over 30 models have been proposed that explain the diversity of corals (and other marine groups) by invoking various combinations of species radiations, species accumulation, refugia, vicariance events, dispersal patterns and habitat availability. This paper evaluates spatial and temporal scales and environmental settings that are most relevant to modern diversity within the coral triangle, and then ranks the models by their likelihoods within these contexts of history and settings. It then addresses the nature of biogeographic boundaries of the coral triangle and the existence of subdivisions within the triangle, by concentrating on evidence for the integrity of the Bismarck-Solomon Seas Ecoregion as a distinct sub-unit.

Distribution Patterns of Coral Reef Fishes within the Coral Triangle of Southeast Asia

Gerald R ALLEN*, Timothy B WERNER, Robert WALLER

1 Dreyer Road, Roleystone, WA 6111, Australia
tropical_reef@bigpond.com

Reef fishes are an exceptional flagship group for showing overall trends of endemism and general biodiversity in marine systems, particularly at local and regional scales. They are easily observed and most groups are relatively well known taxonomically. Moreover, because numerous species have limited dispersal capabilities and consequent restricted geographic distributions, fishes are an excellent indicator of endemic regions of variable size, from small isolated oceanic islands to major oceanic basins. The present study provides an in-depth analysis of the geographic distributions of more than 2,000 species of shallow (to 60 m depth) coral reef fishes. The data are used to define the much-heralded Coral Triangle, the heart of which is composed of Indonesia, Philippines and the island of New Guinea. Although there is universal agreement that this area harbours the world's richest marine biodiversity, its boundaries remain only vaguely defined. The analysis also provides a basis for dividing the Coral Triangle into a number of sub-units or provinces based on regional endemism. The resultant framework is particularly useful for conservation planning and prioritization in an area that not only contains the world's richest coral reefs, but also its most threatened.

Seahorse Phylogeography in the Coral Triangle

Sara A LOURIE*

Project Seahorse, Department of Biology, McGill University, 1205 Avenue Dr Penfield, Montreal, H3A 1B1 Canada
sara.lourie@mail.mcgill.ca

As with many fish species, seahorses (genus *Hippocampus*) attain their highest species richness in Southeast Asia. It is likely that the complex geological history of the region and the effects of Pleistocene sea-level changes have contributed to this diversification although the precise mechanisms remain unclear. Since seahorses are presumed to be low dispersing relative to many other marine species they are ideal for testing hypotheses relating to geological history. They may also be appropriate as a baseline for conservation efforts, especially if general phylogeographic patterns can be deduced. I used cytochrome *b* (mitochondrial DNA) sequence data to assess the relationships among individuals of four different species of seahorse across Southeast Asia, and to compare them to those expected under hypotheses of ocean basin isolation and post-glacial recolonisation of continental shelf waters. In all species, lineages and haplotypes were found to be geographically restricted. However, the degree of localisation, and the precise geographic location of genetic breaks varied by species. Focusing on *Hippocampus kuda* provides support for the potential role of both major, and minor, ocean basin isolation in driving diversification. The patterns also suggest the possibility of a brackish-water refuge that may have existed on the Sunda Shelf throughout the last glacial cycle(s).

Species Distributions, Endemism, and the Coral Triangle: In Search of the Global Center of Coral Reef Diversity Using the Mushroom Coral Model

Bert W HOEKSEMA*, Daniel F R CLEARY

P.O. Box 9517, NL-2300 RA Leiden Kingdom of the Netherlands
Hoeksema@naturalis.nnm.nl

Most Indo-Pacific scleractinian distributional ranges overlap within the so-called Indo-Malayan triangle, consisting of Malaysia, Indonesia, the Philippines, and Papua New Guinea. The boundaries of this diversity centre are not known exactly and therefore it is also not well understood which processes have been most important for the delimitation of this area. For a thorough analysis, accurate data on species distribution (especially presence-absence data) is needed. It appears that there is little endemism in the Fungiidae. We know, for example, that species previously considered endemic actually have much wider distributions following recent field surveys. Rare, cryptic or patchily distributed species (due to local extinction) are also often overlooked in many field surveys. To prevent overestimations of species richness, diversity estimates should not be based on extrapolated species ranges. Species numbers, on the contrary, should be based on records from localities where field surveys have actually been performed, preferably by specialists with detailed taxonomic knowledge of the group in question. Using the Fungiidae as a model taxon for delineating the boundaries of global coral reef diversity we note that two fungiid species have ranges from eastern Africa to central America. Most species, however, have Indo-West Pacific ranges, from the western Indian Ocean and the Red Sea to the central Pacific. Fewer species occur predominantly from eastern Indonesia and the Philippines to the West Pacific. The area in which the ranges of this last category overlaps with those of the more widespread species appears to be the most important for determining the centre of diversity. Since the last ice age, these species have probably not been able to disperse over the newly inundated Sunda shelf and appear to have survived along the continental shelves and islands in eastern Indonesia, the Philippines and part of the western Pacific.

Coral Diversity in and around the Coral Triangle: A Rapid Technique for Finding Triangle Boundaries and Gradients

*Douglas FENNER**

P.O. Box 8067, Pago Pago, AS 96799, USA American Samoa
dfenner@blueskynet.as

Total numbers of species known from different areas can be used to delineate latitudinal and longitudinal gradients in diversity and the boundaries of the area of highest coral reef diversity (the Coral Triangle). But the comparison of different areas based on the total number of species known in different areas requires the comparison of species lists gathered with very different amounts of effort, by different investigators, at different times, and so on. Additional search effort yields additional species, just as searching larger areas reveals additional species (species-area effect). Additional search effort produces diminishing returns, but a final total is not reached. It may be possible to assess a region's diversity with significantly less effort, time, money, and personnel if comparisons are made based on standardized amounts of effort and area searched, by the same investigator. Searches for coral species were made during dives averaging one hour in length, at 420 dive sites in the Philippines, Malaysia, Indonesia, PNG, and neighboring areas. The data show a very strong species-area effect, which best fits a log relationship. Comparisons were made between areas based on the number of species found in equal numbers of dives. No latitudinal gradient was found within the Philippines, and northern Luzon was found to be within the Coral Triangle area of highest diversity. The eastern tip of Papua New Guinea was also found to be within the Coral Triangle. Outer GBR reefs nearly reach the diversity of Coral Triangle sites. Sabah, Malaysia appears to be within the Coral Triangle, Sarawak appears to be at the boundary or just outside, and east coast Peninsular Malaysia and the Andamans are clearly outside the Coral Triangle. Other studies have reported that western Indonesia has lower coral diversity than the Coral Triangle.

Patterns of Diversity and Endemism in Indonesian Reef-associated Stomatopod Crustacean Assemblages

*Mark V ERDMANN**

PO Box 1020, Manado, North Sulawesi Republic of Indonesia
erdmann@nrm.or.id

As with many marine taxa, coral reef-associated stomatopod crustaceans attain maximum species diversity in the so-called Coral Triangle bounded by the Philippines, Indonesia, and Papua New Guinea. Intensive collections by the author within Indonesia over the past 12 years illuminate a number of interesting patterns of diversity and endemism within the heart of the coral triangle. The Indonesian stomatopod fauna represents an intersection of Pacific and Indian Ocean species, with sibling species often occurring sympatrically. Additionally, there are a number of species (often comprising 10-20% of the species list of a particular Indonesian reef system) that are apparent Indonesian endemics, with a smaller but still significant number of species that appear to be endemic to individual reef systems. The highest stomatopod alpha diversity tends to occur in those reef systems with the highest habitat diversity; these reef systems are predominantly located in the clear, deep waters of eastern Indonesia near larger islands with strong onshore-offshore gradients of salinity, sedimentation, turbidity, exposure, and depth. The epicenter of reef-associated stomatopod diversity occurs around the Raja Ampat Archipelago off NW Papua, where a stunning diversity of habitat types and the intersection of Indonesian and western Pacific faunas seem to account for this diversity peak.

Biogeography of Southeast Asiatic Larger Benthic Foraminifera: Patterns and Processes

*Willem RENEMA**

P.O.Box 9517, 2300 RA Leiden, the Netherlands Kingdom of the Netherlands
Renema@naturalis.nl

Larger foraminifera require similar environmental conditions to zooxanthellate corals. Their occurrence is limited by high temperature and nutrient poor conditions. Larger foraminifera leave a rather complete fossil record that allows a discussion of the processes and conditions underlying patterns of diversity. Recent revisions in some families of larger symbiont-housing foraminifera reveal higher species richness than was previously assumed. Apart from widespread species that occur in the entire Indo-west Pacific region (IWP), species with a restricted distribution pattern also occur. For example, in *Calcarina* (one of the genera that is found in star sands), formerly 4-5 species were recognised, but at the moment 7-8 species can be separated. Many species show range overlap within the so-called coral triangle.

High diversity is directly related to habitat diversity, habitat partitioning and size of the area. To determine whether the IWP is species-rich just because of its high diversity in habitats, or whether the area is also rich within each habitat, more than diversity must be taken into account. Some habitats, like reef flats, can be especially rich in species. These are unlikely to get preserved in the fossil record and the occasional preservation of such a setting, or specimens derived from this environment, will increase diversity in a time slice. For comparison between regions or time slices diversity within a sample from a similar habitat, or the use of other diversity indices, are preferred.

The longevity of the extant genera is very variable. They originated in the Palaeocene/Early Eocene, Oligocene or Pliocene. However, the oldest records of the Palaeocene/Early Eocene genera is not from within the IWP.

Economic Value of Coral Reef Biodiversity with Focus on Southeast Asia

Andre Jon UYCHIAOCO, Edgardo D GOMEZ, Herman S J CESAR, Rollan C GERONIMO, May T LIM, Tac An NGUYEN, Melissa Anne F ESTRADA, Doug H MCGLONE, Johnrob BANTANG*

Velasquez St., University of the Philippines, Diliman, Quezon City 1101 Republic of the Philippines
andreu@upmsi.ph

It often seems the proper value of coral reefs is not being considered by society in allocating resources for the management and protection of the reefs and their biodiversity. Thus in many cases, individuals seek their own short-term financial gains at the expense of coral reef degradation and overall societal benefits. While reefs per se may regenerate, the worth of species that go extinct is not well known. We estimate the value of coral reef biological diversity focusing on the following 3 aspects—reef-related tourism, reef-associated fisheries and reef conservation value attributable to coral reef biodiversity:(1) In our survey of tourists in 4 Southeast Asian tourist spots, underwater biodiversity accounts for 7.9-13.6% of a reef-side tourist's considerations in the selection of a site to visit. If respondents won a vacation, they were on the average each willing to pay from US\$19 to US\$197 in additional travel costs in order to upgrade their vacation to a site with all the same above-water conditions but higher underwater biodiversity.(2) We built an agent-based trophic simulation composed of a reef bottom wherein coral and algae compete and occupy empty space and another layer wherein individual fishes and invertebrates move, feed, grow, reproduce and mutate. An initial level of diversity is being generated and then 100%, 10% and 1% of this diversity will be used in 3 separate simulation runs. Corresponding levels of fisheries yields will be reported.(3) GEF coral reef funding per country was correlated with more km² of coral reefs, higher population and lower GDP. However in our analyses, GEF coral reef funding was not statistically correlated to coral species richness, poverty incidence, and % reefs at risk.

The Effects of Experimental Transplantation on Reproduction of Fragments of *Goniopora* Corals

*James R GUEST**

14 Science Drive 4, Blk S2, NUS, Singapore, 117543

Republic of Singapore

scip9051@nus.edu.sg

Transplantation of fragments of coral colonies is commonly used to restore damaged reefs, however, little is known about how fragmentation and transplantation affect reproductive effort and spawning of the fragments, or the donor colonies. Fragmentation has been shown to reduce fecundity in some corals and can even result in colony mortality, although fragmentation is also an important mode of asexual reproduction in many corals. Large (>6m), colonies of the gonochoric coral genus *Goniopora* (Poritidae) are relatively common on reefs south of mainland Singapore. These colonies are made up of many short columns, and living coral tissue is concentrated at the tops of columns. For this project I removed individual columns from colonies of *Goniopora columna* & *G. lobata* to create smaller clonal colonies that could be used for transplantation experiments. Coral fecundity was measured in transplanted fragments after approximately one year, just prior to the predicted spawning date. Fragmentation had no effect on the fecundity of coral pieces transplanted within the same site. However, one parent colony appeared to have spawned whereas the transplanted fragments a few meters away had not. Fecundity was, however, reduced in fragments transplanted to a site closer to the mainland of Singapore, that had lower water quality and to depth. Reproductive strategies, fecundity and other life history characteristics should be key considerations when choosing species or colonies for coral transplantation for reef restoration, if the aim is to produce populations and communities of corals that will be reproductively viable.

Coral Reef Restoration and the Use of Corals of Opportunity and Nurseries

*Jamie A MONTY**, *David S GILLIAM*, *Kenneth BANKS*, *David STOUT*, *Richard E DODGE*

8000 North Ocean Drive Dania Beach, Florida, 33004 United States of America

vernacch@nova.edu

Coral reef injury from ship groundings and construction activities is unfortunately a common occurrence off southeast Florida, USA. Restoration generally begins with the rescue and reattachment of dislodged and fragmented scleractinian corals. Unfortunately, recovery is slow and dislodged colonies may die during legal enforcement action delays. Transplanting additional colonies to restore natural densities can accelerate reef recovery. Typically, corals available for transplantation have been rescued from the injury area (if available), grown in laboratories, or taken from non-injured reef areas. Growing corals in a laboratory is time consuming, expensive, and the colonies may not be adapted to receiver site environmental conditions. Removing attached corals from one reef for transplantation elsewhere may result in no net gain or harm to the donor site. An alternative source of donors are "corals of opportunity", which we define as corals detached from the reef through natural processes or unidentified injury events. The Coral Nursery Project is a cooperative effort between local scientists, resource managers, and resource users. This Project locates, collects, and transports corals of opportunity detached from the reef to an established nursery site (artificial reef). These corals are tagged, affixed to the substrate, and monitored quarterly for growth and survivorship. Nearly 300 corals of opportunity of 17 species have been transplanted to the nursery. Survival and growth rates of these colonies has been similar to rates of control corals naturally attached to reef. The ultimate project goal is to use the rescued corals of opportunity from this nursery as a source of transplants for future reef restoration. In addition, Project results will provide resource managers with information on coral species- and colony size-specific transplantation success and growth. Cooperative efforts like the Coral Nursery Project that use rescued corals of opportunity may become important tools in future coral reef restoration and mitigation projects.

Efficacy of Coral Nurseries for Reef Restoration in South Florida

Robert W CARTER, *Shay VIEHMAN*, *Dan DIRESTA*, *Thomas CAPO*, *Richard CURRY**

4600 Rickenbacker Causeway, Miami, FL 33149 United States of America

rcarter@rsmas.miami.edu

The approximately 68,000 acres of coral reef area in Biscayne National Park (Florida, USA) are impacted by numerous (greater than 20 per year) small vessel groundings impacting 5-30 m² of reef area and less frequent (5 in 25 years) major ship groundings. Most of the damaged areas require stabilization of the substrate and broken corals, and some require intensive restorative action. The National Park Service, in cooperation with the University of Miami Experimental Hatchery, has established a coral nursery for coral fragments too small to be stabilized on site. In two years, over 300 fragments have been rescued. Coral fragments and colonies too small for on-site stabilization are rescued from grounding sites and transported to one of two field nurseries where they are subdivided into approximately 5 cm × 5 cm fragments, epoxied onto PVC dowels, and inserted onto a stable structure. A Passive Integrated Transponder (PIT tag) is embedded in the epoxy base for identification. Field corals are maintained under natural regimes of turbidity, temperature, nutrients and current. A subset of fragments are maintained under controlled conditions in a laboratory nursery at the Hatchery. Survivability and growth vary between lab and field nurseries, with higher growth rates and lower mortality observed in lab corals. To optimize survival and growth, coral fragments damaged by groundings will be initially stabilized in a controlled laboratory nursery and then moved out to a field nursery to be grown to a size useful for restoration. The long term goal of the project is to provide corals for restoration as an alternative to removing corals from healthy reefs.

Experimental Assessments for the Gardening Concept in Coral Reef Restoration

*B RINKEVICH**, *S SHAFIR*

Tel Shikmona, P.O.Box 8030, Haifa 31080, Israel

buki@ocean.org.il

The concept of "gardening coral reefs" with sexual and asexual recruits has been suggested to be used as an important tool for rehabilitation of damaged reef areas, especially in popular reefs suffering from recreational activities. In this strategy, new coral colonies developed from coral branches, small colony fragments (nubbins) and laboratory or in situ settled planula - larvae are transplanted to denuded reef area for restoration. The approach is further improved when transplants are first cultured in situ, within special designed nurseries that are established in protected areas. Here we assess several methodologies employed during the phase of coral mariculture. The nurseries were placed near (6 m away, 6 m depth) fish cages belonging to the net-pan fish farms situated at the north shore of the Gulf of Eilat, Red Sea. We used colonies of the branching species *Stylophora pistillata*, *Acropora* sp. and *Pocillopora damicornis*. To further evaluate the effectiveness of using low cost measures, untrained volunteers were asked to prepare nubbins. More than 5000 nubbins and coral branches were glued to plastic pins attached on a net within plastic frames (80-110 nubbins/frame). Observations were performed every month. The time two untrained people used for preparing 100 nubbins from *Acropora* was 2 h (resulting from mucus that was secreted following branch pruning) and only 0.5 h for *Stylophora* and *Pocillopora* nubbins. A 100 day follow up study on 5072 nubbins of the above 3 coral species revealed 7% mortality and 17% disconnections from the plastic pins. After 144 days of culturing *Acropora*, *Stylophora* and *Pocillopora* nubbins a 15.5%, 17.1% and 5.7% respectively increase in ecological volume was documented. Modification in the gardening measures are assessed and discussed.

Coral Reef Biodiversity Enhancement with the Use of Live Giant Clams and Other Methods

*Edgardo D GOMEZ**, *Patrick C CABAITAN*, *Michelle Z REYES*

UPMSI, Velasquez St., (UP)Diliman, Quezon City, 1101 Republic of the Philippines

edgomezph@yahoo.com; edgomez@upmsi.ph

In the process of rehabilitating degraded reefs several approaches have been tried by various individuals, principally introducing coral transplants, inducing larval settlement, and stabilization of unconsolidated substrate. In addition, artificial reefs have been tried, sometimes in combination with one or another of the methods just mentioned. In the Pew Project demonstration sites in the Philippines, several methods have been adopted to test their efficacy. What distinguishes this project as a novel approach is the use of giant clams as living structural components of a reef community in addition to the more common approach of transplanting corals. In this endeavor, the Pew project has used a combination of methods, including cementing fragments on natural coralline rock and introducing boulders as substrates. Cement has been used in the majority of demonstration sites with sufficient firm substrate. Transplantation on boulders deployed for the purpose has been initiated in one location, due to the limited available natural substrate. At each site the experimental areas are divided into four treatments: coral transplants, giant clam transplants, a combination of the two, and a control with no intervention. The sites have been monitored and the preliminary results are presented to show the trends related to the enhancement of the fish and invertebrate biodiversity.

Culture and Rehabilitation of Soft Corals from Korea

*Jun-Im SONG**, *Sung-Jin HWANG*

Department of Life Sciences, Ewha Womans University Seoul 120-750, Korea
jjisong@ewha.ac.kr

Jeju Island, southern part of Korea, is directly being affected by the Kuroshio Warm Current. 92 species (70%) out of 132 species in total of Korean anthozoans inhabit the area and also, 66 species (50%) are the endemic species being found in this area only. Particularly, soft coral community is being found in the southern part of Jeju Island such as the shallow waters of Munsom and Beomsom. Approximately 20 soft coral species are distributed downwards 45m deep in the sub-tidal zones. However, the clean sea area is now suffering from a lot of marine pollution due to many aqua-farms and restaurants built in its coastal lines. Moreover, soft coral community has been directly damaged by marine leisure-sports. Therefore, among Korean anthozoans, since Korea Ministry of Environment designated 15 species as "Extinct, Crisis and Protective Species of Korea" in 1997, they have been under protection by "Natural Environmental Conservation Law" from 1998. Moreover, Korea Ministry of Culture and Tourism declared four Natural Protected Zones in the Jeju Island area as Natural Monument No. 420-423 in 2000. And now, we are trying to conserve the soft coral community as a Natural Monument. Fortunately, this project "Culture of Protective Species of Anthozoans and Rehabilitation" has been investigated by the Korea Institute of Environmental Science and Technology for 10 years. One of our aims is to establish the technology for conservation of the protective corals through their culture and propagation. We have got useful good results through the studies of sexual and asexual reproduction of the protective and dominant species. We are monitoring the growth rate of soft corals in relation to their species and population. And also, we are studying the factors regarding their growth and survival at natural habitat, natural and artificial sea waters.

The Science Behind Biophysical Design of Coral Reef MPA Networks

*Stephen R PALUMBI**

Hopkins Marine Station, Pacific Grove, CA 93950 United States of America
spalumbi@stanford.edu

Because of their strong impact on human use of reef resources, marine reserves on coral reefs tend to be small. Small marine protected areas can provide substantial benefit if they exist as part of a coordinated network that can stabilize marine populations, increase diversity or reduce fishing mortality. Design of marine reserve networks is difficult, and has been largely lacking in driving principles. The original Ballantine Hypothesis was that any collection of protected areas would eventually function as a network once the collection became dense enough. However, it is unknown how close together reserves should be to allow seeding from one area to the next, or to allow stock buildup. Recently, mathematical models and new ways of tracking marine larvae have combined to suggest the density of effective reserve networks. As an example, marine reserves in the Philippines may be becoming dense enough to start to form Ballantine Networks. Finally, information from biological science can go only part of the way to designing marine networks. Just as important - or more so - is the social, economic, and cultural system in which human communities agree to protect marine resources for the future. Information from local communities, and from the social sciences must be used in order for network design to succeed.

The Sociopolitical Dimension: People as Key Ingredients in Design of Effective Protected Area Networks

*Roger B GRIFFIS**

1305 E-W Hywy, NOS/ORR/SSMC4 10201, Silver Spring, Maryland, 20910 United States of America
roger.b.griffis@noaa.gov

The successful design and implementation of protected area networks to help conserve and manage coral reef ecosystems requires careful consideration of social and political parameters, as well as information on ecosystem biological and physical characteristics. Taking stock of the social, political and economic "landscape" and using this information in the design of protected area networks is as one of the most important and challenging aspects of network design. This presentation presents a synthesis of recent information and approaches to incorporating a range of sociopolitical factors into the design of coral reef protected area networks. A framework is presented to assist network designers in addressing key issues such as assessing uses and values of resources, building broad base social support, bridging existing jurisdictional boundaries for effective governance, integrating network designs with natural resource management and economic development strategies, incorporating contributions of local and indigenous communities, and building effective financing mechanisms and capacity to support the network

Successful Marine Protected Areas Require Broad Support: Philippine Case

Alan T K WHITE, Rose-Liza E OSORIO, Stuart J GREEN*

5th Floor, CIFIC Tower, North Area, Cebu City, Republic of the Philippines
awhite@mozcom.com

Small marine protected areas (MPAs) were established in the Philippines as early as 1974. These models set forth a framework for coral reef management that has been shown to enhance fish yields to traditional fishers as well as protect and maintain near-shore coral reef habitats for biodiversity and multiple economic uses. The history of MPAs is described in relation to the evolution of integrated coastal management (ICM) in the Philippines. Devolution of authority for management of natural resources to local governments in 1991 was a major national policy shift that has supported more localized management efforts. This policy shift has encouraged more MPAs but not a higher rate of success. As the numbers of MPAs increased, the need for a support base beyond the MPA has become apparent. A convergence of MPAs within ICM programs was seen by 2000. Numerous experiments in coastal management have thus been conducted that range from broad area management planning for whole bays to small community-based MPA projects. Important lessons with implications for broader-based support systems required by MPAs within ICM, include: The importance of a well-articulated process that includes community participation and ownership in collaboration with single or multi-municipal governments; the role of multiple stakeholders, government and donor agencies in planning and management; the creative use of financial mechanisms to create long-term self-supporting MPAs; the need for localized periodic monitoring and evaluation to provide feedback to managers, and the need for nesting of MPAs within ICM through broad area planning and implementation.

Too Much of a Good Thing? Initial Thinking on Adaptively Managing Coral Reef MPA Networks

John E PARKS, Robert S POMEROY, Lani M WATSON*

212 Merchant Street, Suite 200, Honolulu, Hawaii 96813 United States of America
john@conservationpractice.org

As the science underlying the rationale, design, and use of marine protected areas (MPAs) has increasingly become better understood, so too has our enthusiasm grown in using these tools to address a suite of coral reef conservation needs. Although necessity requires that we objectively and holistically assess the impacts of our management efforts through time, it was not until recently that we have begun to pay careful attention to how to best evaluate MPA performance. No sooner have we begun to critically consider how to use MPAs at "priority" coral reef sites than we are now advocating for the replication and networking of such MPAs across broad geographic, political, and sociocultural conditions. In our push to globally design and implement MPA networks, we must also address the inevitable need to evaluate such efforts once operational. Despite conventional wisdom, simply "scaling up" site-specific impact measures to be collected across multiple MPAs is alone insufficient. How then must we learn to measure and improve on the effectiveness of coral reef protection beyond single sites? Based upon the synthesis of real-world experience and learning from three international MPA networks, the authors first present a set of common errors to avoid when evaluating the performance of networked coral reef MPAs, followed by a recommended set of standards of practice in completing and acting upon such cross-site investigations. From this guidance, a decision-making framework is offered to assist officials and managers in their challenge to accurately diagnose and adjust MPA network performance in a timely manner. The paper closes with the presentation of an applied research agenda of five key questions needing to be addressed regarding the adaptive management of MPA networks worldwide.

Scaling up to Seascapes: Studying the Functions of MPA Networks in the Bahamas

*Daniel R BRUMBAUGH**, Kenneth BROAD, Robert COWEN, Craig P DAHLGREN, Rob DESALLE, Alastair R HARBORNE, Alan HASTINGS, Katherine E HOLMES, Carrie KAPPEL, Philip KRAMER, Urmila MALVADKAR, Sandra MCLAUGHLIN, John MCMANUS, Fiorenza MICHELI, Peter J MUMBY, Donald B OLSON, Stephen R PALUMBI, James N SANCHIRICO, Richard W STOFFLE, Liana TALAUE MCMANUS

Central Park West at 79th Street, New York, New York 10024 United States of America

brumba@amnh.org

The need to investigate effective ways to design networks of marine protected areas (MPAs) in coral reef ecosystems increases as various governments have initiated plans for MPA networks. Unfortunately, because of the scarcity of existing or even incipient networks, little research to date has addressed how networks of ecologically connected MPAs may function across realistic seascapes. In addition, most research on MPAs has been about their biological effects, with much less attention being directed towards the socioeconomic impacts of MPAs. Given that the biophysical and socioeconomic dynamics are inextricably linked across space and time, a full understanding of the function of MPA networks requires an integrated, interdisciplinary research approach. The five-year Bahamas Biocomplexity Project (BBP) was initiated in 2001 to address this important need. The Bahamas is currently in the process of expanding its set of MPAs, both through the implementation of the first phase of a new network of marine reserves and a recent expansion of the national park system. Drawing on diverse approaches from oceanography, ecology, anthropology, and economics, the BBP is integrating theory and data in statistical and computational models about Bahamian coastal dynamics. Major areas of interest include (1) the crucial interactions and feedbacks among physical, biological, and social systems that influence how MPA networks function; (2) the roles of different stakeholder groups, such as fishermen, tourists, local businesspeople, and other residents in determining these MPA functions; and (3) the relative function of networks designed to maximize biodiversity or fisheries objectives versus those designed to minimize certain socioeconomic impacts. Ultimately, models allowing comparative scenario testing will support future decision making in The Bahamas while answering questions of widespread significance about the design of MPA networks. This presentation provides an overview of these research objectives and the general research approach.

Moving towards a Network of Marine Sanctuaries in the South China Sea

*Porfirio M ALINO**, Miledel C QUIBILAN, Hazel O ARCEO, Hiyas G ALANO, Andre T UYCHIAOCO

Marine Science Institute, University of the Philippines, Diliman, Quezon City Republic of the Philippines

pmalino@upmsi.ph

Previous work in the South China Sea has highlighted the need for improved understanding of the coral reef dynamics in the South China Sea. This information has been crucial in the planning for the sustainable development of the fragile coral reef complex in this region. Both recruitment and post settlement mortality processes have been identified as critical to the maintenance and sustained utilization of resources in the region. Through a series of simulation experiments utilizing information on the recruitment and community structure of selected reefs in the Philippine-side of the South China Sea, a strategy for a functional network of coral reef marine sanctuaries is proposed. This framework strategy is utilized as one basis in the formulation of a biogeographic ecosystem approach as part of a national coral reef strategy for the Philippines. Simulation experiments suggest that in order to mitigate for the combined effects of mortality during recruitment and post settlement mortality, improved management of no-take areas and those outside no-take areas is imperative. Tactical and strategic steps to target full protection of around 10 percent of the good reefs together with the sustainable use of the remaining reefs, would take over a 100 years if present business-as-usual efforts are taken. Considering the exacerbated threats from human and natural induced impacts, the recovery rates would take longer unless more concerted efforts are taken. Scientific inputs in enhancing spillover, recruit survivorship and connectivity that go hand in hand with good environmental governance are derived from the simulation scenarios. Scaling-up of local efforts on larger marine sanctuaries is now being undertaken. It is envisioned that the marine corridor efforts at the transition zones would contribute to integrating efforts to accelerate and improve effectiveness into an ecosystem-based Philippine Archipelagic Development framework.

Designing Marine Protected Areas from Spatial Prediction Using Generalized Regression Spatial Analysis (GRASP) and LANDSAT 7 ETM+ Imagery

*Joaquin R GARZA-PEREZ**, *Nestor MEMBRILLO-VENEGAS*, *Carlos GONZALEZ-GANDARA*, *Serge ANDREFOUET*, *Jesus E ARIAS-GONZALEZ*
Carretera Antigua Progreso Km 6, Cordemex, Merida, Yucatan United Mexican States
rodgarza@mda.cinvestav.mx

Alacranes Reef in the Campeche Bank is an extraordinary well developed sea-plain/atoll type reef (22°28N - 89°40W) with an area of 293 km² (26.5 × 14.8 km). It has a Marine Park status and is a very important source of fishing resources as lobster, conch, groupers, snappers and sharks in the Yucatan Peninsula in Mexico. Nevertheless, the management plan of this reef lacks important scientific basis necessary to establish correct exploitation policies. We applied GRASP methodology, which relies on Generalized Additive Models, to spatially model the distribution of coral and reef fish communities. We obtained results in the form of predictive maps of cover percentage of the reef components such as corals, algae, sponges, sea-grass; geomorphologic features such as calcareous pavement, sand and sediment; and biomass distribution of fish such as dominant and commercial species. GRASP methodology is being implemented as well to predict coral reef fishes assemblages associated to habitats. Eleven habitats were defined (using multivariate classification procedures) and mapped (using GIS spatial analysis) for the whole reef (using a LANDSAT 7 ETM+ as base image). Associated fish species/assemblages predictions were represented in terms of biomass for each mapped habitat. This information could be used to define biophysical effective coral reef marine protected area. This gives the resource managers a valuable tool for making decisions, as shown in the reserve zoning design which comprises the most important ecological features of the system, in order to develop sustainable use strategies.

Evaluating Source-Sink Structure of Coral Reef Fish Metapopulations Using Simulation Modeling

*Will F FIGUEIRA**

135 Duke Marine Lab Rd., Beaufort, NC 28516 United States of America
wff@duke.edu

The conceptual step of viewing coral reef fish systems as metapopulations has been taken and increasingly accepted however methods to effectively use this concept remain elusive. The power in the approach is the ability it offers to understand system dynamics both holistically as well as the scale of individual member sub-populations. Such flexibility can be especially useful for evaluation of conservation and management scenarios such as the establishment of networks of marine reserves. Here I present a simulation modeling approach which incorporates local-scale demographics and large-scale system connectivity towards the end of both tracking system dynamics as well as identifying the source-sink structure of the individual patches. For this I use a spatially-realistic, stage-structured metapopulation model with individually-based larval dispersal and habitat-specific demographics. Using the Florida Keys as the described system, I use this model in conjunction with variations in the pattern of system connectivity as well as local demographic rates to evaluate the stability of resulting dynamics and especially source-sink structure in the face of such variability. There were relatively strong effects of demographic variability on the magnitude and pattern of source sink structure indicating a need to carefully consider habitat-specific demographic rates. While variability in system connectivity certainly caused alterations to source-sink structure, there were some patterns that remained despite this variability. These findings demonstrate the usefulness of this approach for identifying source-sink structure and for the assessment of marine reserve design. Results also highlight the need to carefully consider both habitat-specific demographic rates as well as patterns of variability in system connectivity.

Fish Larval Flux Studies in a Marine Reserve in Southern Guimaras, Central Philippines

*Wilfredo L CAMPOS**, *August S SANTILLAN*, *Noel P EVANO*, *Pacifico D BELDIA II*

University of the Philippines in the Visayas, Miag-ao, Iloilo 5023 PHILIPPINES
oceanbio2002@yahoo.com

This study is part of a larger investigation on the functional role of an existing marine reserve in southern Guimaras, Central Philippines. Surface and near-bottom ichthyoplankton samples from the 2 major channels for water exchange were collected every hour from sunset to sunrise on 5 spring tide (full & new moon phases) occasions in 2002 and 2003. Drift studies using surface drogues were also done to trace water circulation in the reserve on 2 occasions. The results show that flow direction in the main channel is consistently outward, while that in the shallower and narrower channel shows reversals in direction consistent with the tides. The resulting relationship of larval concentration and tide suggest that there is net influx of larvae into the reserve at certain months of the year. The potential roles of coastal (mangrove stands) and hydrographic (gyre formation) features and the nursing ground function of the reserve are discussed.

A Criteria on Minimum Size of Coral Reef Protected Area Located at Outer Reef

*Shuichi FUJIWARA**

2-6-19 Aja, Naha, Okinawa Japan
fshuichi@notes.metocean.co.jp

Quantitative criteria on optimal size of coral reef protected area has not been developed sufficiently. Most important role of the protected area is to preserve species diversity. Hence, I examined quantitative criteria on minimum size of the protected area located at outer reef based on species diversity of reef building corals which form fundamental ecosystem of coral reef. Species-distance curve of corals was obtained from results surveyed at reef margin and slope using serial spot checks along outer reefs in the Sekisei lagoon, Ryukyu Islands and Tubbatata atolls, Sulu Sea, Philippines (Woesik 1995). Increasing number of coral species is no longer conspicuous exceeding 30 km long in the Sekisei lagoon and 6 to 16 km long in the Tubbatata atolls. It is suggested that minimum size of coral reef protected area at outer reef should be taken 30km long in the Sekisei lagoon and 6 to 16 km long in the Tubbatata atolls, with reef width.

The Importance of Habitat Linkages in Coral Reef Ecosystems to MPA Design

*Rikki GROBER-DUNSMORE**, Thomas FRAZER

7922 NW 71st Street, Gainesville, Florida 32653 United States of America
rikki_dunsmore@usgs.gov

Coral reef ecosystems continue to show signs of increased pressures and are deteriorating worldwide. Marine protected areas (MPAs) represent an important tool for managers of these diverse, valuable, and threatened systems. The effectiveness of MPAs, however, is contingent on our understanding of key ecological patterns and processes at appropriate spatial scales. Because most coral reef investigations have been conducted at spatial scales that are considerably smaller than those encompassed by MPAs, we know little about how the arrangement of habitats within or outside MPA boundaries might influence their function. Here, we discuss a landscape approach to identifying "hotspots" of diversity and abundance for reef-associated fishes. We explored the relative influences of reef configuration (e.g., size and shape), reef context (i.e. identity and diversity of surrounding habitats and their areal extent), and fine-scale habitat parameters (e.g., rugosity) on species composition and abundance of fishes at 20 reefs in the Virgin Islands National Park (VINP). In general, abundances of individual species, family-level groups and trophic guilds of fishes were best explained by landscape-scale measures of reef context. For example, the abundance of mobile invertebrate feeders (MIFs) was positively correlated with the amount of seagrass in close proximity to reefs. In some cases, the addition of fine-scale measures of reef rugosity improved relationships. In an effort to corroborate these results, we sampled 22 additional reefs in VINP. Total fish abundance, species richness, and abundances of particular fish groups, e.g., MIFs, haemulids, lutjanids, and serranids, were greater at reefs with adjacent seagrass. Data collected from 17 spur and groove reefs in the Florida Keys National Marine Sanctuary are presently being analyzed to determine if these habitat relationships might be generalized more broadly throughout the Caribbean region. Our findings highlight the value of employing a landscape-scale approach to design effective MPAs.

Habitat Heterogeneity of NSW Marine Protected Areas: A Comparative Observational Study

*Ben M FITZPATRICK**

18 Hall Street Exmouth, Western Australia, 6707. PO Box 201, Exmouth Western Australia, 6707 Australia
oceanwise@bigpond.com

Ensuring that habitat heterogeneity is effectively encompassed by Marine Protected Areas (MPAs) is an essential element in the conservation of a representative sample of Australia's marine habitats. In this study, a MPA is defined as an area that does not allow for extractive resource utilization and is equivalent to what is termed a Sanctuary Zone in NSW. This thesis examines whether MPAs within three NSW marine parks are representative through a comparative observational study of habitat heterogeneity. One of the challenges presented by this question is that currently within New South Wales (NSW) MPAs, knowledge of habitat heterogeneity at depths greater than 10m is insufficient. This study employed a rapid habitat assessment technique to define habitat heterogeneity at depths between 10 and 60m. Specifically, habitat heterogeneity of sub tidal benthic communities is compared within and adjacent individual MPAs within Jervis Bay Marine Park (JBMP), Solitary Islands Marine Park (SIMP) and Cape Byron Marine Park (CBMP), NSW. Towed video transects and SIMRAD sonar data were used to measure habitat features along replicate 250m transects. Video transects were analyzed using the Australian Institute of Marine Science (AIMS) Automated Video Transect Analysis System (AVTAS). Percent cover of biophysical habitat variables and measures of physical habitat derived from sonar data were analyzed using the multivariate statistical program PRIMER. Data was validated by comparison with previously described reef types at SIMP. This study established a baseline dataset of habitat within existing MPAs and contributes towards the identification of priorities for achieving representativeness of habitat heterogeneity within MPAs of JBMP, SIMP and CBMP.

Habitats as Surrogates for Biodiversity and the Conservation of Rare Species

*Carrie V KAPPEL**, Fiorenza MICHELI, Alastair R HARBORNE, Peter J MUMBY, Craig P DAHLGREN, Katherine E HOLMES, Daniel BRUMBAUGH
 Oceanview Blvd, Pacific Grove, CA 93950-3094
 United States of America
ckappel@stanford.edu

Networks of marine reserves, encompassing seascape scale patterns of diversity and connectivity, have been proposed as a tool for the conservation of coral reef communities. Biodiversity conservation, including the preservation of rare species, is often a stated goal in the design of such networks. When data on the distribution and population status of species within potential conservation areas are scarce, and funds are limited for gathering additional data over large planning areas, habitats may be used as a proxy for underlying biodiversity and the presence of particular species. The degree to which the distribution of habitats can be used to accurately predict the distribution of species and of species diversity across a seascape is unknown. Even less certain is whether the distribution of rare species, which may be of particular conservation concern, can be predicted by the distribution of habitats or other seascape level proxies. We surveyed benthic and fish communities in 12 to 15, shallow (0 to 15 m), coastal habitats at nested spatial scales, from local (10s to 100s m) to seascape (100s km), across the Bahamas Archipelago. Maps of shallow water habitats and of habitat diversity were created from high resolution remotely sensed images. The distributions of individual low abundance coral and fish species were related to overall species diversity and habitat type of sites where they were found, and to habitat diversity of the neighboring seascape. We assessed the accuracy of habitat as a proxy for rare species distribution and its usefulness in the design of reserve networks. The explanatory power of habitats as proxies differed between fish and benthic assemblages. Implications for conservation planning are discussed.

Determining Ecological Representation of the Marine Protected Areas Network in the Mesoamerican Reef

Melanie D MCFIELD, *Sylvia MARIN**

PO Box 512, Belize City, Belize
mcfield@wwfca.org

The Mesoamerican Reef (MAR) extends for approximately 1000km, along the Caribbean coasts of Mexico, Belize, Guatemala and Honduras. It is significant for the extent and variety of marine habitats types, its high biodiversity and its relative ecological integrity. A major focus of WWF's conservation strategy involves the development and effective management of an ecologically representative and functional network of marine protected areas (MPAs). WWF's ecoregional planning process included a preliminary representation analysis of habitat types for its nine highest biodiversity priority areas in the region, which were identified through a participatory process based on focal taxa, representative habitats, and key ecological processes. The transboundary nature of this large and interconnected ecosystem was recognized by also focusing on connectivity, larval distribution, currents, habitat linkages, and upwelling. A similar but more detailed analysis is planned for examining representation within the system of existing MPAs. There are now over 30 MPAs in the region. Belize has a particularly well developed system with 18 MPAs covering 13% of the territorial waters. However, there has not been any systematic analysis of MPAs to determine potential gaps and robustness of the regional representation. The planned analysis will take into account ecological representation of key habitats, populations, processes and will also incorporate aspects of reef resilience/resistance and connectivity. It will entail wide collaborations among research, conservation and governing/managing agencies and will result in a robust MPA network design(s) which will be taken to stakeholders and decision makers. Two studies have been conducted thus far: a regional reef assessment in 2001, gaining comparative data on benthic communities, coral recruitment, coral health and urchins. In 2003, a pilot project to identify representative zooxanthellae diversity revealed the extent of genetic diversity and helps reveal how different reefs may respond to predicted increases in the frequency of mass bleaching episodes.

Marine Protected Areas and Community-based Fisheries Management in Hawaii

*Alan FRIEDLANDER**, *Eric BROWN*

Makapu'u Point, Waimanalo, Hawaii 96795 United States of America
afriedlander@oceanicinstitute.org

There are a variety of marine areas in Hawaii that have some type of protected status. The size and quality of habitats within these protected areas vary greatly and management regimes range from areas where all fishing is prohibited to areas where virtually all forms of fishing are allowed. Areas completely protected from fishing have distinct fish assemblages with higher standing stock and species diversity than areas where fishing is permitted. Locations under community-based management with customary stewardship harbor fish biomass that is equal to or greater than that of no-take marine protected areas. In addition to levels of protection, good habitat diversity, complexity, and reserve size have been shown to have a positive effect on fish standing stock, whereas, areas with partial protection from fishing and/or poor habitat quality have limited value in protecting local marine resources. The recently created Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve represents a vast (1.4 million hectares) coral reef ecosystem with limited human impacts. The remoteness and limited fishing activities in this area allow it to function as a large no-take reserve that is dominated by large apex predators such as sharks and jacks. These predators have a profound impact on the entire coral reef ecosystem and their dominance may represent a more intact trophic structure compared with most coral reef ecosystems today. A number of communities throughout Hawaii are currently strengthening local influence and accountability for the health and long-term sustainability of their marine resources through revitalization of local traditions and resource knowledge. The rediscovery of these traditional techniques, coupled with MPAs including no-take reserves, offers great promise for improving the health of our coastal marine environment and the management of marine fisheries in Hawaii.

The Responses of Fish and Benthic Communities on Degraded Reefs that Are Turned into Marine Reserves

*Jonathan A ANTICAMARA**, *Amanda C J VINCENT*

2259 Lower Mall, Vancouver, B.C., Canada
j.anticamara@fisheries.ubc.ca

No take marine reserves (MRs) can provide us with opportunities to understand fundamental reef community processes, in this case, reassembly of communities, in the absence of the confounding effects of fishing. This paper will present the patterns of response of fish and benthic communities in degraded and overfished areas of Danajon Double Barrier Reef (a.k.a. Danajon Bank), Central Philippines. The results of initial monitoring of six marine reserves and two fished reefs indicated that NW section of Danajon bank is heavily depleted and degraded. The analyses of fish community structure of the eight study sites indicated very low density, species richness, and species diversity. In addition, all the eight study sites have been subjected to destructive fishing, resulting in a very low live coral cover and very high percentage of rubble. Detailed analysis of the fish community structure indicated predominance of labrids, scarids and pomacentrids. Comparative analysis across all eight study sites indicated that there were significantly more and larger fish species inside MRs established at least three years previously than the younger MRs and fished sites. Marine Reserves can facilitate recovery of fish and benthic communities, but the level of past exploitation and degradation may have a strong influence on the rate and direction of the recovery process.

Larval Supply Is Sometimes Not Key to Recruitment

*Danielle JAYEWARDENE**, *Charles BIRKELAND*

Department of Zoology, 2538 The Mall, Room 164, University of Hawaii at Manoa, Honolulu, HI 96822 United States of America
jayeward@hawaii.edu

Newly settled coral spat and very small colonies of two size classes were set out on the subtidal reef at Hanauma Bay, a marine protected area. The newly settled spat did not survive because of the deposition of fine sand by turbulent waters. The larger, yet still small (1 cm tall) colonies survived well. Although the vulnerable size class is only within a small size range, this prevents successful larval recruitment from being prevalent. The great majority of small corals in Hanauma Bay are remnants of larger colonies and derived by asexual reproduction from relatively few larvae generations ago. Much of the research these days is focused on the connectivity of reefs by the dispersion of larvae, but it may be the case that larval recruitment is sometimes a small component of reproduction, even in some of the best coral reefs.



Oral Session
June 30 (Wed)



Response Specific Metrics for a Coral Reef Index of Biotic Integrity: New Diagnostic Cellular Assays and Future Research Directions

*Stephen C. JAMESON**, Craig A. DOWNS, Kennard W. POTTS

4254 Hungry Run Road, The Plains, VA 20198-1715 United States of America
sjameson@coralseas.com

In our continuing effort to create a new paradigm for coral reef monitoring and assessment (i.e., one with early warning and diagnostic capabilities) we provide new information on response specific cellular assays for a coral reef index of biotic integrity (IBI). These assays not only have the power to determine specifically WHAT is causing the change in coral reef systems but can also provide vital insight into HOW the stressor is operating within the metabolism of the target organism. Cellular assays fit within the Individual Condition category of the framework for a coral reef IBI and can potentially have relevance to all the attributes within this category. While potentially very powerful, cellular assays should not be used as the only metric(s) in biological monitoring and assessment. We discuss the suggested number of metrics, from each metric type, that should be included in a well-constructed IBI to reflect the multiple dimensions of biological systems. Not using this multi-dimensional strategy can result in flawed assessments and poor management decisions. Finally, we show what cellular assays work now for coral reefs, discuss research pitfalls to avoid and outline promising areas for future cellular assay research for diagnostic coral reef monitoring and assessment.

Integrating Marine Biotechnology into Coral Reef Health Assessment

Cheryl M. WOODLEY, *John C. HALAS**, Pamela HALLOCK-MULLER, John E. FAUTH, Craig A. DOWNS, Elizabeth M. FISHER, Samantha L. RYAN, Judith HALAS

Hollings Marine Laboratory, 331 Ft Johnson Rd., Charleston, SC 29412 United States of America
cheryl.woodley@noaa.gov

Increasing anthropogenic impacts threaten the health and stability of coral reef ecosystems, yet the mechanisms underlying these problems remain largely unknown. Current methods of assessing ecosystem health focus on abiotic and ecological components because well-developed procedures are available to detect contaminants and monitor the responses of individuals, populations and communities. However, technologies that can reveal the molecular and cellular physiological processes that govern how organisms respond to environmental stressors (which is the critical link between environmental contaminants and whole organisms) are now available. To aid in establishing the link between stressor and organism response, we conducted a study in the Florida Keys that integrated new biotechnologies, able to assess processes occurring at the molecular and cellular level of coral (*Montastraea annularis*), turtle grass (*Thalassia testudinum*), calcareous green algae (*Halimeda opuntia*), corallivorous snails (*Coralliophila abbreviata*), bicolor damselfish (*Stegastes partitus*) and white grunts (*Haemulon plumieri*), with well-established methods for assessing standard parameters of coral reef health. The study region was particularly relevant in that it included areas of extensive coral degradation associated with frequent and intense ocean warming events (El Niño) and suspected local stressors. Our goals were to 1) use a new biotechnology, Environmental Cellular Diagnostics, to characterize the health of a coral reef ecosystem in the Florida Keys; 2) verify the technology can detect and characterize subtle and chronic effects of environmental stressors on this ecosystem; 3) determine if point-source pollutants or global climate changes (e.g., increased ocean temperatures or UV-B radiation) are stressing coral reef ecosystems; 4) compare the precision, sensitivity and prognostic capabilities of the technology to those of traditional measures of ecosystem health, and 5) encourage the participation and understanding of the general public and scientific, industrial, and managerial communities in using marine biotechnologies to assess and manage the health of coral reef ecosystems.

Cellular Stress Responses and their Application as Early Warning Signals of Coral Bleaching: A Great Barrier Reef Test Case

*Carolyn R. SMITH**, Sophie G. DOVE, Madeleine VAN OPPEN, Ove HOEGH-GULDBERG

35 Jacaranda Crescent, Annandale QLD 4814, Australia
c.smith@aims.gov.au

Global climate change and rising sea temperatures are likely to increase the frequency and severity of mass coral bleaching events adding significantly to the current decline of coral reef ecosystems. It is vital that we are able to differentiate reef decline due to elevated sea temperatures from that due to direct anthropogenic effects such as coastal run-off and point source pollution. Monitoring of cellular levels of key proteins such as heat shock proteins (HSPs) and antioxidant enzymes (such as copper zinc superoxide dismutase) has been proposed as a method for both predicting the occurrence of coral bleaching events and diagnosing their cause. This study tested this cellular biomarker monitoring approach as an early warning signal for coral bleaching in a common Great Barrier Reef (GBR) coral species namely *Acropora millepora*. Both laboratory heating and field based monitoring were carried out. Field samples were taken regularly leading up to and throughout the 2002 bleaching event on the GBR. Little change in the cellular levels of several key biomarkers (eg HSP60, glutathione peroxidase, ubiquitin and others) were detected for this hard coral species during laboratory heating or in the field during a natural bleaching event. This contrasts the results of published experimental studies on both *Montastrea faveolata* and *Goniastrea aspera* and suggests the potential for significant differences in the strength of cellular stress responses between coral species. Field monitoring revealed an apparent peak in biomarker levels around the time of annual spawning. This peak, however, occurred in the lead up to both bleaching and non-bleaching summers. Such a result highlights the requirement for cellular biomarker data to be cautiously interpreted in the context of seasonal physiological status.

Detecting Coral Response to Environmental Stress in the Field Using a cDNA Array

*Sara E. BROGDON**, Terry W. SNELL, Michael B. MORGAN

311 First Drive, Atlanta, Georgia 30332 United States of America
gte405r@prism.gatech.edu

Common stressors associated with declining coral communities include variations in temperature, changes in salinity, suspended sediment, and exposure to UV radiation. There is an urgent need for biomarkers that can be used to diagnose the type of stressors impacting natural populations of corals. Our work has focused on developing genetic biomarkers of stress for the reef building coral *Montastrea faveolata*. Using a variety of techniques, we developed a cDNA array consisting of thirty-two gene probes. The known function of these genes allows changes in their expression to be associated with thermal stress, oxidative stress, and sediment stress among others. We used this stress gene array to monitor corals in the Florida Keys over a seven-month period from April to October in 2001. Five replicate samples of *M. faveolata* were collected biweekly from East Turtle Shoals near Long Key and processed on site using Trizol to inhibit RNA degradation. Several months later, RNA was extracted, labeled with a chemiluminescent tag, and hybridized to the cDNA array. Stress gene expression by *M. faveolata* was evident in late May, June, July, August, and September. Strongly up-regulated genes included carbonic anhydrase, thioredoxin, polyubiquitin, and an uncharacterized stress gene. Expression of some ribosomal genes also co-varied with these stress genes. By correlating gene expression patterns with environmental parameters we should be able to track the timing of stress events and to diagnose the main classes of stressors impacting natural populations of corals.

A Framework to Identify Ecological Change and its Causes: Effects of Terrestrial Run-off on Coral Reefs

*Katharina E FABRICIUS**, Glenn DE'ATH

PMB No. 3, Townsville MC, Qld 4810, Australia

k.fabricius@aims.gov.au

Many inshore reefs of the Great Barrier Reef (GBR) are exposed to terrestrial run-off from agriculture. However, detecting ecosystem change and attributing it to the increasing river discharges of nutrients, sediments and pesticides is difficult, both philosophically and practically, and in this case complicated by the large spatial scale, presence of additional disturbances (bleaching, crown-of-thorns starfish) and lack of historic data. Nevertheless, ecosystem management depends on early detection of change and identification of factors causing such change, as well as a clear and transparent communication of scientific results to the broader public. We developed and applied a framework to address these problems. The framework is based on epidemiological causal criteria that are both scientifically rigorous and understood by non-specialists, and on improved methods of statistical estimation. Ecological attributes, namely benthos cover, octocoral richness, and community structure, were used to discriminate between potential causes of change. These attributes were surveyed along water quality gradients in two regions; one that receives river flood plumes from agricultural areas, and one exposed to run-off from catchments with little or no agriculture. The surveys showed increasing macroalgal cover and decreasing octocoral biodiversity along the gradients within each of the regions, and low hard coral and octocoral cover in the region exposed to terrestrial run-off. Effects were strong and ecologically relevant, occurred independently in different populations, agreed with known biological facts of organism responses to pollution, and were consistent with pollution effects found in other parts of the world. The framework enabled us to maximize the information derived from observational data and other sources, weigh the evidence of changes across potential causes, make decisions in a coherent and transparent manner, and communicate information and conclusions to the broader public.

Comparing the Effectiveness of Species Assemblages and Indicator Species as Surrogates for Biodiversity in Hard Corals

*Ben T RADFORD**, Ken R ANTHONY, Terry J DONE, Jane GRIFFITH,

Loisette M MARSH, Kimberly VAN NEIL, Bette L WILLIS

School of Earth and Geographical Sciences, University of Western Australia, Hackett Drive, Crawley 6009 Australia

benrad@segs.uwa.edu.au

Selection of priority areas for Marine Park conservation is often compromised by the lack of comprehensive biodiversity data and the resources and expertise necessary to gain this information (Blanford and Gaston 1999, Margules and Pressey 2000). One cost effective solution to this problem could be to use subsets of large taxa such as species groups or indicator species as affective surrogates for much the total biodiversity. Hard corals may have member species that act as affective total biodiversity surrogates as it has been demonstrated that there is good correlation on a range of spatial scales between coral, reef fish and invertebrate diversity (Bellwood and Hughes 2001, Beger et al., 2003). Using hard corals taxa as an example, we investigated; i) to what extent coral co-occurrence based species groups (or guilds) can be used as surrogates for total coral biodiversity and rarity ii) how does this compare to using indicator species for the same objectives iii) when selecting biodiversity priority areas for marine park planning how affective are coral groups and indicator species when compared to total coral biodiversity. To achieve this we have examined the distribution of 198 coral species from 49 genus over 52 reef sites covering a range of environments. These environments span the reef of the Dampier Archipelago situated in the North West Shelf of Western Australia. Our results showed that selecting a small number of optimal indicator species (between 15 and 20) could provide very high correlation with both total coral biodiversity and rarity. Indicator species were considerably more effective than using co-occurrence based species groups and produced similar outcomes to using total coral biodiversity for selecting priority biodiversity conservation areas.

Applied Paleoecology: Using the Past to Restore Coral Reef Ecosystems*William F PRECHT**, *Richard B ARONSON*

2001 NW 107th Avenue, Miami, FL 33172 United States of America

bprecht@pbsj.com

The use of reference ecosystems is vital to developing success criteria in restoration programs. The goal in most restoration projects is to use "unimpaired" sites adjacent to the injured resource as the reference ecosystem. In coral reef systems many of these reference sites are themselves heavily disturbed, limiting their use as templates for the reconstruction of lost ecological services. Here we propose that the paleoecologic information stored in Quaternary reefs is the most appropriate analogue for placing current site conditions in context. Quaternary fossil-reef sections almost always exhibit species composition and zonation similar to modern, undisturbed reefs at the same location. Thus, Quaternary reef-coral communities within the same type of environment are more distinct between reefs of the same age from different places than between reefs formed at different times in the same location. Often the subsurface Holocene reef history exposed by the injury itself serves as the best reference ecosystem. Quaternary examples provide a baseline of community composition that predates human impacts thereby recording natural system variability, and they form the basis for identifying desired future conditions. Thus, the past should be used as a model to reconstruct the future. Because historical science is largely inductive, and because interpretation of the fossil record can be highly subjective, the challenge to restoration ecologists is to combine paleoecologic data and reconstructions with field experiments, model simulations, and long-term monitoring. Only through combining these different types of studies will we develop the tools necessary to understand what works in practice, what does not, and why. The future success of reef restoration efforts will be predicated on our ability to design multidisciplinary restoration programs in a historical context.

Coral Restoration: How Much Is Enough?*Sharon K SHUTLER**, *Steven R GITTINGS*, *Joseph A SCHITONE*, *Tony PENN*, *William F PRECHT*, *Lisa C SYMONS*

1315 East West Highway, Building 3, Silver Spring, MD 20910 United States of America

sharon.shutler@noaa.gov

Governments need legally defensible tools to quantify the amount of compensatory restoration owed by parties liable for injuries to coral under a variety of statutory schemes. Compensatory restoration differs from primary restoration. Primary restoration is intended to restore the injured resources to their baseline, or pre-injury condition, as soon as possible. Compensatory restoration is intended to compensate for lost resource services from the time of injury until the time the resources have returned to their baseline condition. One tool that has been upheld in the United States judicial system as appropriate for quantifying compensatory restoration for seagrass ecosystems is the Habitat Equivalency Analysis (HEA). The HEA provides a means to scale the size of the compensatory project such that the amount of ecological services lost due to the injury, are equal to the amount of ecological services gained through the implementation of a particular compensatory project. Development of an HEA for coral ecosystem injuries would have significant advantages. However, its application must be understood in the context of key service losses and an "operational" definition of coral ecosystem recovery. Selection of metrics by which to evaluate recovery is also critical to a defensible coral HEA. Challenges in developing the coral HEA include (1) selection of a metric(s) that captures key ecological service flows, (2) development of methods to project recovery horizons using available empirical data, (3) identification of future research and data collection to improve recovery horizon projection. Meeting these challenges will improve the ability of the HEA to measure how much compensatory restoration is required to compensate for lost ecological services.

Coral Restoration- How Much Is Enough? II. Balancing Biological Realism and Restoration Reality in a Spatially Explicit Coral Recovery Model*Gregory A PINIAK**, *Mark S FONSECA*, *W Judson KENWORTHY*, *Paula E WHITFIELD*, *Gary FISHER*

USGS Pacific Science Center, 400 Natural Bridges Drive, Santa Cruz, CA 95060 United States of America

gpiniak@usgs.gov

Assessment of an injury to natural resources requires a legally defensible estimate of the time required for the resources to recover to baseline conditions that would exist but for the injury. To that end, we have developed two complementary, highly flexible spatial modeling approaches that combine biological processes with geographically accurate data from an injury to predict the recovery of that injury. These models were first developed for seagrass injuries, and are being adapted for use in coral reefs, salt marshes, and rocky intertidal systems. The current form of the coral models use a generalized coral species to test the effects of injury size, injury shape, demographic parameters, and storms on injury recovery rates. As the goal of this exercise is to build models that provide compensatory restoration commensurate with the lost interim ecosystem services of an injury, model structure and assumptions are based on a balance between available biological data and the economic and legal considerations inherent in the restoration process. In their final form, the models will produce recovery horizons for use as input data for Habitat Equivalency Analysis, which determines the compensatory restoration required for the injury.

Coral Recruitment on Artificial Reefs off Fort Lauderdale, Florida*Donald R DEIS*, *Vladimir N KOSMYNIN*, *William F PRECHT**

7785 Baymeadows Way, Suite 202, Jacksonville, FL 32256 United States of America

drdeis@pbsj.com

As part of mitigation for the installation of five telecommunication cables over the reefs off southeast Florida, thirty designed artificial reef modules were installed. These modules were installed at a permitted artificial reef site off Fort Lauderdale, Broward County, Florida, and were designed to compensate for impacts to scleractinian corals that could not be restored or remediated (such as where the cable could not be moved off of a stony coral and, subsequently, shades or touches a portion of the coral). When they were deployed in January 2000, the modules were placed on the bottom in five groups of six modules each in a wave stable configuration. In the Year Three monitoring (2002), we began to identify and count scleractinian coral recruits and juveniles on the modules. In Year Four monitoring (2003), thirteen species of scleractinian corals had recruited onto the fourteen monitored modules. A total of 311 individuals of these thirteen species were counted providing an estimate of 9.6 coral colonies per m² on the monitored modules. This data can be compared to other data on scleractinian coral colonies on the reefs off southeast Florida. The number of coral colonies on the hard bottom has been estimated to be between 0.7 and 2.6 colonies per m². Patterns in the recruitment of scleractinian corals were also noted on these modules and other artificial substrates within the area.

Coral Recovery Experiments Using Sexual Reproduction in the Open Sea
*Mineo OKAMOTO**, *Satoshi NOJIMA*, *Yasuo FURUSHIMA*, *Shuichi FUJIWARA*, *Masahiro TABATA*, *William C PHOEL*
 4-5-7 Konan Minato Tokyo 108-8477, Japan
okamotom@s.kaiyodai.ac.jp

Coral larvae, obtained from a mass spawning event of corals on May 2001, were successfully settled on special stone settlement sticks and raised, in situ, for eventual transport to other reefs. The test area, Sekisei lagoon, Okinawa Prefecture, Japan, is located close to the warm Kuroshio current and is thought to be the source from which all Japanese corals are derived. One hundred thirty one settlement sticks, with small holes in their sides to increase protection from grazing, were deployed in the lagoon the day before the mass spawning of corals. After three months 61 sticks were recovered containing 71 corals, mostly in the holes. After one year three corals were confirmed to be growing well and extending outside the holes of the 70 sticks left in the water at the lagoon site. They survived two potentially lethal conditions, i. e. high water temperatures with associated extensive coral bleaching and continuous grazing pressure from predators. Based upon the experiment new china settlement devices were developed to satisfy three criteria; 1) they had to be of a shape conducive for settlement of the coral larvae, 2) they had to afford the settled larvae and juvenile corals protection from predation, and 3) they had to be easy to handle underwater, especially during transplantation. New experiments using the china started on April 2002 and May 2003. The concept, experiments and results of the new coral recovery program using china will be presented. This procedure is applicable for large-scale coral transplantation, not only in Japan but also in other tropical countries.

Small Scale Coral Reef Restoration and Management in Barrang Caddi Island, South Sulawesi, Indonesia

*Jamaluddin JOMPA**, *Dewi YANUARITA*, *Natsir NESSA*, *Rahmat IBRAHIM*
 Fak. Ilmu Kelautan dan Perikanan, Kampus Unhas Tamalanrea, Km. 10 Makassar, Indonesia
jjompa@indosat.net.id

Coral reefs and their resources in the Spermonde Archipelago, including in Barrang Caddi Island had become main income and food sources of hundreds of thousand of fishermen and their families. In general, coral reefs in this archipelago, however, have been badly degraded mainly due to ongoing destructive fishing practices such as dynamites, cyanides, and coral mining. Although regulations have been set up nationally and regionally to band such activities in all Indonesian waters, there have been a great difficulties to enforce the law in such remote places. Several management policies/approaches were carried out, but most of them seemed to be ineffective to tackle the problems. In order to find a more effective approach, we introduced a small scale, community based coral reef restoration and management in Barrang Caddi Island. The program started with intensive discussions with the local communities to raise important issues on coral reef destruction and its future consequences for the increasing populated small island of Barrang Caddi. Based on their own self motivations, they have established two small no take zone sanctuaries and buffer zones around the island, regulated and managed by their own people. The sanctuary is locally considered as brood stock protection areas and around the buffer zone only line-fishing is allowed. In order to accelerate the ecosystem recovery, we introduced concrete artificial reef and coral transplantations as well as restocking of giant clams in side the sanctuaries. This approach seemed to be a promising coral reef management tool to be applied on the remote small island in developing countries where formal regulation or low enforcement is difficult to be implemented.

Hypotheses-based Restoration Study for Mitigation of a S.E. Florida USA Coral Reef Damaged by the Grounding of a Nuclear Submarine
*T Patrick QUINN**, *Elizabeth G FAHY*, *Judy L ROBINSON*, *Richard E DODGE*, *Richard E SPIELER*
 8000 N. Ocean Dr., Dania Beach, Florida 33004 United States of America
spielerr@nova.edu

This multivariate project compared settlement, growth, and survival rate of corals amongst concrete artificial reefs with and without potential coral attractants. One hundred-sixty small (1.13 m) Reef Balls™ were organized into 40, 4-module reef units (quads), each in a square configuration with 3-m sides. Each quad had Reef Balls with one of four attractant treatments: iron, limestone, coral transplants or plain concrete (control). Each Reef Ball had two standardized settlement plates incorporating one of the attractant treatments. The quads were further divided into four treatments of structural complexity by filling the central void space of the Reef Ball with differently sized fill (empty, small, mixed, large). This allowed the determination of the interactive effects of four different fish communities on coral settlement and growth. Different complexities generated different fish assemblages. Empty reef balls did not differ in total fish abundance from those with mixed fill, although both these treatments were significantly less than either small or large fill which did not differ from each other. Additionally, empty reef balls had fewer species than those with small fill which, in turn, had fewer than either mixed or large fill treatments, which did not differ from each other. An understanding of the potential interaction of these differing assemblages with coral recruitment and mortality awaits photographic analysis of the settlement plates. *Montastrea cavernosa* and *Meandrina meandrites* were selected for coral transplantation. 100% of the *M. cavernosa* and 27.5% of the *M. meandrites* transplants maintained or increased their tissue surface area. The remaining 72.5% of the *M. meandrites* transplants showed varying degrees of tissue mortality. These species-specific differences in transplant growth and mortality indicate that species selection must be considered in future coral reef restoration efforts.

Connectivity among Reef Populations: A Major Challenge, and an Important One for Sustainable Management

*Peter F SALE**

401 Sunset Ave., Windsor, ON Canada
sale@uwindsor.ca

By their patchy distribution, coral reefs force component species to exist as numerous, small, local populations. These are interconnected to an unknown degree by the dispersal of larval propagules among them. Connectivity measures the extent of this interconnection as both rate (proportion of recruits coming from outside the local population), and spatial range (the distance over which significant exchange of propagules takes place), but we have few tools to measure connectivity, and only very limited data on either rate or spatial range for any species of reef organism. Connectivity is dependent on local hydrodynamics, and also on an ontogenetically changing set of sensory and behavioral skills possessed by the larva that make it potentially, progressively less dependent on hydrodynamics. Measuring connectivity is never going to be easy, yet we must gain greater knowledge of connectivity if we are to enhance sustainable management of coral reef systems ? particularly if through the use of spatially explicit tools such as no-take marine protected areas. Direct tracking of larvae is technically difficult if not impossible in most cases, and larvae are not easily tagged for later recovery. Genetic tools tell us something about larval exchange, but genetic homogeneity does not necessarily mean high rates of larval exchange, and some patterns of genetic differentiation among locations may be a consequence of post-dispersal selection. Here I review the reasons why we need to know much more about connectivity, particularly if we plan to use no-take reserves for conservation or fishery management, and the tools that are available for certain taxa. I suggest there is a major need for coordinated, multidisciplinary studies of connectivity, conducted at relatively large spatial scales, and discuss some progress towards building these.

Extreme Connectivity: Links across the Eastern Pacific Barrier

*Ross ROBERTSON**

STRI, Unit 0948, APO AA 34002, USA Republic of Panama
dr@stri.org

Transpacific fishes occur on both sides of the world's largest marine barrier, the ~5000km wide Eastern Pacific Barrier (EPB). Representation of transpacifics in the tropical eastern Pacific (TEP) fauna relates strongly to adult pelagic dispersal ability: they constitute 98% of oceanic species, 25% of inshore pelagics, but only 10% of demersal shorefishes. Taxa with multiple pelagic life-history stages are best represented. Among demersal fishes that produce pelagic larvae, pelagic-spawners are better represented than demersal-spawners in the transpacific fauna. There are strong phylogenetic effects on representation in the transpacific fauna: elasmobranchs are better represented than teleosts, even teleosts with more pelagic life-history stages, and while some speciose teleost taxa with adequate larval dispersal characteristics have many transpacifics others have none. Although migration across the EPB is thought to be almost entirely eastward, the distributions of 1/5 of the transpacific shorefishes indicate westward migration. A strong bias towards eastward migration likely does not reflect a strong diversity gradient across the EPB: the native TEP reef-fish fauna, although depauperate in global terms, is about as rich as the island faunas on the western edge of the EPB. A response to underpopulation of particular families or ecological groups in the native shorefish TEP fauna is not primarily responsible for the structure of the eastward-migrant fauna. Eastward migrants represent a cross-section of the donor fauna, tempered by phylogenetic variation in dispersal ability. Stronger eastbound currents can account for the directional bias, although there is little evidence of increased eastward migration on El Nino enhanced currents. Molecular data on transpacifics indicate that conspecific populations of oceanic species (especially) and shorefishes are genetically well connected across the EPB, and that invasions have occurred in both directions. The rarity in the TEP of the primary central Pacific habitat, tropical oceanic reefs, may strongly limit migration in both directions.

Ecosystem Thresholds of Resilience in Coral Reefs and their Implications for Connectivity and Marine Reserves

*Peter J MUMBY**

Hatherly Lab, Prince of Wales Road, Exeter EX4 4PS United Kingdom of Great Britain and Northern Ireland
p.j.mumby@ex.ac.uk

Coral reefs are experiencing unprecedented levels of disturbance and managers face a problem of bewildering complexity. Tools are needed to diagnose the resilience of reefs to disturbance and identify whether resilience can be managed. We use a spatially-explicit ecosystem model to explore the resilience of corals to many processes. Fishing of parrotfishes has a disproportionately large and deleterious impact on the ability of coral recruits to escape overgrowth by macroalgae. The resulting bottleneck in coral population dynamics leads to low resilience. We then develop an analytical model which predicts threshold levels of herbivory and coral cover that permit recovery of reefs from disturbance. Reef resilience will be enhanced by a cessation of parrotfish exploitation and by taking urgent action. Resilience declines with falling coral cover.

Genetic Connectivity in Coral Populations between Kerama and Okinawa Islands

Akira NISHIKAWA, Kazuhiko SAKAI*

3422 Sesoko, Motobu, Okinawa Japan
akira_nishikawa@hotmail.com

The 1998 coral bleaching event was the most extensive and severe yet recorded in the world. Coral bleaching is a global phenomenon that is probably linked to global climate change and increasing ocean temperatures. Mortality rates due to the 1998 bleaching in corals varied among locality. The coral populations in the Okinawa Islands, particularly populations of branching species, declined severely. By contrast, the Kerama and Yaeyama Islands, located respectively 30 and 400 km southwest of the Okinawa Islands, maintained healthy coral communities on many reefs compared to the Okinawa Islands. The study of ocean current supported the hypothesis that the Kerama populations are one of the coral larvae sources for the Okinawa populations. For population genetic information of this hypothesis, we assessed genetic differentiation (F_{ST}) among populations in Yaeyama-Kerama-Okinawa by using allozyme electrophoresis in at least four species (*Acropora tenuis*, *Aropora digitifera*, *Goniastrea aspera* and *Stylophora pistillata*). The F_{ST} values were two times low between the Kerama and south-Okinawa populations, compared the Kerama and north-Okinawa populations. Geographic distance, ocean current and present population genetic analysis support largely the larvae source hypothesis in the Kerama populations for Okinawa populations. In reproductive modes, relatively high genetic differentiations were found among regions in brooding coral *Stylophora pistillata*, compared to spawning corals. Planula behavior due to reproductive mode may influence these genetic differentiations. These results may indicate that Kerama populations of brooding species are more critical for recovery of populations in the Okinawa Islands compared to spawning species.

Connecting the Dots: Modeling Ecological Linkages Large Reef Ecosystems

*Bruce G HATCHER**, *Brian DIXON*, *Brian J FRYER*, *Dan HEATH*, *Jake KRITZER*, *Barry RUDDICK*, *Peter J SALE*, *Jinyu SHENG*, *Liqun TANG*
1376 LeMarchant Street, Halifax, Nova Scotia, B3H 3P9, Canada
bhatcher@dal.ca

Ecosystem-based management is predicated on practical understanding of connections among targets of management (exploited populations, essential habitats, etc.). Processes linking such units in marine ecosystems comprise the complex interplay between advection and directed movement of biomass and materials. Quantitative prediction of trajectories and statistics of dispersal at the scales of large marine ecosystems might be achieved through a combination of numerical models and suitably-scaled empirical measurements for model verification. Our multi-disciplinary program of research uses a nested set of numerical, bio-physical, and transition matrix models to predict the pattern and pace of larval fish dispersal from designated sources to all possible sinks within a large coral reef province: the Mesoamerican Barrier Reef System. Simultaneously, we try three tools to test predictions of inter-reef connections generated from the models. Measures of genetic distance between putative source and sink populations using microsatellite and MHC sequencing; measures of spatially-traceable variations in the chemistry of larval fish otoliths using laser ablation ICP-mass-spec technology; and temporal patterns of habitat-specific settlement of fish to reefs may permit accurate calibration of models. Outputs can identify modes and magnitudes of connectivity, assess effectiveness of networks of MPAs and map land-based inputs of pollutants.

Retention and Connectivity in Coral Reef Fish Populations: How Far Do Larvae Disperse?

*Geoffrey P JONES**, *Serge PLANES*, *Simon R THORROLD*
Townsville, 4811, Queensland Australia
geoffrey.jones@jcu.edu.au

One of the unsolved mysteries in marine science is how far pelagic larvae disperse away from their parents. What is a typical distribution of dispersal distances for juveniles successfully recruiting into adult habitat? The answer to this question has become crucial for developing long-term sustainable exploitation and conservation strategies for marine species. In this talk, we briefly review the case for ecologically significant levels of local retention within populations of coral reef fishes, including genetic differentiation, natural population markers, introduced and endemic species, hydrodynamic and meta-population models. We argue that for most reef fishes, direct larval marking techniques are essential to ground-truth estimates of larval dispersal. An experiment in which clownfish (*Amphiprion polymnus*) larvae were marked en masse over three-month periods in two consecutive years will be described. This study suggests that the minimum dispersal distances may be much shorter than we have previously thought. Implications for the design of marine protected areas and assessing extinction risk will be discussed.

Larval Growth History Determines Juvenile Growth and Survival in a Tropical Marine Fish

*Mark IMCCORMICK**, *Andrew S HOEY*
Townsville, Qld 4811, Australia
mark.mccormick@jcu.edu.au

Processes that occur around the transition between larval and juvenile life-stages can have a major affect on the population dynamics of organisms with complex life cycles. We explore the roles of larval history and selective post-settlement mortality in determining the growth and survival of newly-settled individuals of the damselfish, *Pomacentrus amboinensis* (Pomacentridae). Specifically, we determine whether the direction and intensity of selection on the recruits differs among various size-classes of predators. A cage experiment, conducted in 2 habitats (reef flat and base), manipulated the sizes of predators that could access newly settled *P. amboinensis* to determine whether the resulting mortality of the recently settled fish was influenced by larval growth history or size at settlement. Ten days after the start of the experiment individuals that grew slowly in the second half of their larval life had been lost from most of the experimental treatments. Small fish were also selectively lost from the coarse-mesh cage on the reef base. Significant positive relationships between pre- and post-settlement growth rates were found in both habitats for the fine mesh cages, cage controls and open patch reefs. This relationship was reversed in the coarse mesh cages in both habitats. This growth compensation was facilitated through the action of a particular size range of predators, whose impact was disrupted or masked in the open treatments by the action of a diverse predator pool. The present study underscores the complexity of the processes that influence the early post-transition growth and survival in organisms with complex life-histories.

Larval Dispersal History Modifies Early Life History Traits and Survival in a Coral Reef Fish, *Thalassoma bifasciatum*

*Scott L HAMILTON**, *Robert R WARNER*

Department of Ecology, Evolution, and Marine Biology; Univeristy of California; Santa Barbara, CA 93106 United States of America
s.hamilt@lifesci.ucsb.edu

Recent research has demonstrated the prevalence of self-recruitment in many marine systems. The degree of larval retention and larval exchange at any one location may directly influence population dynamics if dispersal history influences individual performance. For bluehead wrasse (*Thalassoma bifasciatum*) on the island of St. Croix in the Caribbean, otolith microchemistry has demonstrated that recruitment occurs from two separate sources; (1) self-recruitment resulting from the retention of local production and (2) long distance dispersal from upstream sources. The northwest shore of St. Croix tends to receive large pulses of retained fish while the southeast shore often receives highly variable recruitment from distant sources. As nearshore waters are often enriched in nutrients and plankton locally retained fish may develop in beneficial environmental conditions, while dispersed fish will often face harsh oceanic conditions during development. These nearshore developing larvae grow faster in the plankton and settle at larger sizes. Intense mortality and size- or growth-selective mortality immediately following settlement will likely have important consequences for individual survival in this species. We examined the consequences of nearshore (i.e. local retention) and offshore (i.e. long distance) dispersal on larval growth, condition, and post-settlement survival for three cohorts of bluehead wrasse recruiting to different sides of St. Croix. Within and among cohort variation in larval growth and condition appear to be associated with dispersal histories. In addition, there are strong shifts in early life history trait distributions (e.g. growth rate, metamorphic band widths, etc.) as a result of selective mortality and these shifts are affected by variation in recruitment intensity between sites. Finally, there appears to be a strong influence of dispersal history on post-settlement survival, which may have important implications for population dynamics.

Pre- and Post-settlement Dynamics of Caribbean Coral Planulae in a Variable Planktonic Environment

*Nicole D FOGARTY**, *Mark J A VERMEIJ*, *Margaret W MILLER*

115 Conradi Building, Tallahassee, Florida 32306-1100 United States of America

fogarty@bio.fsu.edu

Although both pre- and early post-settlement processes are crucial in structuring coral populations, their relative importance is currently not well understood. This study examines implications of a variable planktonic environment in terms of salinity (18‰ to 36‰) and light on pre- and post-settlement mortality, larval behavior, and settlement of *Montastraea* spp. Lowered salinity and light affects the survival and behavior of planktonic *Montastraea* planulae. Mortality rates drop sharply below 20‰, and at 18‰ only 4% of the planulae survive the first 24hrs. In addition, planulae were subjected to five salinity treatments ranging from 28‰ to 36‰. Reductions in salinity (1) increased the mobility of planulae, (2) decreased survival rates, (3) reduced the duration of the planktonic period and (4) limited the ability to distinguish between optimal habitats for settlement. Salinity has no effect on settlement rate, i.e. the number of planulae settling per unit of time. During the early planktonic phase (0-52hrs) the proportion of moving and positively geotactic planulae within a population increased with lower salinity and under dark conditions. Thereafter (>67h), most planulae (>60%) became positively geotactic independent of salinity, and settlement began after 144hrs. These findings show, since variable environments affect planulae survival, habitat choice and post-settlement success, the survival of corals after settlement is not independent of their planktonic history; thus emphasizing the importance of pre-settlement processes in structuring coral populations.

Life History Variation among Endemic and Non-endemic Coral Reef Fishes

*Stephen E SWEARER**

Department of Zoology, University of Melbourne, VIC 3010 Australia

sswearer@unimelb.edu.au

Recruitment of pelagic larvae plays a fundamental role in benthic marine populations, yet the sources and destinations of recruits are unknown for nearly all marine species. Because endemic species rely on retention of locally spawned larvae, they provide a novel opportunity for investigating the mechanisms allowing self-recruitment. Here I present results from an on-going study of the reef fish fauna of Lord Howe Island, Australia comparing the life histories of 6 pairs of endemic and closely related non-endemic reef fishes to determine the mechanisms of self-recruitment. Contrary to terrestrial insular fauna, endemic coral reef fishes tend to be numerically dominant within each taxonomic group. Furthermore, other traits associated with increased ability to self-recruit (i.e., higher fecundity, larger egg size) appear to be associated with endemism. These findings suggest that endemic species are well adapted to local environments and some life history traits predicted to enhance self-recruitment appear to be under selection.

Connectivity of Reef Fish among Reefs Separated by Kilometres to Tens of Kilometres

*Michael J KINGSFORD**, *Kerry BLACK*, *Heather PATTERSON*, *Julian HUGHES*

James Cook University of North Queensland, Townsville QLD 4811 Australia

Michael.Kingsford@jcu.edu.au

Knowledge of levels of connectivity among population units is fundamental to understanding population dynamics. The purpose of this talk is three-fold: (1) describe the dispersion of particles from releases of tracer; (2) present the outputs of an oceanographic model that describes the movements of particles around reefs in the Capricorn Bunker Group over a period of 9 days; (3) describe differences in the elemental signatures of fish otoliths among reefs in clusters separated by spatial scales of hundreds of metres to hundreds of kilometres. Oceanography based on the tracer and modeling indicated that passive transport to other reefs (4-10 kilometres away) can happen rapidly. High levels of passive retention of particles were also found near the natal reef (One Tree Island) after nine days. Some reefs were relatively isolated oceanographically. A brooder, *Acanthochromis polyacanthus*, was used to test the potential to discriminate source reefs. Differences were found between clusters of reefs separated by hundreds of kilometers and differences between sites within reefs were often clear. Elemental signatures unique to individual reefs were rare or absent despite evidence for oceanographic separation. The utility of elemental chemistry to resolve reefal sources requires strong and unique ambient chemistry - which is rare on the Great Barrier Reef.

Bioerosion in a Fluvially Influenced Nearshore Reef Environment: Implications for Carbonate Budgets in Rio Bueno, Jamaica

*Jennie MALLELA**, *Christopher T PERRY*

Room E402, Dept. Env and Geog., Manchester Metropolitan University, John Dalton Ex. Building, Chester st., Manchester, M1 5GD United Kingdom of Great Britain and Northern Ireland

j.mallela@mmu.ac.uk

Reefs are being increasingly subjected to land based threats (e.g. rivers and sewage) and resource exploitation (e.g. overfishing), and we are only just beginning to understand the consequences of this for coral reef ecology and carbonate production. Reefal framework growth is the product of a multitude of interacting processes some of which build and actively produce calcium carbonate (e.g. coral growth, encrustation and cementation), and others which remove framework and produce sediment (e.g. grazing and boring). Research so far has tended to focus upon the effects of terrestrial inputs (e.g. sediment) on carbonate producing organisms, primarily coral. We currently know far less about how these impacts affect carbonate erosion. A handful of studies have found direct relationships between deteriorating water quality (e.g. eutrophication) and increased borer infestations, whilst other studies have postulated that grazing species may promote boring by removing surface layers and weakening the carbonate substrate. This study focuses upon Rio Bueno, north Jamaica, an area where reefal development and community structure naturally vary along a gradient of fluvial influence. All sites have also been impacted by overfishing, wide spread mortality of the keystone herbivore *Diadema antillarum* and hurricane damage. In order to quantify rates of bioerosion recently dead coral samples were collected from two contrasting sites. The outer site being a clear water, high-energy environment, and the central site a low-energy, highly turbid environment close to a river mouth. Results highlight the importance of *Clionid* sponges which dominate both sites with regards to framework destruction and account for up to 92% of the macroboring community, whilst *Agaricia agaricites* proved to be the most susceptible coral with regards to macroborer infestation. The results presented here form part of a larger project that aims to produce a calcium carbonate budget for Rio Bueno.

Bioerosion by the Bluechin Parrotfish (*Scarus ghobban*) in an Eastern Tropical Pacific Coral Reef: Importance of Body Size, Density, and Foraging Rate

*Juan M JIMENEZ**, *Fernando A ZAPATA*

Department of Biology and Biochemistry, University of Houston, SR 2 room 369, Houston, TX, 77204 United States of America

jjjimene@mail.uh.edu

To estimate the bioerosion rates by *Scarus ghobban* in a Gorgona Island fringing coral reef (Eastern Tropical Pacific) indirect and direct methods reported in the literature were combined. Fish size, time of day and reef zone as well as the foraging substrates were considered. Bioerosion was highest at the back-reef and diminished towards the slope, following the distribution and abundance pattern of the species. Small individuals showed the highest bioerosion rates in the reef as a whole ($1.2 \text{ kg m}^{-2} \text{ Y}^{-1}$) given their highest abundance. On the other hand, a single large individual eroded more sediment than small one ($123.6 \text{ Vs. } 8.2 \text{ kg Ind.}^{-1} \text{ Y}^{-1}$, respectively). High densities and large body sizes found for *S. Ghobban* in this reef resulted in greater bioerosion rates ($1.6 \text{ Kg m}^{-2} \text{ Y}^{-1}$) than the rates found for other scraping species, but lower than the bioerosion rates found for excavating species in other oceans.

Sponge Bioerosion in Light and Shade: Symbiotic Dinoflagellates Do Not Only Help Calcification

*Christine H L SCHOENBERG**

Slip Rd., Seddon Building, St. Lucia, QLD 4072, Australia

c.schoenberg@marine.uq.edu.au

Some bioeroding sponges contain symbiotic dinoflagellates, which microscopically resemble those in corals. Coral dinoflagellates have been shown to support the calcification process of corals. Their role in bioeroding sponges is much less well studied, but symbionts appear to be beneficial to the sponges as well. The main hypothesis is that sponges receive photosynthates from the symbionts and will grow and erode faster in light. A simple field experiment at Orpheus Island, Palm Islands, Australian Great Barrier Reef investigated the influence of light on symbiont densities, sponge graft survival, tissue growth and bioerosion activity. Replicate sponge grafts of *Cliona orientalis* Thiele, 1900 were fixed onto $8 \times 8 \times 1 \text{ cm}$ blocks cut from clean coral skeleton and left in the field for 6 months. Half of the blocks were exposed to ambient light, and half were placed under shade cloth. All sponge grafts survived, with the exception of one. Sponge tissue covered with sediment was creamy white, and sponges under shade cloth were paler than those fully exposed to ambient light. Pigment extraction of sponge tissue for spectroscopy gave an estimate of differences in chlorophyll content between the sponge tissue in the different treatments. Tissue growth and erosion activity of the sponges were evaluated by tracing sponge tissue for image analysis and re-weighing experimental blocks. Data analysis was still ongoing at the time of abstract submission.

Impact of Bleaching on Rates and Agents of Bioerosion on the GBR

*Patricia A HUTCHINGS**, *Mireille PEYROT-CLAUSADE*, *Anke STUKEN*

6 College Street Sydney NSW 2010 Australia

path@austrmus.gov.au

Worldwide the incidence of bleaching is increasing and often this results in the death of the coral colony and this increases the potential amount of coral substrate available for colonisation by bioeroding organisms. Increases in rates of bioerosion may lead to long term loss of the coral reef platform and prevent the recovery of that reef. To test this hypothesis, replicate samples of coral colonies recently killed by known bleaching events were collected on the reef flat at Heron Island and in the lagoon at One Tree Island, Great Barrier Reef. These samples were then used to determine the density and biomass of the bioeroders as well as to assess rates of internal bioerosion which were determined by thin sectioning and image analysis. Thirty nine months after their death, the five *Acropora* species collected differed greatly in the rates at which their skeletons were eroded. Skeletons of *A. formosa* were the least eroded with only 1% of internal volume removed, compared with *A. aspera* and *A. nobilis* where 8% was eroded by macrobioeroders. Boring sponges were responsible for more than 80% of this internal erosion. *Polydora* spp, Fabricinae and *Aspidosiphon elegans* were the most abundant boring worms. These results will then be discussed in terms of the variations between species and compared with those obtained from these corals from non bleached reefs, and the consequences of these findings for bleached re

Micro-borers in Corals During Bleaching- The Hidden Element*Maoz FINE**, *Ove HOEGH-GULDBERG*

St. Lucia Queensland 4072 Australia

m.fine@marine.uq.edu.au

The micro-endoliths inhabiting the skeletons of corals during a bleaching event at Heron Island (Great Barrier Reef) were studied. We examined the dynamics of photosynthetic pigment and biomass of endoliths in the skeletons of bleached and healthy corals. During a bleaching event these endolithic algae and cyanobacteria, recognised for their low light utilisation potential, receive increased photosynthetic active radiation (PAR). We questioned their response to increased PAR when the screening effect of the symbiotic zooxanthellae is reduced. We found that soon after the visible stages of bleaching the micro-endoliths increase markedly in biomass. Chlorophyll fluorescence techniques were used to assess photoacclimation capability, of the micro-endoliths, to increased irradiance. These measurements demonstrate that micro-endoliths under healthy parts undergo photoinhibition when exposed to ambient light intensities, whereas endoliths under bleached parts of the colony photoacclimate to ambient irradiances. In dissected skeletons of bleached coral, we found evidence to chronic annual bleaching. According to our findings, the endolithic algae bloom during the bleaching event when they receive increased light intensities. This bloom results in increased bioerosion as apparent from cavities and porous sections in the skeleton. This bloom terminates with the recovery of the coral and/or gaining its normal zooxanthellae densities. It has been suggested that endolithic algae are among the possible factors contributing to survival of coral species during coral bleaching, providing an alternative source of energy as they produce increasing amounts of photoassimilates during bleaching, which are in turn, translocated to the coral. On the other hand, increased bioerosion is not beneficial to the coral, making it susceptible to physical and biogenic disturbances. We demonstrate the high complexity of within colony processes during a bleaching event. While usually ignored, these processes may have a major role in shaping the future of coral reefs.

Reefcheck: A Tool for Monitoring the Impact of Oil & Gas Development Program on Coral Reefs of the Nay Band Bay, Northern Persian Gulf, Iran*Mohammad Reza SHOKRI**, *Nahid SHOKRI*

#227, Shokofeh St., Navab Safavi Ave., Tehran, 13466, Islamic Republic of Iran

mrshok@hotmail.com

Nay Band Bay is located within the Pars Special Economic Energy Zone (PSEEZ) on northern Persian Gulf, Iran. The marine ecosystem of this Bay was given Protected status due to the presence of sensitive biophysical coastal areas, including productive creeks, aesthetic coastal scenery, physically diverse features, presence of sea turtle nesting sites, existence of coral reefs, mangrove forests, marine mammal habitats and aquatic fowl communities. The patch corals at this bay were surveyed as Reef Check site in 2000 and 2003, in which the collected data was then utilized in two EIA projects conducted by the petrochemical companies considering as the most consistent input to the EIA reports. Data was collected on coral diversity and distribution, health status, and on abundance of target vertebrate and invertebrate organisms along the permanent transects in 2000 and 2003. The Reef Check data along with the turbidity map, classification results and satellite images of the PSEEZ and Nay Band Bay areas between 1998 (a year before land reclamation activities) and 2003, were utilized in the assessment of the status of coral reefs and the future fate of them at this highly impacted area. In view of fine sediments, the comparison of Reef Check data between 2000 and 2003 revealed an increase in the percentage of fine sediments with depth increases. Likewise, the amount of fine sediments is appeared to increase since 2000 to 2003 at 9m depth. This is also shown in the turbidity map and satellite images, in which a significant increase in turbidity in Nay Band Bay was noted over the period of 1998 to 2003. Such an increase has probably occurred due to the presence of increased suspended sediment concentrations resulting from construction and land reclamation activities, where suspended sediments have been transported by marine currents into Nay Band Bay.

Regional Status Report on Coral Reef in the ROPME Sea Area*Hamid REZAEI-MARNANI**

P.O. Box 26388., Safat 13124 State of Kuwait

rezaihamid@hotmail.com

The marine environment of the ROPME Sea Area is particularly suffering from the impacts of haphazard coastal developments, physical alterations, destruction of habitats, sedimentation, high salinity, extremes of temperature, and a great number of land-based and sea-based pollution hot spots. Dredging, reclamation and some other anthropogenic interventions are widely practised with tremendous damaging effects on the most productive and sensitive areas of the marine environment. The operational and accidental oil pollution is a major challenge in the Region. The impacts of offshore oil installations particularly that of produced water on the marine environment are enormous. The operational pollution from ships and dumping of ballast water are among the main causes of chronic oil pollution in the Region. There are also a great number of oil spill emergencies resulting in substantial pollution to the marine environment. The stress factors, both anthropogenic and climatic, are a continuous threat to the marine ecosystems and to the biodiversity of species that depend on them. Fish and corals are more susceptible to such stress factors and respond to changes quickly. Such being the case, coral bleaching episodes in the ROPME Sea Area have been numerous and catastrophic. Major natural threats to corals are temperature, disease and predation by the Crown of Thorns Starfish (COTS) and boring mussels. Major anthropogenic threats to the viability of coral reef ecosystems in the Region are unsustainable coastal developments, destruction of habitats, dredging and reclamation activities, municipal sewage, industrial discharges, oil pollution, unsustainable fishing practices particularly indiscriminate trawling, plastic and other litter, abandoned fishing nets tangled around coral reefs, anchor damage and careless diving. This Report summarizes the status of coral reefs in the coastal waters of Bahrain, Iran, Kuwait, Oman, Qatar, Saudi Arabia and UAE. It also presents the Regional Action Plan for Conservation of Corals.

Patterns of Reef Coral Recovery by the Regrowth of Surviving Tissues Following the 1997-98 El Nino Warming and Upwelling Events in Panama, Eastern Pacific

Peter W GLYNN, Peggy FONG*

University of Miami, Miami, Florida United States of America
PGlynn@rsmas.miami.edu

Zooxanthellate coral bleaching during the 1997-98 El Nino warming in Panama resulted in spatially variable patterns of colony mortality, depending upon the magnitude and duration of sea temperature anomalies. At reef sites that experienced bleaching, several species suffered partial mortality with patches of surviving tissue that were repopulated by zooxanthellae within weeks to a few months following the disturbance event. Live tissue cover (%) per colony and extent of tissue regeneration were assessed annually for seven coral species for four years (1999-2002) at three reef sites: Saboga and Iguana Islands (upwelling areas, Gulf of Panama), and Uva Island (a nonupwelling environment, Gulf of Chiriqui). Surviving tissues of ramose corals (2 pocilloporids) re-capped dead branch tips. In massive coral species (1 poritid, 4 agariciids), surviving tissues on colony sides or in fissures grew laterally and covered dead upper surfaces. All surveyed species at Uva Island, where bleaching was pronounced, demonstrated significant increases in live tissue from 1999 to 2000: pocilloporids, 7.2-37.9%; poritid, 23.1%; agariciids, 15.3-46.9%. Pocilloporids decreased in average size by ~50% from 1999 to 2000, probably due to loss of dead branches, increasing thereafter. In contrast, massive corals did not show a consistent temporal pattern of change in total size (live + dead areas). Patterns of pocilloporid live cover and colony size at Iguana were similar to Uva, though reported bleaching was not pronounced at this location. Massive corals were larger on Iguana than Uva, and some species showed significant temporal increases in size corresponding to increases in live cover. Live cover at Saboga was not low after 1997-98, rather it decreased in 2001, corresponding to extreme low upwelling temperatures that caused bleaching and tissue loss. Summarizing, coral colonies that experienced partial mortality from stressful elevated or depressed temperatures demonstrated rapid regrowth, promoting the resiliency of Panamanian coral reefs...

Can Upwelling Pulses and Turbulent Mixing Prolong the Survival of Corals in the Gulf of Panama (Eastern Pacific) during ENSO Warmings?

Juan L MATE*, Magnolia O CALDERON, Luis D' CROZ

Unit 0948, APO AA 34002-0948 United States of America
matej@naos.si.edu

Intermittent sea surface temperature cool-downs possibly occur during ENSO episodes due to upwelling and turbulent mixing. We carried out a mesocosm experiment with two branching coral species (*Pocillopora damicornis* and *P. elegans*) and two massive coral species (*Pavona varians* and *Porites panamensis*) to investigate if sea surface coolings can mitigate bleaching and mortality of corals during ENSO sea-warmings. Corals were alternately exposed to a cycle of elevated water temperature ($30.0^{\circ}\text{C} \pm 0.96$) for two weeks followed by ambient temperature ($29.0^{\circ}\text{C} \pm 0.89$) for two weeks. The experiment ran for four cycles (112 days). Coral mortality involved a single colony of *P. elegans* that died after four weeks into the experiment, and very likely because of the algal overgrowth. Intraspecific differences in bleaching were evident during the study. Bleaching was the result of the reduction of the number of zooxanthellae and the decline in the concentration of photosynthetic pigments. Zooxanthella density reductions were as follow: *Porites panamensis* (67.3%), *P. damicornis* (53.8%), *Pavona varians* (18.6%). The number of zooxanthellae was increased in *P. elegans* (29%) when exposed to warm water pulses. Chlorophyll pigments per zooxanthella decreased only in *P. panamensis*. *Pocillopora damicornis* was the most sensitive coral species and showed the greatest intraspecific response. *Pavona varians* was the most heat resistant species. Experimental results confirmed that branching coral species are more susceptible than massive species to the detrimental effect of elevated water temperature. This study has demonstrated the possibility that intermittent sea surface coolings during ENSO episodes can extend the survivorship of corals for at least 16 weeks, in comparison to 9 weeks or less when corals get exposed to continuously elevated temperatures.

Recovery of a Coral Community Following Bleaching and Death Associated with the 1997-98 El Nino-Southern Oscillation, Punta Espejo, Marchena Island, Galapagos Islands, Ecuador

Joshua S FEINGOLD*

8000 North Ocean Drive, Dania Beach, Florida 33004 United States of America
joshua@nova.edu

All corals within a 25 x 25 meter quadrat in 7m water depth at Punta Espejo, Marchena Island, Galapagos Islands, were assessed for condition during and after bleaching associated with the 1997-98 El Nino-Southern Oscillation (ENSO). This is the last known robust coral community in the south/central Galapagos archipelago, so monitoring recovery is important to the management of this marine resource. The quadrat was surveyed in March and May 1998 during the highest Eastern Pacific sea surface temperature anomalies and follow-up surveys were performed in June 1999, August 2000 and May 2002. Nine scleractinian coral species were present at the site. Although most species were represented by few ($n < 7$) colonies, predominant species included important reef builders such as *Porites lobata*, *Pocillopora elegans* and *Pocillopora damicornis*. Live colony numbers of *Porites lobata* declined from 454 to 312 from March to May 1998 and then recovered to 426 colonies by May 2002. Also, decreases in pigmentation reversed and nearly all colonies exhibited normal coloration by the end of the survey period. In March 1998 nearly half (48%) of the *Porites* colonies had more than 50% of their tissues exhibit normal pigmentation. This decreased to 25% by May 1998 and then recovered to 95% in May 2002. In contrast, the numbers of *Pocillopora* spp. colonies maintained a little more than 100 live colonies from March 1998 (103) through May 2002 (103). Pigmentation decreased from 69% of colonies having more than 50% normal pigmentation to 50% in May 1998. This recovered to 100% normal pigmentation in May 2002. Thus, the coral community at Punta Espejo has recovered to population levels and pigmentation intensities consistent with those present before the ENSO impact.

Lipids, Carbohydrates, and Proteins in Bleached and Recovering Corals from Kaneohe Bay, Hawaii

Lisa J RODRIGUES*, Andrea G GROTTOLI

240 South 33rd Street, Philadelphia, PA 19104-6316 United States of America
rodrigul@sas.upenn.edu

During bleaching, zooxanthellae and/or chlorophyll concentrations decline resulting in a decrease in photosynthesis and consequently, photosynthetically fixed carbon. Therefore, corals may have to rely on stored energy reserves, including lipids, carbohydrates, and/or proteins for their source of fixed carbon to survive and ultimately recover from bleaching events. On September 4, 2003 fragments from three coral species (*Montipora verrucosa*, *Porites compressa*, and *Porites lobata*) from Kaneohe Bay, Hawaii were experimentally bleached in out-door tanks by raising the seawater temperature 3°C above ambient to 30°C . Additional fragments from the same parent colonies were maintained at ambient seawater temperatures (27°C) in separate tanks as controls. After one month in the tanks, a subset of the fragments was immediately frozen and all remaining fragments were placed back on the reef for *in situ* recovery. Both control and experimental fragments were analyzed for chlorophyll *a*, lipid, carbohydrate, and protein concentrations, and rates of photosynthesis, respiration, and calcification at three time intervals: before, immediately after, and 6 weeks after bleaching. After one month at elevated seawater temperatures, preliminary results indicate that relative to the controls, both *M. verrucosa* and *P. compressa* were visibly bleached (white in color with significantly lower chlorophyll *a* and photosynthesis levels), had depleted their lipid, carbohydrate and protein energy reserves, continued to respire at pre-bleaching rates, and slowed their calcification rates. At the same time, fragments of *P. lobata* did not visibly bleach as much as the other two species (beige in color) with no significant difference in any measured physiological or metabolic variables between control and experimental fragments. During 6 weeks of recovery on the reef, none of the species had changed color. Analyses of all of the physiological parameters after 6 weeks of recovery are still in progress.

Mass Coral Bleaching on High-latitude Reefs in the Hawaiian Archipelago

*Jean C KENYON**, *Greta S AEBY*, *Russell E BRAINARD*, *Joe D CHOJNACKI*,
Matthew J DUNLAP, *Casey B WILKINSON*

Kewalo Research Facility, 1125B Ala Moana Blvd., Honolulu, Hawaii 96814
United States of America

Jean.Kenyon@noaa.gov

The first mass coral bleaching ever recorded in the remote Northwestern Hawaiian Islands (NWHI), a chain of small islands, atolls, and banks that span ~1800 kilometers over more than five degrees of latitude in the northwest portion of the Hawaiian Archipelago, was documented in late summer 2002. Between 9 September and 5 October 2002, towed-diver surveys covering more than 195 km of benthic habitat and belt-transect surveys at 118 sites were conducted at ten reef systems throughout the NWHI to assess coral bleaching across latitude, depth, zone, and taxon. Incidence of bleaching was quantified as percent cover of coral that was bleached in whole-image analysis of towed-diver survey videotapes, and as the percentage of colonies with bleached tissue from colonies counted within belt transects. Both methods indicated that the incidence of bleaching was greatest at the three highest-latitude atolls in the Hawaiian Archipelago (Pearl and Hermes, Midway, and Kure), with lesser incidences of bleaching on reefs at Lisianski and farther south in the NWHI. At the three northern atolls, bleaching was most severe on the backreef, moderate in the lagoon, and low on the deeper forereef. The average incidence of coral bleaching experienced in different geomorphic systems and zones closely corresponds to the composition of the dominant coral fauna coupled with its susceptibility to bleaching. Sea surface temperature (SST) data derived from both remotely sensed satellite observations as well as in situ Coral Reef Early Warning System (CREWS) buoys suggest that prolonged, elevated SST is a likely explanation for the bleaching response. Resurveys of selected sites in July-August 2003 indicated a varied response by different coral taxa to the bleaching event. Annual monitoring of established sites will assist in better understanding the longer-term impacts of the bleaching event on corals, other members of the benthic community, and reef fish assemblages.

Recovery without Restoration: Persistent Disturbances Cause Long-term Changes in Community Structure or Coral Reef Assemblages

*Michael L BERUMEN**, *Morgan S PRATCHETT*

c/o Marine Biology, James Cook University, Douglas, QLD, 4811 Australia
michael.berumen@jcu.edu.au

In 2003, the reef community at Tiahura Reef, Moorea, French Polynesia, was studied following a series of disturbances (Acanthaster planci outbreaks and coral bleaching events) to assess community recovery and composition. Although total abundance of both butterflyfish and corals declined significantly after the disturbances, recovery seems to have occurred with abundances reaching similar values to a 1979 survey. Despite this apparent recovery, it also appears that there was little community resilience, with both fish and corals showing variation in the community composition. Persistent disturbances with disproportionate impact on certain species of corals may have prevented recovery of those species, and subsequently impacted the recovery of some specialist corallivore butterflyfish. Persistent disturbances, even at low levels, may have a large effect on the resulting community structure of reef assemblages.

Competitive Relationships between Algal and Coral Polyps Communities under Direct and Indirect Contacts on Damaged Corals

Eduard A TITLYANOV, *Tamara V TITLYANOVA*, *Irina M YAKOVLEVA**

Palchevskogo St. 17, Vladivostok, 690041, Russia Russian Federation
etitlyanov@mail.ru

Interactions between algal communities (or some algae) and coral polyps under direct and indirect contact were studied under long term experiments (about one year) in the field and in outdoor aquaria at Sesoko Station (Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, Japan). The investigations were conducted in three main directions: (1) Competition between settlers (algae and animals) and coral polyps for injured area (newly formed substrate) of scleractinian coral colonies; (2) Succession of algal communities on the boundary and out of the boundary with coral polyps, seasonal influence of light and temperature; (3) Physiological state of coral polyps living on the boundary with different types of algal communities. It was shown that in the field and in aquaria under normal physiological conditions, more than 120 algal species did not lead to death of the coral polyps living in direct or indirect contact with the algae. It turned out that only two species *Lyngbya majuscula* and *L. bouillonii* (Cyanobacteria) were poisonous for corals. In most cases the corals were able to overgrow algae with the average rate from 1 to 10 mm over the year. The rate of overgrowth of algae by coral polyps depended on many factors. One of them is physiological state and growth morphology of the coral polyps. On the other hand, life form, biomass, chemical features and constancy of algal community are also factors impeding the overgrowth by polyps. On the basis of data obtained, we suggest that the recovery of the fringing reef of Sesoko Island might occur not before than 50-100 years in the absence of natural catastrophes over the period.

Coral Recruitment and Recovery of Coral Communities after 1998 Mass Coral Bleaching around Okinawa Island

*Kazuhiko SAKAI**, *Soyoka MUKO*, *Akira NISHIKAWA*, *Akihiro IWASE*,
Adnrew J HEYWARD

3422 Sesoko, Motobu-cho, Okinawa 905-0227 Japan
sakaikz@lab.u-ryukyu.ac.jp

Coral recruitment and coral community structure were studied along west coast of Okinawa Island, where coral communities were much degraded during 1998 mass coral bleaching by setting coral-larva settlement plates and surveying randomly placed quadrats in 2002 and 2003. Ten stations in 3 areas and 18 stations in 6 areas were set along the west coast of Okinawa Island in 2002 and 2003, respectively. Percent cover of hard corals was less than 5% at all the stations in both years. There were few mature *Acropora* colonies around Okinawa Island, since mortality of branching corals was extremely high during the mass bleaching. However, settlement of corals belonging to Acroporidae was relatively high on the settlement plates in 2002. In 2003, the settlement was lower than in 2002 probably due to a typhoon that hit Okinawa Island just after the *Acropora* spawning. Great recruitment of *Acropora* corals in 2001 was estimated to be great from the size distribution of the small colonies in the community survey. The highest density of the small *Acropora* colonies exceeded 40 m⁻². Coral recruitment was tended to be higher at the areas closer to Kerama Islands, where coral communities still possess high percent cover and species diversity. This suggests that the source populations of *Acropora* recruits to Okinawa Island were in Kerama Islands. The density of recruited *Acropora* colonies decreased significantly from 2002 to 2003 at central western coast of Okinawa Island, where density of the small *Acropora* colonies was the highest in 2002. A few individuals of *Acanthaster* were preying on the *Acropora* colonies there. This study shows that coral communities degraded by coral bleaching may recover if source populations of larvae are present nearby, but the environment of the degraded reefs should be favorable to recruited corals for the recovery.

Coral Community Responses to Hydrodynamic and Thermal Environments in Shiraho Fringing Reef Area in Ishigaki Island, Okinawa

*Wataru KUMAGAI**, Hitoshi TAMURA, Kazuo NADAOKA, Saki HARII, Jun MITSUI, Youichi SUZUKI, Hajime KAYANNE

W207 west8 2-12-1 Ookayama, Meguroku, Tokyo Japan

kumagai@wv.mei.titech.ac.jp

It is well known that there are distinct differences in coral species coverage and their population as indicated by Kayanne et al (1999, 2002) in Shiraho Reef, Okinawa. Their time series transect study on this reef flat in 1998 showed that coral species responded in different degrees of bleaching. To understand the physical and thermal conditions which may be responsible for this differences in such a small scale landscape (about 1km×2km wide), field data analysis of currents and water temperature and hydrodynamic numerical simulations were undertaken. Water temperature data were obtained from 26 observation points in the field surveys conducted during the winter (December 2002 to January 2003) and summer (July 2003) periods. Results indicate that among the three topographic areas: the reef edge, the near-beach and the deeper parts of reef flat, the daily maximum temperature rises higher at points near the reef edge and the near-beach than those on the deeper parts of reef flat. However the cumulative period where temperatures falls below the critical 30°C is longest at the reef edge because of cross-shore advection effects. Furthermore, temperature at some observation points near the reef channel rises as an effect of along-shore advection due to warmer water outflow through the channels resulting in increase in cumulative period of temperature over 30°C near the channel. We can therefore recognize some form of thermal and physical zonation on the reef flat by considering cross-shore and along-shore advection effects and spatial variations of coral coverage are seen to correspond to this thermal phenomenon. The correlation between the variation in recovery from the coral bleaching and the thermal phenomenon will be discussed. For considering the influence of physical factors on the thermal environment quantitatively, hydrodynamic numerical simulations will be shown during the presentation.

Responses of Reef Fish Communities to the 1998 Bleaching Event in Tubbataha Reef National Marine Park

*Micaela C. LEDESMA**, Marlowe G SABATER, Marivel P DYGICO

3 Wescom Road, Puerto Princesa City 5300, Palawan Republic of the Philippines

kaila@tubbataha.org

The over-exploitation of marine fisheries in the Philippines leaves the coral reefs in a critical state making marine reserves the feasible option to sustain the food security of the country. However in this age where global warming increases sea surface temperatures, subsequent bleaching events are expected to occur frequently. The change in the benthic community following this event may have an acute impact on reef fishes since they are highly influenced by their habitat. Will marine reserves therefore be a sufficient tool in protecting our resources given this changing environment where disturbances may be well beyond our control? This study aims to investigate responses of reef fish communities to the bleaching event in a marine protected area. The study site is Tubbataha Reef National Marine Park, situated in the center of the Sulu Sea. The video and benthos point intercept transect methods were used to quantify benthic lifeforms in percentage cover while the fish visual census was used to estimate the variety, numbers and sizes of reef fish in seven permanent transect sites monitored since 1997. A multivariate analysis was used to determine changes in the fish community structure while parametric tests were used to determine significant changes over time. Results from this study showed evident shifts in the fish community after the 1998 bleaching event, attributed to the significant increases in density and biomass of several trophic groups. The increase in herbivores was associated with the significant increase in algae while the increase in other trophic groups could be due to other factors. The characteristics of Tubbataha being remote and protected with a large area and diversity of reef types, it may have the capacity to recover faster compared to other reefs in the country since it is relatively free from human impacts that adds stress and hinders recovery.

Monitoring Corals and Other Macro-invertebrates at Fixed Sites at US Pacific Remote Islands and Atolls

James E. MARAGOS*

300 Ala Moana Blvd., Rm 5-231, Box 50167 United States of America
jim_maragos@fws.gov

Since 2000, the U.S. Fish and Wildlife Service surveyed corals and conspicuous macro-invertebrates at 80 established monitoring sites at 18 remote islands and atolls under U.S. jurisdiction (Necker I., Nihoa I., French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan I., Lisianki I. and Neva Shoal, Pearl and Hermes A., and Midway Atoll in the N.W. Hawaiian Islands; Rose A. and Swains I. in American Samoa; Johnston A., Kingman Reef, Palmyra A. and Jarvis I. in the Line Islands; Howland I. and Baker I. in the Phoenix Islands) or U.S. affiliation (Ailinginae A. in the Republic of the Marshall Islands). Baseline surveys were accomplished at all sites and resurveys accomplished at half the sites in 2000-2002. Rapid ecological assessment and monitoring protocols were required due to ship-based, hour-long limitations at each site. Monitoring transects were "permanently" marked via Global Positioning System coordinates and *in situ* installation of stainless steel monitoring pins at 5-m to 10-m intervals along a 50-m or 100-m transect at each site. Digital video and 1-m² photo-quadrats were collected at each of the sites along surveyor tapes temporarily attached and removed along the pins during each transect survey. A flat-bed Mirage™ film scanner and Sigma Scan™ image processing software were used to identify and calculate the maximum diameter, projected area and genera of all corals and to count the number and genera of each conspicuous macro-invertebrate whose centers fell within 0.5 m of the transect line. These data were used to calculate 1) frequency of corals and macro-invertebrates and 2) mean diameter, percent live coral cover, diversity, and population size distribution and other parameters of corals along each transect. Estimates of recently dead, diseased, fragmented, bleached, and preyed-upon corals were also tabulated. Updated results of all monitoring surveys are presented in the report.

Genetic Differentiation between Johnston Atoll and Hawaii in the Pomacentrid *Plectroglyphidodon imparipennis*

Jason PHILIBOTTE*, Phillip S LOBEL

7 MBL St, BUMP/MBL, Woods Hole, MA 02543 United States of America
shark@bu.edu

Larval dispersal is considered the sole method of genetic exchange among biogeographically separated populations. Approximately 90% of coral reef fish have a pelagic larval stage including *Plectroglyphidodon imparipennis*. This study explores the question of whether pelagic larval duration can be correlated with genetic differentiation. The larval duration of *P. imparipennis* is too short for larvae to reach Johnston Atoll according to satellite tracked drogoue data. Samples were collected in 1981 and 1982 from Hawaii and in 1982 and 2003 from Johnston Atoll. A 377 bp fragment of Mitochondrial DNA control region was sequenced from 115 samples. Genetic structuring analysis was conducted in Arlequin, including Fst and theta values. According to Fst and theta values the 1981 and 1982 Johnston Atoll and Hawaiian population were homogeneous, but sample sizes were small (8 from JA and 17 from HI). This is contradictory to what was predicted by length of pelagic larval duration. A sample size was increased with 57 samples from 2003 and 38 more 1981/82 samples from Hawaii, revealed significant genetic structuring between JA and HI populations. Although there was a significant difference between populations the results did not suggest complete genetic isolation (Fst = 0.077). The differing results could be due to a small sample size in the 1981/82 populations or slight genetic structuring in the 20 years since the first samples were collected.

Protecting Helen Reef a Community-based Conservation Success Story in Palau

Wayne ANDREW*, Michael GUILBEAUX, Scott ATKINSON

212 Merchant Street Suite 200 Honolulu, HI 96813 Republic of Palau
helenreef@palaunet.com

Hatohebi State, also known as Tobi, in the distant Southwest Islands is one of Palau's smallest States, yet is home to Palau's largest atoll, Helen Reef, which is believed to be one of the most biologically diverse reefs in the insular Pacific. Helen Reef is home to extensive corals and reef fish, and provides excellent nesting habitat for marine turtles and seabirds. Located over 300 miles from mainland Palau, Helen Reef has long been poached and degraded by foreign fishers from Asia and overused by Micronesian citizens themselves. After years of attempting to control the over-exploitation of their marine resources, the Tobi community has succeeded over the past four years in fully protecting Helen Reef. A series of actions on the part of the community and state have resulted in elimination of overuse of natural resources. These include: the execution of a thorough biological survey involving both local people and a team of renowned marine biologists, a thorough community-based strategic planning process to identify conservation priorities and actions, the training of eight community members in enforcement, the creation of a Helen Reef Management Board, and cooperation with outside support agencies and donors including: the Community Conservation Network and numerous donors. This paper outlines the lessons learned at Helen in remote reef management and discusses several of the ongoing challenges facing the Tobi community, foremost of which is developing a mechanisms to ensure the sustainability of their management success.

Management Planning for the Rock Islands Southern Lagoon Area of Koror State

Katherine CHASTON, Ilebrang U OLKERIIL, Adalbert ELEDUI*

P.O. Box 116, Koror, Republic of Palau PW 96940 Republic of Palau
rica@palaunet.com

The Rock Islands-Southern Lagoon Area (RISLA) of Koror State is internationally known for its spectacular beauty both above and below the water. As a world-class dive destination, the area provides the foundation for Palau's tourism industry and in turn, the nation's economy. In addition to ecotourism, subsistence and commercial use of the area's natural resources contributes to the nation's economy. But the value of the RISLA to Palau goes far beyond economics. The area is also an integral part of Palau's cultural heritage, contributes significantly to Palau's biological diversity, and provides important habitat for threatened and endangered species. Consequently, the need to properly manage and maintain the ecological integrity of the area is vital for the well being of Palau's economy, culture and diversity. The impetus for this work did not come solely from scientists. Both the traditional and elected leadership at the Koror State and national level have recognized the cultural, biological and economic value of maintaining the ecological integrity of the area. As a result, Koror State Government, with assistance from The Nature Conservancy, is in the process of developing a comprehensive management plan for the RISLA. The Conservancy's Conservation Area Planning tool has been used to identify key species and ecological systems within the RISLA and the main threats to each of these. The tool has been useful in identifying and prioritizing the management issues and actions needed to reduce the key threats to biological diversity. The tool however does not directly address socio-economic issues. To identify socio-economic concerns, Koror State has conducted consultations with community groups and all stakeholder groups who utilize the areas resources. We will discuss our progress to date, the challenges we have faced, information gaps and the key management issues that the state will need to address.

Dong-sha Atoll in the South China Sea: Past, Present and Future*Chang-Feng DAI**

P. O. Box 23-13, Taipei, Taiwan

corallab@ccms.ntu.edu.tw

Dong-sha Atoll, or Pratas Island, is the northernmost atoll in the South China Sea at 20°35'-47'N and 116°41'-55'E. The atoll is about 28 km wide in diameter and covers an area of about 600 km². The atoll was surveyed in June 1994 and a total of 137 species of corals with approximately 80% coral cover and 369 species of fish in 62 families were recorded. The atoll has been intensively fished during the past decade. For example, in 2001, a total of 7976 boats were fishing around and within the atoll with a peak in March and April. These vessels fish with gill nets, long lines, purse seines, and destructive practices such as dynamite and cyanide. The effect of fishing was devastating as revealed in a survey in April 1998. At one reef site, there were 45 species of corals and 118 species of fish recorded in 1994, but only 3 corals and 32 species of fish in 1998. Over 90% of the reef and its inhabitants were killed and replaced by filamentous algae or macroalgae. The food web was virtually collapsed with only low trophic level fish such as algivores and planktivores present. A survey in October 2001 showed that thick beds of dead corals covered all the substrate with no trace of live ones between 1-7 m depth in the lagoon. However, at 10 m depth, about 25% of the substrate was covered by live corals, mostly *Echinopora* spp., fungiids, and poritids. A total of 107 species of corals were recorded and most of them were newly-recruited small colonies. To facilitate the recovery of coral reef, the government of Taiwan has designated Dong-sha Atoll as a marine protected area in December 2003 with an aim to develop appropriate protection and restoration measures.

Heterogeneity and Collective Action: A Study of Community-based Marine Protected Area Management in Fiji*Yae SANO**

310 Graduate House, ANU, Canberra ACT 0200 Australia

yae.sano@anu.edu.au

For effective implementation of protected area management, community involvement is considered the best possible approach. However, the role of heterogeneity among resources users in affecting the likelihood of their collective action has been debated in the theoretical literature of common property institutions. The study will examine how the degree of heterogeneity can affect the capacity of the community to take collective action in order to achieve successful conservation in the context of marine protected area management in Fiji. The study will look at group heterogeneity in three dimensions: social and cultural variations; differences in the nature of individual interests or objectives; and inter-individual variations in some critical endowments. The analysis is based on a field study in several coastal areas of Fiji.

New Markers for Molecular Phylogenetic Studies in Scleractinian Corals*Joel STAKE**, *Joe NEIGEL*

PO Box 42451, Lafayette, LA 70504 United States of America

jstake@yahoo.com

Molecular systematic approaches have demonstrated the need for reevaluation of both scleractinian species designations and classification at higher levels. Unfortunately the set of gene sequences available for the Scleractinia are not sufficient for these tasks. As is the case with many metazoan groups, the nuclear ribosomal genes of the Scleractinia evolve too slowly to resolve closely related taxa. Unlike most metazoa, however, this is also true for mitochondrial genes. Although a few nuclear encoded structural genes have been sequenced for representatives of the Scleractinia, more loci are needed to accurately resolve phylogenetic relationships. To address this need, we have screened genomic libraries for the Poritidae and Agariciidae for single copy, phylogenetically informative sequences. Characteristics of these sequences and their usefulness for phylogenetic inference will be examined.

Combined "Supertree" Phylogeny of Scleractinia Using Matrix Representation Parsimony*Alexander M KERR**, *Andrew H BAIRD*

Centre Coral Reef Biodiversity, Dept Marine Biol, James Cook Uni, Townsville 4811 Australia

alexander.kerr@aya.yale.edu

Numerous issues in coral-reef biology would benefit from the application of a formal comparative evolutionary approach. Hence, estimating a phylogeny of Scleractinia (over 1314 extant species) is a growing problem in the field. However, an important constraint on estimating large phylogenies is computational effort, which scales super-exponentially with the size of a problem. Another important limitation is data acquisition, because no research group has access to all regional faunas. Currently, the most promising tack around these issues is to use a polynomial-time, "supertree" algorithm that combines subtrees generated from smaller, overlapping datasets. We briefly review supertree construction methods and then demonstrate their utility via the most widely implemented form, matrix representation parsimony. Thirty-one published phylogenetic analyses of scleractinian corals comprised of 5 to 80 species were merged to produce a supertree of more than 350 species. The topology was most sensitive to the inclusion of phylogenies derived from morphological characters. Resolution was considerably enhanced by specifying a constraint set of well-accepted supraspecific taxa left uncontradicted by the subtrees. Post-hoc grafting of species to congeners whose monophyly is uncontroversial (e.g., *Acropora* and *Porites*) results in a considerably larger, though less resolved tree, nevertheless useful for studies involving ancestral-state optimisations or path-length analyses. Preliminary ancestral-state mappings of sexuality and reproductive mode indicate that gonochorism and spawning are ancestral in corals. Supertree methods offer the quickest and most economical route to a fairly complete phylogeny of Scleractinia. Towards this end, phylogenetic studies should consider routinely including some easily obtained taxa that maximise overlap with previous work. Additionally, an important design will consist primarily of exemplars that maximise the usefulness of existing studies in contributing to a supertree.

Preliminary Cladistic (Morphology-based) Analyses of Extinct and Extant Scleractinians*Brian R ROSEN**, *Sebastien HODGE*, *Brendan HEVER*

Cromwell Road, London SW7 5BD, Great Britain United Kingdom of Great Britain and Northern Ireland

B.Rosen@nhm.ac.uk

Phylogenetic understanding of scleractinian corals continues to lag behind that of many other groups of organisms. To date, at the level of families and genera, we have (1) subjective morphology-based phylogenies in the older literature, (2) a recent scheme of microstructural groups, subjectively but incompletely branched to suggest possible relationships, (3) good recent progress on molecular phylogenies, and (4) a recent scheme synthesising subjectively all the foregoing. Surprisingly, there is as yet no morphology-based cladogram for the group as a whole that can be compared directly to molecular results. This means that (1) we still have no clear idea about how extinct scleractinians relate to molecular phylogenies (hence a very incomplete evolutionary understanding of scleractinians), and (2) that there is inadequate fossil control on divergence ages established from molecular work (cf. molecular clock). With regard to the first problem, we need to know how common and widespread extinct groups like the *Microleptena* relate to extant groups. Furthermore, traditional classifications keep several large extinct families distinct from apparently similar extant families (e.g. the *Montlivaltiidae* and *Faviidae*), while grouping together other families that have long been thought distinct on microstructural grounds (e.g. *Poritidae*, *Fungiidae*, *Microsolenidae* and *Agariciidae*). These classifications may be artifacts of different subjective palaeontological and neontological traditions. We report on preliminary attempts to generate morphology-based cladograms based on a few extinct and extant key genera like *Microsolenia*, *Favia*, *Fungia* s.s., *Thecosmilia*, *Acropora* and *Stylophyllopsis*, and three extinct non-scleractinian corals as outgroups. Critical, has been the need to pioneer satisfactory ways of character-coding microstructural data, colony modularity, and of treating the highly heterogeneous (and non-homologous?) array of features traditionally described as walls.

Conventional Taxonomy Obscures Deep Divergence between Pacific and Atlantic Corals*Hironobu FUKAMI**, *Nancy KNOWLTON*

9500 Gilman Drive, La Jolla, California 92093-0202 United States of America

hukami@ucsd.edu

Only 17% of 111 reef-building coral genera and none of the 18 coral families with reef-builders are considered endemic to the Atlantic, whereas the corresponding percentages for the Indo-west Pacific are 76% and 39%. These figures depend on the assumption that genera and families spanning the two provinces belong to the same lineages (i.e. are monophyletic). Here we show that this assumption is incorrect for the suborder Faviina based on analyses of mitochondrial (COI, cyt b) and nuclear (β-tubulin) genes. Most Atlantic lineages conventionally assigned to the *Mussidae* and *Faviidae* (*Montastraea* being the only exception) are not distributed within the more numerous Pacific lineages of these "families", but instead represent a well-defined clade that probably diverged over 34 million years ago. Notably, the Atlantic "faviid" *Favia* and the Atlantic "mussid" *Scolymia* are more closely related to each other than they are to their respective "congeners" in the Pacific. Moreover, the distinctiveness of this previously unrecognized Atlantic clade is greater than that of a number of conventionally recognized families (*Merulinidae*, *Pectiniidae*, *Trachyphylliidae*) that are restricted to the Indo-west Pacific. In other words, the Atlantic clade clearly deserves recognition at the family level (*Mussidae* Ortmann 1890 is the senior available family name), whereas several currently recognized Pacific families probably do not. Several morphological characters largely ignored by previous workers substantiate our molecular phylogeny. Preservation of evolutionarily distinct lineages is an important aspect of conservation, but phylogenies have played little role in marine conservation except in the context of "living fossils" such as the coelacanth. The evolutionary distinctiveness of these Atlantic corals suggests that factors in addition to diversity and endemism at the species level need to be considered in planning conservation actions, especially in light of the precarious state of most Caribbean reefs.

Reassessment of Morphologic Characters Used in Phylogeny Reconstruction and Classification within the Suborder Faviina (Anthozoa: Scleractinia)

*Ann F BUDD**

121 Trowbridge Hall, Iowa City, Iowa United States of America
ann-budd@uiowa.edu

New molecular analyses using mitochondrial and nuclear genes do not support conventional taxonomic groupings based on morphologic characters. The families Faviidae, Mussidae, Merulinidae, and Pectinidae are clearly polyphyletic, as are many genera that are conventionally assigned to them (e.g., *Montastraea*, *Favia*). Instead of grouping with their Pacific congeners, Atlantic lineages within the Faviidae and Mussidae represent a well-defined and previously unrecognized clade. Members of the exclusively Pacific families Merulinidae and Pectiniidae are scattered among the Pacific faviids and mussels in molecular trees. These results call into question the homology of morphological characters that have long been used in scleractinian classification, and suggest that new characters and approaches need to be identified for both living and fossil taxa. Conventional characters, which are associated with colony formation, corallite budding, and the size, shape, and arrangement of corallites within colonies, exhibit homoplasy. However, several microstructural characters that have largely been ignored by previous workers substantiate the molecular phylogeny. For example, the corallite walls of Atlantic *Favia fragum* and many Atlantic faviids are formed by septal thickening (septothecal), whereas the walls of the Pacific *F. stelligera* and related taxa on the molecular tree are constructed by the insertion of skeletal structures with distinct trabecular centers between the costae (trabeculothecal). Atlantic mussels have corallite walls formed partially by thin dissepiments, whereas Pacific mussels have walls composed of dissepiments thickened by sclerenchyme. Other morphologic characters that are related to the size, shape, and arrangement of trabecular centers and septal ornament agree with molecular results. Preliminary trees including microstructural characters show greater congruence with molecular results.

Polymorphism in the Nucleotide Sequence of a Mitochondrial Intergenic Region in the Scleractinian Coral *Galaxea fascicularis*

*Toshiki WATANABE**, *Mutsumi NISHIDA*, *Katsutoshi WATANABE*,
Defny S WEWENGKANG, *Michio HIDAHA*

1-15-1 Minamidai, Nakano, Tokyo 168-0064 Japan
toshi@ori.u-tokyo.ac.jp

The mitochondrial DNA of the scleractinian reef coral *Galaxea fascicularis* was amplified by long range PCR, and its partial nucleotide sequences were determined. An intergenic region of 826 bp was identified between the *cytochrome b* (*cyt b*) and *NADH-ubiquinone oxidoreductase chain 2* (*ND2*) loci. Nucleotide sequences were determined in a part (625 bp) of this region in 95 individuals collected at nine sites in two areas of the Ryukyu Archipelago in southwestern Japan. A total of eight haplotypes were found, and a deletion of 290 bp was found in three of them. The presence/absence of the deletion was highly correlated with the hard/soft morphotype. The deletion was found in the majority of hard type colonies, but in a small number of soft type individuals. Frequencies of the haplotypes were significantly different at three of the sampling sites, and highly correlated with the occurrence of the soft and hard types. These results indicate genetic differentiation between the two morphotypes, but also suggest occasional breeding between the two morphotypes. The analysis of the mitochondrial DNA in *G. fascicularis* indicates conservation of the arrangement of mitochondrial loci between Acroporidae and Oculinidae including the presence of a non-coding region between *cyt b* and *ND2*. This observation suggests that an intergenic sequence may be present at an equivalent location of the mitochondrial DNA in many scleractinian species. Analysis of such a region may be useful in phylogenetic studies and detection of genetically differentiated groups within species.

Is the ITS Region the Solution to the "Species Problem" in Corals? A Case Study of Intragenomic Variation, and Alignment Permutation in *Porites*, *Siderastrea* and Outgroup Taxa

*Zac H FORSMAN**, *Gerard M WELLINGTON*, *George E FOX*

Dean Hall, Rm. 2, 2450 Campus Rd., Honolulu, HI 96815 United States of America

zac@hawaii.edu

Scleractinian coral were used as a test case to examine two widely acknowledged problems with the use of the ribosomal ITS region as a phylogenetic marker: intragenomic variation and alignment ambiguities. Sequences from Caribbean and Eastern Pacific *Porites* and *Siderastrea* species were examined, as well as outgroup sequences from GenBank (*Tubastrea*, *Balanophyllia*, *Scapophyllia* and *Montastrea*). Intragenomic variation was lower than previously reported in corals, and most species were fully resolved. Despite a patchwork of conserved sequence motifs among all taxa, objective alignment between higher taxonomic levels became problematic as INDELS increased. Fifty alternative alignments were generated by gap-penalty permutation, and compared by a M-L consensus method. Tree topologies were remarkably congruent; the majority of nodes were unanimously supported. Midrange gap-penalty-alignments were considered optimal by criteria based on character congruence between gaps and substitutions, and ts/tv ratios; therefore, the "mid-point" alignment was chosen to estimate phylogenies with likelihood, parsimony, and distance methods. The resulting phylogenetic relationships were clearly resolved and consistent with previous molecular and fossil studies. Abbreviations: ITS; Internal Transcribed Spacer, M-L; Maximum-Likelihood, ts; Transition, tv; Transversion, rRNA; ribosomal RNA; INDELS; insertions and deletions.

Molecular Phylogenetic Analyses Indicate Growth Form Does Not Contribute to Resolve the Taxonomic Status of Species Group for Genus *Montipora* (Scleractinia; Acroporidae)

*Chaoching George CHANG**, *Chang-Feng DAI*, *Chaolun Allen CHEN*

Institute of Zoology, Academia Sinica, Nankang, 11529, Taipei, Taiwan
biojoe@gate.sinica.edu.tw

Reef-building corals exhibit morphological variations over a series of contiguous biotopes in response to gradient environmental changes. Over a wide depth range, such as between reef flat and slope, morphological variations of grow forms can be enormous. *Montipora* is ranked the second speciose genus of Indo-Pacific reef-building corals with 73 species currently described. Twelve species groups were used to catalog the *Montipora* spp. based on growth forms and fine structures of coenosteum and corallites. In this study, we examined the contribution of growth forms and fine structures to the species phylogeny of *Montipora*. 28 species, representing 10 species groups, were collected from several reefs off Taiwan, and molecular phylogenies were constructed using three independent loci, including a mitochondrial intergenic spacer (mtIGS, 472bp) spanning between CYTB and ND2 genes, nuclear ribosomal internal transcribed spacer (ITS1+ITS2, 393bp), and an intron spanning between exon 2 and 3 of Calmodulin gene (CaM-I, 333bp). Sequence analyses based on mtIGS and ITS failed to resolve the species phylogeny of *Montipora* due to slow evolution of mtIGS and reticulation of ITS, respectively. In contrast, species phylogeny based on CaM-I using nested clade analysis (NCA) and a Bayesian approach clearly grouped *Montipora* spp. in according to the coenosteum and corallites, and indicated that growth forms did not contribute to resolve the taxonomic status of species group for genus *Montipora*.

Evaluation of Molecular Markers for Species Phylogeny of Genus *Acropora* (Cnidaria; Scleractinia; Acroporidae)

*Nu-Wei V WEI**, Carden C WALLACE, Ho-I LIN, Jackie WOLSTENHOLME, Chang-Feng DAI, Chaolun A CHEN
R403, Institute of Zoology, Academia Sinica, Nankang, Taipei, Taiwan Taiwan
teresa@gate.sinica.edu.tw

Acropora is the most speciose genus in coral reef with 113 species currently described. Diversified morphology and potential of cross-species hybridization have drawn our attention in defining the species boundary, constructing species-level phylogeny, and inferring mechanism of speciation for this genus. Although endeavours have been taking in developing molecular markers in the last decade, several unique features such as slow evolution of mitochondrial genome and abundant ribosomal pseudogenes of *Acropora* neither provide little resolution for phylogenetic inference, nor equivocal conclusions in contrast to phylogenies based on fossil records and morphological characters. In this study, we evaluated 4 molecular markers, including mitochondrial cytochrome b gene (*Cytb*), mitochondrial intergenic spacer spanning between *Cytb* and ND gene (*mtigs*), mini-collagen intron 2 (*mci2*), and nuclear histone 2a and 2b gene (*H2ab*), for constructing species phylogeny of genus *Acropora*. All the 4 loci supported the two subgenera, *Isopora* and *Acropora*, as two distinct evolutionary lineages, and relocated *Acropora togianensis* as the fifth species in the subgenus *Isopora*. However, *Cytb*, *mtigs*, and *mci2* suffering from either low variability or sharing unsorted polymorphisms between the Caribbean and Indo-Pacific species provided no further resolution in resolving phylogeny in subgenus *Acropora*. In contrast, phylogeny constructed based on *h2ab* gene using Bayesian approach supported, in part, to Wallace (1999) that *A. humilis* group and *A. austera* form the basal clades of morphological phylogeny. The utility of nuclear coding genes in resolving species phylogeny of *Acropora* is highlighted.

Analysis of Intraspecific and Interspecific Variation Using Reproductive and Molecular Evidence to Interpret Evolutionary Relationships in a Scleractinian Coral Species Complex

*Jacqueline K WOLSTENHOLME**
Museum of Tropical Queensland, 70-102 Flinders Street, Townsville, Queensland, 4810, Australia
jackie.wolstenholme@jcu.edu.au

Morphological characters are traditionally used to define species of corals. However, defining species boundaries in scleractinian corals is impeded by the difficulty of distinguishing between ecological and evolutionary influences on the appearance of colony morphology. To facilitate accurate definition of species, I used reproductive evidence (relative timing of spawning and fertilisation potential) and molecular evidence (mtDNA intergenic region) to interpret the extent to which intraspecific and interspecific morphological variation is indicative of microevolutionary relationships in species of the *Acropora humilis* species group. The eight species of the *A. humilis* group (*A. humilis*, *A. samoensis*, *A. globiceps*, *A. gemmifera*, *A. monticulosa*, *A. digitifera*, *A. retusa* and *A. multiacuta*), six intraspecific morphs and seven intermediate morphs were used as the sampling units. Intraspecific and intermediate morphs were defined on the basis of morphological appearance, with the former appearing as distinct units within a single species and the latter sharing characters with more than one species. Samples were collected from Taiwan, Indonesia, Great Barrier Reef, PNG, Solomon Islands, American Samoa and French Polynesia. This study demonstrates that examining intraspecific and interspecific patterns of polymorphism is valuable for interpreting evolutionary relationships in corals. Combined evidence derived from the reproductive and molecular criteria suggests that the morphs are at various stages of divergence from the species with which they share morphological characters and that the morphs may indicate possible zones of speciation and hybridization. Reproductive data provided a greater level of resolution than the molecular data, suggesting that reproductive boundaries have evolved more rapidly than the mtDNA intergenic region in the *Acropora humilis* species group. Recognition of morphs also avoided the possibility of taxonomic error, from forcing colonies into incorrect or inappropriate species categories, and was therefore essential for the accurate interpretation of evolutionary boundaries.

Molecular Systematics of Guam *Acropora*

*Sandra L ROMANO**

#2 John Brewer's Bay, St. Thomas, USVI 00802 Virgin Islands of the United States
sromano@uvi.edu

Despite the use of a variety of characters such as morphology, reproduction, behavior, and more recently genetics, species boundaries in scleractinian corals remain difficult to define. Molecular studies demonstrate that some closely related species of *Acropora* and *Madracis* are not genetically distinct. Analyses of molecular characters do not result in phylogenies that are completely congruent with morphological analyses. Hypotheses to explain these results include incomplete lineage sorting of ancestral genotypes and interspecific hybridization. *Acropora* is the most speciose genus of extant scleractinian corals and has been the focus of a number of studies at both the morphological and molecular level. Data from the fossil record indicate that high diversity within the genus is due to rapid speciation in the Indo-Pacific throughout the last 20 Ma. Like many other *Acropora* species, those from Guam spawn on the same night, with overlapping but not completely synchronous spawning times. Interspecific hybridization has been observed in the laboratory between some of these species. RAPD markers amplified from DNA extracted from frozen coral sperm clearly differentiate most of the Guam *Acropora* but a few species cannot be unambiguously distinguished from each other. Analyses of DNA sequences from the *Pax-C* nuclear intron and the mitochondrial putative control region from these species are underway. Phylogenetic analyses will be used 1) to determine the relatedness of Guam *Acropora* to species from other regions and 2) test hypotheses about molecular evolution in scleractinian corals.

Hybridization, Mosaic Introgression, and a Genic View of Coral Species

*Steven V VOLLMER**, Stephen R PALUMBI

Hopkins Marine Station, Stanford University, Pacific Grove, CA 93950 United States of America
svollmer@oeb.harvard.edu

Broad sympatric ranges of reef corals provide a unique opportunity to study hybridization on the scale of ocean basins, and examine the role that local hybridization plays in the evolution of reef corals. In the Caribbean, we have shown that hybridization among two sympatric staghorn corals (*Acropora cervicornis* and *A. palmata*) generates a diverse suite of first generation (F1) hybrids, whose morphology is determined by its maternal parent. One-way backcrossing of the hybrids with *A. cervicornis* allows genes to flow unidirectionally (or introgress) from *A. palmata* into *A. cervicornis*. Three out of four genetic loci (the MtDNA control region, and the PaxC and Calmodulin nuclear introns) introgress in *A. cervicornis*. These introgressed loci are found at similar frequencies within populations, but the frequency of introgressed alleles as a whole varies significantly across the Caribbean. In contrast, no introgressed alleles have been found in *A. cervicornis* at the fourth genetic locus (a MiniCollagen intron). The lack of introgression at MiniCollagen is significant because it shows that selection can severely limit introgression at some gene regions. This pattern of differential introgression corresponds to the emerging genic view of species, which has demonstrated that species genomes are differentially permeable to introgression and that selection acts to maintain gene regions important to the identity of species.

Microbial Contributions to Phanerozoic Reef Development

*Constance M SOJA**, *Brian WHITE*, *Anna I ANTOSHKINA*

13 Oak Drive, Hamilton, NY 13346 United States of America
csoja@mail.colgate.edu

Despite stromatolite decline in the Late Proterozoic, temporal and geographic evidence from many sites suggests that stromatolites had a persistent presence in many reef (and level-bottom) habitats throughout the Phanerozoic. Post-Cryptozoic stromatolites were not restricted to the intertidal zone nor did they function primarily as “disaster” taxa following times of global ecologic crisis. Compositional and biofabric differences in Phanerozoic stromatolites also imply recovery and evolution of microbial-algal-invertebrate communities after the Cambrian explosion, rather than a resurgence of Precambrian-like “anachronistic facies.” Sediment trapping and syngedimentary cementation induced by a diversity of calcimicrobes enhanced upward accretion in reefs and reef mounds and facilitated nucleation and growth of associated macrobiotas. Significantly, these microbial reef carbonates contribute to ecologic and biogeographic databases for elucidating the conditions that were conducive (or detrimental) to stromatolite growth and evolution in the Phanerozoic. During the Late Silurian, for example, stromatolites of subtidal origin formed impressive reefs along the margins of the Uralian Seaway. In the Alexander terrane of Alaska, microorganisms and early marine cementation at the platform margin produced a reef-fringed rim, which influenced platform sedimentation patterns in backreef sites. Despite sea-level fluctuations and tectonic instability, the stromatolite reefs were rebuilt periodically following episodes in which platform margin debris was shed to the foreslope. Demise of the stromatolite reefs resulted from catastrophic platform collapse and regression during culminating phases in an orogenic event in the Early Devonian. Similarity to Silurian stromatolites in the Urals and Siberia indicates the Uralian Seaway was an important migratory route for invertebrate and microbial organisms. Depauperate metazoans associated with the stromatolites suggest the subequatorial seaway was a partially enclosed, narrow marine corridor. Compressional activity along the northern margins of Laurentia and Baltica in the Late Silurian produced fluctuating environmental conditions favorable for the diversification and preservation of microbial-sponge reefs.

Late Devonian Canadian High Arctic Reefs Prior to the End Frasnian Global Mass Extinctions

*Paul COPPER**, *Evan EDINGER*

ramsey lake road, sudbury, P3E 2C6 Canada
pcopper@laurentian.ca

Frasnian reefs of the Mercy Fm., Banks Island (73°N latitude, Canadian western high arctic) were developed as part of the Mercy Platform, at four stratigraphic levels (labeled A, B, C, D) within a ca. 300m thick unit of carbonates and siliciclastics. During Late Devonian time (ca. 380Ma), this area was located some 15° north of the equator, on the northwestern flanks of Laurentia, similar geographically today to the Rowley Shoals (NW Australian shelf). The time over which these Banks Island reefs were deposited was about 2 million years. The Banks Island reefs were initiated as a series of smaller patch reefs and reefal mudmounds, constructed on the distal margins of a giant delta complex extending some 1500km westwards from Greenland and Ellesmere islands. Intercalated with reefs, and capping reefs, were dark grey to black siliciclastics carrying abundant woody pteridophyte trunks up to 15cm diameter, some of which also occur within reefal limestones. Reef types include small patch reefs up to 10m diameter and 2-3m thick, grading into large reefs over 1-2 km diameter and 30-70m thick, and reef clusters or tracts spread over tens of km. Reef diversity was low in the region, limited to ca. 30 species of tabulate and rugose corals and stromatoporoids. These are the only Frasnian age reefs in the Canadian arctic, as the 2500km long Middle Devonian reef shelf had vanished. Reefs were lacking in the late Frasnian, buried by encroaching sands and silts from the east due to the rising Caledonian mountains, and restrained by sealevel lowstands. The F/F boundary occurs within wood and spore-bearing terrestrial siliciclastics.

Triassic Reefs of North America and the Tethys: Outposts in the Ancient Pacific

*George D STANLEY JR.**

Missoula, Montana 59812 United States of America
fossil@selway.umt.edu

During the Middle to Late Triassic, reef building were centered in the tropical Tethys seaway. During the Norian interval of the Late Triassic, reefs witnessed the most major phase of development since the mid-Paleozoic expansion. This occurred along extensive carbonate platforms that bordered the Tethys as well as on microcontinents in that seaway. During Norian time, shallow-water sphinctozoid sponges and scleractinian corals emerged as major paleoecologic players. Diversity of both group increased during the Late Triassic to climax during the Norian. Reef building continued during the last interval of the Triassic (Rhaetian) but diversity declined. Along the far-eastern fringes of the Panthalassa ocean, sphinctoid sponges, and scleractinian corals, as well as many other reef-dwelling and reef-building organisms, remarkably similar to those of the Tethys, also experienced a Norian reef expansion in tropical to subtropical settings. However, these occur in displaced terranes now accreted to the North American craton and they presently are distributed from Alaska to South America. The majority existed as ancient volcanic islands, similar to atolls and island arcs of today. Before accretion to North America, they inhabited the central and eastern Panthalassa. Inboard sites in Nevada, California, and Sonora Mexico were associated with an island arc system along the edge of North America. In the Americas Norian reefs and carbonates were not as well developed nor as large and taxonomically diverse as counterparts in the Tethys. Of paleogeographic interest is the high biotic similarity at genus and species levels, between Norian terrane sponge and coral biotas and those of the Tethys (60 to over 70 percent). These differences may be explained by ocean temperatures, tectonic and eustatic sea-level fluctuations, influx of siliciclastic sediment, nutrient input, and the symbiotic association with zooxanthellae.

Carbonate Deposition on Shallow Shelf and on Deep Sea Floor Deduced from a Carbon Cycle from Cretaceous to Present

*Toru NAKAMORI**, *Kyoko KITAMURA*, *Shinpei NATAKA*

Aobayama, Aobaku, Sendai Japan
nakamori@dges.tohoku.ac.jp

Global carbonate deposition rates, the sum of carbonate accumulation rates on continental shelves and those on deep sea floor, from Cretaceous to present were reconstructed to provide a boundary condition for the carbon cycle model. The rates on the deep sea floor were calculated by carbonate concentration, density, and sedimentation rate obtained through the DSDP and ODP, while the rates on shallow continental shelves including coral reefs were studied by Russian geologists in the 1980's. These rates were averaged every 0.5 million years, resulting in an array of 300 data during the last 150 million years. Ratio of the accumulation rate on the deep sea floor / the global deposition rate was calculated to evaluate a distribution of the carbonates to the shallow environment and to the deep sea. Three periods at which the rate was higher than 1.0 were situated in the Late Cretaceous, Oligocene, and Late Miocene to present. They are called “Event I, II, and III” in this study, respectively. The Event I is not conspicuous, and distribution of carbonate deposition to the shallow environments was at the same level as to the deep sea floor. The Event II started at the Eocene/Oligocene boundary (36 Ma). The Event III also started abruptly in the Late Miocene (12 Ma), and the ratio attained 9.0 in the Quaternary. These facts suggest that a circulation mode between the deep sea and shallow waters suddenly changed in the Oligocene, and Late Miocene. Supply of alkali earth metal and carbonate ions due to a rapid erosion of silicates in the Himalayan and Tibetan plateau must have contributed to a high accumulation rate of carbonate at the Event III. Cenozoic carbonate deposition by reef builders might be affected by these events resulting in a reduction in reef formation.

Circum-Alpine Carbonate Facies Patterns and Developments in the Paleogene: A Key Period in the Evolution of Shallow Water Carbonates and Reefs

*James H NEBELSICK**, Michael RASSER, Davide BASSI

Sigwartstrs. 10, 72076 Tuebingen, Germany Federal Republic of Germany
nebelsick@uni-tuebingen.de

The Paleogene represents is an important period in the evolution of shallow water carbonate systems and reefs. It represent the transition between the end Cretaceous extinction event and the development of modern reefs systems. Shallow water carbonates are characterized by larger foraminiferal and coralline algal dominance and by the paucity of large scale coral reefs. It also represents a period of dramatic climatic change from a Greenhouse to an Icehouse world accompanied by large scaled shifts in climatic zones and circulation patterns. We have investigated shallow water carbonates across the Middle Eocene to Lower Oligocene in the circum-alpine area using detailed studies of the diversity, structure and taphonomy of benthic communities. These carbonates represent classic localities for Paleogene stratigraphy and benthic environmental studies. A synthesis of facies patterns show dramatic developments in spatial and temporal distribution. 14 different Major Facies Types (MFTs) have been distinguished and defined based on the distribution of dominating components, subordinate components, sediment types as well as carbonate fabrics. These MFTs are dominated by coralline algae, benthic foraminifera, corals and bryozoans. Corals can be locally common, but are not characterized by extensive reefal build-ups. The presence of the these MFTs are distinguished along a shelf gradient for the three time intervals: Middle Eocene, Upper Eocene and Lower Oligocene. Temporal and spatial patterns show considerable dynamics of facies presence and development (= Facies Dynamics). Distinct patterns of facies dynamics are recognized include facies appearance, facies disappearance (= extinction) linked to the extinction of larger foraminiferal taxa, immigration, expansion, reduction, stasis, shift and replacement. These are linked to local, regional and global developments including extinction events and biogeography. The study of these facies patterns and dynamics are important as this interval represent a key time period leading to the development of modern carbonate facies patterns.

Reef-Coral Growth and Oceanographic Conditions in the Neogene Caribbean

*Kenneth G JOHNSON**, Mauricio ALONSO SALVA

900 Exposition Blvd., Los Angeles CA 90007 United States of America
KJohnson@nhm.org

The emergence of the Central American isthmus during the Miocene and Pliocene had a profound effect on Caribbean shallow marine biota, including high rates of extinction and wholesale reorganization of benthic ecosystems. There is strong evidence that these biotic changes were caused by long-term decline in surface productivity in the Caribbean basin. Paleooceanographic conditions in the Eastern Pacific during the Neogene remain to be documented, but this seasonally productive region has been used as a modern analog to model oceanographic conditions in the Neogene Caribbean. Skeletal growth rates in living zooxanthellate corals are influenced by environmental conditions such as temperature, light, and nutrient availability, and in this study we explore how variation in growth rates recorded in fossil reef-corals can be used as a proxy for ancient environmental conditions. Annual extension rates of common species of massive fossil corals were measured on skeletal density bands using x-radiographs. Useful growth rates were estimated for both extinct and extant taxa including species of *Colpophyllia*, *Montastraea*, and *Porites*. These data were compared with Recent Caribbean and Eastern Pacific growth rates compiled from the literature. Fossil growth rates were variable, but well within the range observed on Caribbean modern reefs. However, growth rates from both fossil and Recent Caribbean colonies are significantly lower than growth rates from Recent *Porites*, *Pavona*, and *Gardineroseris* living in the Eastern Pacific. This suggests that during the Neogene, conditions in the Caribbean were very different than conditions in the modern Eastern Pacific.

Decline and Transition in a Holocene Coral Reef Complex, Dominican Republic

*H Allen CURRAN**, Lisa GREER, Bosiljka GLUMAC, Gala GUERARD, Lisa BERRIOS

98 Green Street, Northampton, Massachusetts 01063 United States of America
acurran@email.smith.edu

An extensive fringing coral reef system existed along the margins of a marine embayment of the Caribbean Sea that occupied the fault-bounded Enriquillo Valley, southwestern Dominican Republic, in mid-Holocene time (~8-5 ka). Subaerial exposures below present sea level reveal pristinely preserved fossils and present the opportunity to examine with high resolution the three-dimensional record of facies changes of a coral reef system in decline from a high-diversity, "healthy" fringing reef to an essentially monospecific *Acropora cervicornis* reef. Final transition to a serpulid worm-tube dominated facies marked the termination of coral growth. Primary causes for decline and transition in the reef system are attributed to changes in rate of sea-level rise and salinity of the paleo-seaway. Large colonies of *Montastraea annularis* species complex and *Siderastrea* sp. were common in the early reef system, and enormous thickets of *Acropora cervicornis*, now forming coral beds of up to 15 m thick, dominated the later stages of reef development and flourished until ~5 ka. At that time, the connection to the Caribbean Sea began to close, generating conditions of fluctuating salinity that initiated the decline of the coral reef system. As sea level rise slowed and the embayment became restricted, serpulid worms invaded, forming large (2 m high, 3 m diameter), carbonate mounds that extend to elevations of 2+ m above present sea level. These mounds commonly coalesce to form prominent ridges and have a framework of serpulid tubes coated with a layer of porous carbonate tufa. Serpulid layers, 1-3 cm thick, also occur within beds of the coral reef sequence, first appearing ~18.5 meters below sea level. The stratigraphy and stable isotope geochemistry of the Enriquillo corals, serpulid layers, and mounds suggest multiple transitions in salinity of the seaway. Changing composition of microfossil assemblages preserved in the reef deposits mirrors these salinity changes.

Yes, Virginia, There Are Framework Reefs

*Dennis K HUBBARD**, Alicia DAVIS, Gregory LAWSON, Wilson RAMIREZ, Lisa GREER

52 W. Lorain St., Oberlin, OH 44074 United States of America
dennis.hubbard@oberlin.edu

Late Holocene evaporation following closing of a seaway in the western Dominican Republic has exposed spectacular coral-reef deposits in the Enriquillo Valley. General stratigraphy was determined based on close examination of 30 stations in Canada Honda. Coral abundance was quantitatively determined along seven vertical transects at 20-cm intervals. A total of 1360 mollusc samples were collected in 0.7 m² quadrats every 40 cm along the transects and in 10 larger m² quadrats. Five coral facies (*Acropora cervicornis*, mixed corals, two massive zones and a massive/platy facies) were identified and reflect the full range of environments present on modern Caribbean reefs. The facies distribution reflects initial transgression starting nearly 10,000 years ago, followed by regression as sea level slowed, allowing the development of shallower mixed-coral and *A. cervicornis* facies. Coral abundance in outcrop averages close to 50% and most colonies are in place. The relative abundance and diversity of corals and morphologic changes in key species reflect both spatial and temporal changes in sedimentation regime (rate and consistency). Molluscs similarly reflect changing depth and sedimentation, but follow coral facies only partially. The reef reflects high and variable sedimentation. Furthermore, there are indications of periodic disruption by storm waves that, on one occasion, blanketed the deeper reef with debris from shallow water. Coupled with presumably limited circulation in the semi-enclosed embayment, these observations infer an environment that would be considered by most researchers to be marginal and heavily stressed. Nevertheless, twenty-nine coral species and sixty mollusc species were identified. Furthermore, the high sedimentation levels are probably the principal cause for the excellent preservation in this and nearby outcrops. Thus, elevated stress levels were offset by favorable taphonomic conditions, resulting in in-place accretion. This raises questions about how similar factors have played in the preservation of other and older reef systems through time.

On Possibility to Map Living Corals in Species Level by Hyperspectral Remote Sensing

*Tiit KUTSER**

Akadeemia tee 21, 12618, Tallinn, Estonia

tiit@phys.sea.ee

The ultimate goal of remote sensing would be mapping of coral reef habitat, especially corals, on species level. This requires that the differences in reflectance spectra of corals of various species are big enough to be detectable by a remote sensing instrument, but it will also require high within species similarity in case of corals of the same species. In situ measured reflectance and first derivative spectra of four coral species (*Acropora hyacinthus*, *Pocillopora verrucosa*, *Acropora humilis*, and *Porites massive*) were studied to determine whether or not the within-species optical properties are stable and between species optical differences detectable to allow mapping of living coral cover at species level by underwater close range remote sensing. Variability in colony colour within coral species is common. We also found high within-species variability in the reflectance and the first derivative spectra in case of the studied species. *Porites* colonies found in the GBR showed the greatest within group similarities in the first derivative spectra. However, the massive *Porites* colonies were not identified on species level (there are 7 common *Porites* massive species in the Great Barrier Reef). The results of this study show that it is unlikely that optical methods can be used in mapping Scleractinian corals in species level.

Computer-Vision for Benthic Classification

*Ma Sheila Angeli C MARCOS**, *Porfirio ALINO*, *Maricor SORIANO*, *Caesar SALOMA*

Instrumentation Physics Laboratory, National Institute of Physics, University of the Philippines, Diliman, Quezon City Republic of the Philippines

rei_SHI@yahoo.com

There is a need to validate coral reef classification results of remote-sensing algorithms through on-site inspection of reef transects. A video-based, computer vision approach can provide a rapid assessment minus the tediousness of visual inspection. We present a coral reef classifier using color and texture cues derived from digitized frames of a coral reef film. The color feature is derived from normalized *red-green* color histogram of the coral image. The texture feature, a joint distribution of wavelet-energy histogram and Local Binary Pattern histogram are derived from wavelet-filtered video frames. Classification is divided into subgroups: colorful or achromatic for the color feature and regular, irregular or smooth for the texture feature. The ability of the descriptors to distinguish these subcategories is investigated for classification into three benthic categories namely live corals, dead corals and abiotics. The color and texture features were tested on 185 coral image frames, 23% of which are dead corals, 53% live corals and 24% sand images. Classification estimation through the *knn*-rule was performed on the coral images. Live and dead corals were found to be dominantly regular in texture but are colorful and achromatic respectively. This agrees with the fact that live and dead corals are regularly-textured but the latter is bleached. Sand was distinguished as gray in color and irregularly-textured. Overall our technique is capable of tagging a color-texture characteristic to a benthic category (live coral, dead coral or sand) as much as a human observer would.

Application of ROV-based Video Technology to Complement Coral Reef Resource Mapping and Monitoring

*Philip A KRAMER**, *Pamela REID*, *Shariar NEGAHDARIPOUR*,

Arthur GLEASON, *Daniel DOOLITTLE*, *Brooke GINTERT*

MGG/RSMAS 4600 Rickenbacker Cswy United States of America

pkramer@tnc.org

Unmanned submersible systems, including remotely operated vehicles (ROV) and autonomous underwater vehicles (AUV), are rapidly becoming the primary platforms for underwater survey, inspection, and mapping. Here, we report on first year results of a four-year project to develop ROV technology to increase the speed and repeatability with which coral reef plots can be mapped and inventoried. Specific objectives of this work are to 1) apply an advanced 2-D digital video processing technique to construct georeferenced photo-mosaics of small habitat patches on coral reef; 2) extract ecological indices of reef condition from mosaics and validate using independent diver-based methods; 3) evaluate environmental conditions (turbidity, surface relief, etc.) on the application of this technology. Our current system is a Phantom XLT ROV equipped with 2-D video camera system that utilizes angle sensors to determine the pitch and roll angles, magnetic compass for heading direction, and a vision system to estimate the translational motion as well as differential heading changes from video. Positioning is achieved through real-time image processing algorithms of low-resolution frames while final mosaicing done off-line with high resolution frames. Tests of the system to date have mainly involved laboratory tank trials complemented with field trials in Florida and the Bahamas where 3x3 m coral reef plots have been imaged. Computer-assisted image analysis techniques are currently being used to extract ecological information from 2-D mosaic, customizing existing packages and developing new modules as required. Ecological indices which include: species richness based on presence/absence (hard coral, soft coral, macroalgae); substrate cover (% hard coral, soft corals, macroalgae, abiotic, other) by species; types of coral mortality (old, recent, diseased, sediment, etc.); and coral size distribution.

Seagrass Mapping System with Underwater Remotely Operated Vehicle (ROV) and Captive Balloon Cameras

*Kenji OTANI**, *Masumi YAMAMURO*, *Kiyokazu NISHIMURA*, *Ken NOZAKI*,

Ken KATO, *Akira NEGISHI*, *Takeshi HAYASHIBARA*, *Motoya TAMAKI*,

Hirofumi SHIMIZU

AIST-2, 1-1 Umezono, Tsukuba, Ibaraki 305-8568 Japan

k.otani@aist.go.jp

The authors have developed the new mapping system of seagrass beds for three years in order to assess the population of seagrass in subtropical and tropical coast. The system consists of the Remotely Operated Vehicle (ROV), surface-monitoring cameras on a captive balloon and remote observing stations on the ground and on a mother ship. The ROV is equipped with underwater cameras and a quadrat frame for sensing seagrass and other lives in the coastal zone, and the positioning system with GPS (Global Positioning System) and an acoustic navigation system. The CCD cameras on the balloon tethered to the mother ship take aerial photographs of sea surface for tracking the ROV. The captured scenery images from both the ROV and the balloon cameras are transmitted to the mother ship and the ground station. The synchronization of these images provides wide area distribution of the seagrass by using remote sensing techniques. While the images transmitted to the mother ship are used for controlling the ROV and the mother ship itself safely and swiftly, the images transmitted to the ground station are utilized for supervising the monitoring program by professional staffs and for showing underwater and aerial scenery of the coastal zone for public and educational viewings. The demonstration of the mapping system will be shown during the symposium.

A Rapid Classification Tool for Coral Communities Using Multispectral Acoustics

*Nakul SARAN**, Eric D THOSTESON, Robert VAN WOESIK

150 W. University Blvd., Melbourne, Florida, 32901 United States of America
nsaran@fit.edu

This project aims towards the development of a cost effective underwater remote sensing tool that uses acoustics to identify and quantify benthic coral reef communities. Current underwater techniques are either time consuming or expensive, or both. Currently, sonar systems used on coral reefs rely solely on the return signal while ignoring backscatter. Yet, backscatter provides vital information. This acoustic system not only utilizes multiple acoustic bands but also incorporates the entire acoustic envelope that includes phase shifts and frequency changes. The system was initially programmed as a single band sensor with a frequency range of 1-5 MHz. Initial calculations showed that each sensor must be at a maximum height of 1 meter above the reef, thus forming a transect width of 15 cm; multispectral arrays increase the swath width to approximately 1 m. The acoustic backscatter system was first calibrated to determine different attenuation responses of different coral species, algae and sand to develop a library of such constants. The acoustic data will be processed using neural network algorithms to facilitate the development of classification maps. We aim to supplement the system with a laser swath reef geomorphology profiler that will generate relief maps with an accuracy of 1 mm. These maps will then be supplemented by information collected through the spectral bands of the acoustic backscatter system. This technology will allow rapid and efficient assessment of benthic coral reef communities that will be immediately available after leaving the field.

Using Acoustic Tags to Track Fish in Three Dimensions with Sub-meter Resolution

*Mark A TIMKO**, Tracey W STEIG, Bruce H RANSOM

715 NE Northlake Way, Seattle, Washington 98105 United States of America
mtimko@htisonar.com

Acoustic tags have been used to monitor the swimming patterns of individual fish of a variety of different species worldwide. Resulting three-dimensional fish tracks typically had sub-meter resolution. Tags were implanted, either gastrically or surgically, into fish ranging in size from salmonid smolts (95 mm) to adult sturgeon (1.0 m). A variety of different tag sizes were used, however the majority of the tags were approximately 6.5 mm in diameter by 18 mm in length, operated at 300 kHz, and weighed approximately 0.75 grams. Tags were typically programmed to emit an acoustic pulse every second. To detect acoustic signals, passive hydrophones with omni-directional beams were installed at fixed positions. As few as 6 and as many as 32 hydrophones were used to monitor the transmitted pulse from the tagged fish, based on the size of the required coverage area. As fish approached and entered the study area, the transmitted signal from each tag was detected and arrival time was recorded for each hydrophone. The differences in arrival times of signals from an individual tag on each hydrophone were used to calculate a three-dimensional position. Fish were tracked in three-dimensions as they moved throughout their respective study areas, which have included coral reefs, estuaries, aquaculture ponds, dam forebays and navigation locks. Examples of representative three-dimensional fish tracks will be presented. Acoustic tags provide a unique opportunity to get fine scale data on fish movement and behavior in a know area of interest.

Natural Short-term Environmental Changes, Growth and Survival of *Acropora cervicornis* as Viewed through Continued Monitoring

Rocio Del Pilar *GARCIA-URUENA**, Ernesto OTERO

Isla Magueyes Labs. Box 908, Lajas, PR 00667 Puerto Rico
rdelpilar@cima.uprm.edu

La Parguera Natural Reserve (LPNR) comprises a series of marine habitats including mangroves, seagrasses and coral reefs. Reefs within LPNR are subjected to various temporal and spatial water quality patterns. These patterns modulate the underwater light field (ULF) affecting the survival of different coral species and therefore the biodiversity of the system. It is imperative to supplement observations of the distribution of coral reef species with detailed knowledge of temporal and spatial variations of water quality and ULF in systems such as LPNR. We conducted bioassay studies by transplanting a fast-growing coral specie, *Acropora cervicornis*, to determine its response to contrasting ULF and water quality patterns in two locations of LPNR. Branch extension and survival of *A. cervicornis* along with UV light and PAR attenuation coefficients (Kd), salinity and continuous records of temperature, chlorophyll fluorescence (Chla Fl) and turbidity using moored instrumentation were measured from October through December 2003. Water quality and ULF demonstrated a clear significant difference between the reefs with a strong modulation by storms and associated precipitation, runoff and waves. These environmental patterns agree with the bioassay results given that *A. cervicornis* attained ca. 90% survival and 50% of growth relative to the control, while in the more turbid site attained close to 20% of growth and none survived. This work demonstrates the importance for frequent and long-term assessment of short-term environmental variabilities affecting the distribution and health of species in coral reef habitats.

Underwater Laboratory in Coral Reef

*Tadayuki KAWASAKI**, Toshifumi FUKASAWA, Yozo SHIBATA, Naoyuki TAKATSU

3-1-1 Higashi Kawasaki-cho Chuo-ku, Kobe 650-8670 Japan
kawasaki_tadayuki@khi.co.jp

The authors have investigated the recent status on research of marine science in coral reef and proposed a new tool called "Underwater Laboratory" expected by researchers. To efficiently research into ecosystem in shallow water zone, it is ideal for researchers themselves to carry out observing, sampling, measuring and analyzing with their five senses, by going into the sea of their site and seeing and touching with their own eyes and with their own hands the objects in the natural condition. Thus, the development of a facility enabling researchers to make long and safe underwater activities has been expected by researchers. The underwater laboratory allows six persons' habitation and research down to a 50 m water depth. It is located at a 30 m depth and is capable of excursion submerging to a 50 m depth. The environment in the underwater laboratory is controlled to have the same high pressure as the outside on the concept of saturation diving. Researchers can freely go to/return from their site of research at the sea bottom, using this laboratory as their base. Before researchers surface by diving, the pressure in the underwater laboratory is reduced to the atmospheric pressure and then raised up to the same pressure as the outside, with their being kept on staying therein. The underwater laboratory is supplied with air, water, electric power, food, etc. from the surface. The support facility always monitors and controls the condition of the underwater laboratory to ensure the researchers' safety and habitability. A deck decompression chamber (DDC) is equipped for early treatment of decompression sickness. The authors expect that the underwater laboratory will be of great use to researchers of the Pacific Ocean and the Asian seas.

Managing Seascapes for Resilience to Global Change

Paul MARSHALL, *David WACHENFELD**, Laurence MCCOOK

PO Box 1379, Townsville, Qld 4810, Australia P.Marshall@gbrrmpa.gov.au

Local stressors and global change combine to create daunting challenges for the long term viability of coral reef ecosystems. The effects of large scale changes, such as climate trends, on coral reef ecosystems are extremely complex and poorly understood, and the capacity of the system to acclimatise or adapt is almost completely unknown. Reef ecosystems are highly dynamic systems that have evolved to cope with a wide range of often-dramatic natural disturbances. However, human influences have eroded the natural resilience of many coral reef systems, reducing their capacity to cope with disturbance. A resilient system will have the best chance of coping with future surprises. Strategies aimed at rebuilding and supporting the natural resilience of the system are the best investment for ensuring that reefs can continue in the long term to provide the goods and services on which humans depend.

GBRMPA has recently been developing several major initiatives aimed at improving and supporting the resilience of the GBR ecosystem. While these have not necessarily been instigated in response to climate change, they have been motivated by global trends in reef condition that result from the cumulative stresses from human activities. Growing awareness of the threat of climate change has provided additional impetus to these activities, and is leading to development of a resilience-based framework for reef management. GBRMPA has implemented major initiatives aimed at supporting the resilience of the GBR ecosystem: protecting biodiversity; improving water quality and promoting sustainable fisheries.

Factoring Global Climate Change into Marine Reserve Design

*Benjamin S HALPERN**, Brian P KINLAN

735 State St., Santa Barbara, CA 93101 United States of America

halpern@nceas.ucsb.edu

Most recent efforts to develop and implement marine reserves are being done with the goal of these closures being permanent. Given the political and social challenges that these efforts are encountering, it is imperative that these permanent closures are designed not only to account for current ecological and environmental conditions but also to account for long term changes in species and habitat distributions and persistence. Here we develop several modifiers and rules than can be used to adjust the size and location of marine reserves to account for changes in marine environments and ecosystems predicted to occur as a result of global climate change, such as sea surface temperature (SST), sea level, and regional climate regimes. In particular, we show 1) how bathymetric and nearshore topographic slope can be used to predict how sea level rise will affect depth distributions and the likelihood that structural habitats such as coral reefs will be able to “keep up” with sea level rise, and consequently how reserve size and location should be adjusted to account for this; 2) how regional coherence with global and regional changes in SST and climate regimes can be used to determine which locations are least susceptible to deleterious effects of global climate change and therefore more stable locations for marine reserves, and also if reserve size needs to be increased to provide some insurance against future changes in disturbance frequency and intensity; and 3) how predicted range shifts for species can be used to modify the locations selected for reserve closure. We also explore applications of these guidelines to current and proposed marine reserve networks to demonstrate their utility.

Maximizing Coral Reef Conservation

*Sheila A MCKENNA**

1919 M St. N.W. #600, Washington, DC United States of America

s.mckenna@conservation.org

Establishing networks of marine protected areas (MPAs) and no take areas (NTAs) are an effective means of preserving rapidly declining coral reefs. However, coral reef conservation is difficult given that stressors on reefs are multiple and synergistic. Even the best designed and maintained MPA/NTA network is subject to global climate change. Just as the range of stressors on coral reefs is diverse so is the response of coral species to these stressors. The differential bleaching response of coral species to sea temperature increase is an example. Therefore it is important that MPAs /NTAs networks are set up to include the fullest compliment of coral species possible in the area not only to maximize the conservation of biodiversity, but to ensure the survival of coral reefs. Encompassing the majority of known scleractinian coral species of a region in a network of MPAs/NTAs is challenging as these species are difficult to identify *in situ*, many areas lack data and resources are limited (time and money). The Marine Rapid Assessment Program (MRAP) of Conservation International has collected data for scleractinian corals, molluscs and coral reef fish in Indonesia, the Philippines and Madagascar. Here, we use these datasets to test the surrogacy value of each taxon in relation to the others in the selection of priority areas for conservation. That is, the effectiveness of complementary networks of protected areas selected for one taxon in representing others with special focus on zooxanthellate scleractinia. This analysis provides useful insights for guiding future marine conservation planning in regions where biological data is restricted to particular taxa.

Responding to Mass Coral Bleaching Events

*Heidi Z SCHUTTENBERG**, Paul MARSHALL

1305 East-West Hwy; SSMC 4, 11th Floor; Silver Spring, MD 20910; United States of America

heidi.schuttenberg@noaa.gov

The speedy onset and high visibility of mass coral bleaching events requires an effective and timely response by reef managers in order to maintain credibility. Predicting events, understanding their impacts, sharing information, and identifying potential mitigation strategies are core responsibilities for managers faced with mass bleaching. This paper describes the potential elements of an effective mass coral bleaching response as well as the challenges and planning requirements likely to arise. Key response elements include: early warning, rapid impact assessment, communication, and management interventions.

All Our Eggs in One Basket: The Present State of Tropical Marine Biodiversity Conservation

*Edmund GREEN**, Richard WOOD, Richard STUMPF, Gene FELDMAN, Norman KURING, Bryan FRANZ, Ashley HOLT, Corinna RAVILLIOUS, Jamie OLIVER, Julie ROBINSON

219 Huntingdon Road, Cambridge, CB3 0DL United Kingdom of Great Britain and Northern Ireland

ed.green@unep-wcmc.org

A number of calls have been made for increased protection of the marine environment in response to the globally declining state of ecosystems. Targets of 10-20-30% are loosely based on research suggesting that it is necessary to set aside 10-40% of areas to maintain marine biodiversity. Governments have committed themselves to establishing networks of ecologically representative marine protected areas (MPAs) with the specific objective of halting the loss of marine biodiversity, especially in coral reefs and associated ecosystems such as seagrass and algal beds. These shallow-water tropical habitats are a global priority for marine conservation because, according to conservative estimates, one quarter of all marine species occur in coral reefs while human activities are threatening 60% with destruction. Here we show that less than one-tenth of tropical shallow-water habitat is theoretically protected. Almost one-fifth of coral reefs occur within the boundaries of existing MPAs but this proportion is deceptively high with almost three-quarters in just one protected area, the Great Barrier Reef Marine Park, and, until very recently, 41% managed under regimes which can permit destructive activities. We highlight pronounced regional differences in coral reef protection and assess the ecological functionality of the existing collection of coral reef MPA sites as a foundation for a global network.



Oral Session
July 1 (Thu)



Indicators of Coral Reef Health in the Mesoamerican Reef

Melanie D MCFIELD*

PO Box 512, Belize City, Belize

mcfield@wwfca.org

Healthy Reefs Initiative was developed to clarify how to define and measure reef health and complement ongoing conservation efforts in the Mesoamerican reef (MAR). A wide variety of descriptive data can be used to describe ecosystem health, yet the real challenge is deciding which indicators are most relevant for management considerations and what their target or healthy values should be. In parallel with selecting the right physiological and ecological indicators is the need to select diagnostic indicators, appropriate with the application of new biotechnology tools and geochemical techniques. We monitor ecosystem health by measuring specific parameters or metrics of a particular indicator in order to separate out natural variation (or noise) from actual changes in biological integrity. Target indicators represent small, but significant attributes of the overall ecosystem, thus indicators are signals that convey complex data into practical and useful information for managers, with different indicators being chosen for different conservation/management objectives. We have identified a menu of seventeen indicators appropriate for monitoring in the Mesoamerican Reef. The selected indicators are measurable criteria that feed into the following monitoring questions: What is happening to the reef? (structure, processes, etc); Why is it happening? (diagnostic tools); and How does nature influence the outcome? (resistance/resilience factors). Scorecards have been created for each indicator describing management objectives, benchmarks, and targets. Given the current lack of data for most indicators, these should be treated as drafts with the understanding (and research directive) that each indicator will be recalibrated for the MAR until a standard reference condition (the norm) and achievable targets have been well established. The Healthy Reefs Initiative aims to focus and integrate these specific parameters of reef health into existing and new monitoring programs in the region, thus building our capacity to better manage and sustain reef health.

Detection of Thermal Pollution through the Variability of Benthic Communities in an Area of Nuclear Power Plant in Taiwan

Yalan CHOU*, Li-Lian LIU

70 Lien-hai Road, 804 Kaohsiung, Taiwan

m9051607@student.nsysu.edu.tw

The influence of thermal discharge from a coastal nuclear power plant station on sessile invertebrates' recruitment in Kenting (southern Taiwan) was assessed on the basis of 10 years data. Abundance of the benthic assemblages exhibited significant differences between heated effluent and influent locations ($p < 0.05$) when the station operated normally. However, there was no difference in the abundance of benthic communities between influent and effluent areas during the accidentally shut down period (March 18 - April 25, 2001) (MDS analysis). At the same time, a significant difference ($p < 0.05$) in the ranges of temperature fluctuation between normal and shut-down periods was observed. Combined with the data on temperature fluctuation and variability of benthic communities, it is proposed that the range of temperature fluctuation may be more important than increasing water temperature in shaping the benthic communities in the effluent areas.

Evaluation of Condition Indices in Eastern Philippine Reef Communities

Emmi B CAPILI*, Wilfredo Y LICUANAN, Cleto L NANOLA JR.

Velasquez St., Diliman, Quezon City, Republic of the Philippines

emmi@upmsi.ph

Several measures of assessing reef conditions are currently being utilized. Of which Coral cover, Development, Condition, Succession, Mortality indices and Shannon Index of Diversity are most common. However, they do not account for the reefs available space for recruitment, which is essential for reef development. Here, a new index called Coral Habitat Occupancy Index (CHOI) is introduced as a supplement to live coral cover and an improvement over the coral mortality index, it takes into account space such as hard substrate with little algal covering, potentially available for coral recruitment. Along with the other indices, we evaluated their usefulness in eastern Philippine reefs. The indices were evaluated according to their abilities to distinguish good sites from poor ones and differentiate community types derived by more detailed taxonomic inventories of the same sites. Coral generic diversity and fish biomass were used as initial criteria for selecting good sites. Analyses of benthic lifeform data from 21 sites resulted into two communities namely reefs dominated by branching acroporids and reefs dominated by algae. With both criteria, all the indices were not able to differentiate good sites from poor sites as well as community types. In the case of CHOI, it distinguished good sites and community types clearly and can be useful if applied in conjunction with other indices. A relationship between lifeform diversity and coral generic diversity was apparent and it also showed that there is no direct relationship between live coral cover and fish biomass.

Remotely Sensed Rugosity and Relationships with Benthic Indicators of Coral Reef Condition

Ilsa B KUFFNER*, John C BROCK, Linda E GROBER-DUNSMORE,

Victor E BONITO, T Donald HICKEY, Melanie S HARRIS

600 4th Street South, St. Petersburg, FL 33701 United States of America

ikuffner@usgs.gov

With the realization that coral reef ecosystem management must occur across large spatial scales, we are seeking variables that are easily measured over large areas and correlate well with the status of reef resources. In this study, we investigate the utility of new technology in airborne laser surveying (NASA Experimental Advanced Airborne Research Lidar (EAARL)) in predicting the status of shallow (<15 m) coral reef ecosystems. After large portions of Biscayne National Park, Florida, U.S.A. were surveyed remotely using EAARL, reef fish and benthic community structure variables were measured using traditional methods *in situ* on 12 patch reefs. On each reef, measurements of rugosity (i.e. roughness of the benthos) and the abundance and species richness of macroalgae, reef fish, gorgonians, and other sessile invertebrates were made at independent, randomly selected stations ($n = 16$). EAARL submarine topography data were used to produce several novel indices describing rugosity at spatial scales unobtainable using traditional *in situ* methods. Rugosity is important because it provides information about surface area and shelter availability for reef organisms, and has been found to correlate positively with reef fish species richness, abundance, and biomass. Up until now, inability to measure rugosity on spatial scales appropriate to the organisms of interest has constrained research efforts. We conducted correlation, ANOVA, and multiple linear regression analyses to elucidate the predictive power of EAARL rugosity measurements in describing the variance in reef community structure. EAARL rugosity indices were significantly correlated with *in situ* rugosity measurements and weakly correlated with species richness of fishes. Additionally, relationships were found between benthic cover variables and herbivorous fish abundance. The EAARL shows promise as a technique to predict coral reef community structure over large areas and may be an important tool for managers as they strive to protect and restore coral reef resources.

Technological Approaches to the Assessment of Deepwater Coral Reefs in the Northwestern Gulf of Mexico

*George P SCHMAHL**, Emma L HICKERSON, Douglas C WEAVER
1200 Briarcrest Dr., Suite 4000, Bryan, Texas, 77802, United States of America
george.schmahl@noaa.gov

The reefs and banks of the northwestern Gulf of Mexico contain some of the northernmost coral reefs of the continental United States. This series of geologic features, located near the edge of the continental shelf, are primarily the seafloor surface expressions of underlying salt domes or diapirs. Some of these banks are shallow enough to have allowed the establishment of active coral communities. The best known of these are the East and West Flower Garden Banks, which surprisingly contain some of the healthiest coral reefs in the western Atlantic and Caribbean region. Several other banks in the region also contain important coral assemblages but have not been as well documented, including McGrail, Bright, Geyer and Sonnier Banks. Most of these reefs occur at depths from 120 to 160 feet (36 to 49 meters), near the limits of active scleractinian coral growth. The documentation and assessment of these deepwater coral reefs require the use of technological approaches other than SCUBA diving. A series of exploratory expeditions were conducted utilizing manned submersibles and remotely operated vehicles (ROV) to investigate these deepwater coral reefs. A baseline survey methodology was developed utilizing an ROV (or submersible) equipped with digital video and an acoustic tracking system tied into a geographic information system (GIS). This allowed accurate mapping and assessment of the biological communities. Significant coral communities were documented at McGrail Bank at depths of 130 to 145 feet (39 to 44 meters). This coral assemblage is composed primarily of the blushing star coral (*Stephanocoenia intersepta*) at densities that approach 30% benthic surface cover. Less prominent coral reef areas were verified at the other bank features. Although protected from the direct impact of oil and gas operations, these features are currently not protected from a variety of other potential impacts.

Feedback Monitoring in Environmental Impact Assessment on Coral Reefs - Putting the Science into EIA

*John TURNER**, Ricahrd BOAK, Rebecca KLAUS
School of Ocean Sciences, Marine Science Laboratories, University of Wales, Bangor, Menai Bridge, Anglesey Gwynedd, Wales, UK, LL59 5EN United Kingdom of Great Britain and Northern Ireland
J.turner@bangor.ac.uk

Environmental Impact Assessment (EIA) is a more effective tool in reef management when feedback loops are employed during the construction and operational phases of a development. Monitored environmental parameters become thresholds or 'control panel criteria' within which developers must work. If thresholds are exceeded in the near-field of the development, then a far-field (control) site is monitored to assess whether a change in parameter is due to the development (in which case construction must cease) or another cause. Feedback monitoring was embedded in an EIA for a major wastewater scheme employing primary treatment, chlorination and a sea outfall through a coral reef on Mauritius in the western Indian Ocean. The new outfall replaces existing outfalls which discharge domestic and industrial effluent directly onto shores, into lagoons and onto a reef crest, causing eutrophication, sedimentation, and pathogen levels above acceptable limits. The project was novel, because one option involved bore hole injection of wastewaters into a lava tunnel under the reef, while another involved construction of a submarine pipeline to -35m depth on the reef front. A baseline coral reef and water-quality survey, in which permanent monitoring stations were established, was undertaken at the construction site, near-field sites and far-field sites to determine a suite of realistic control panel criteria which could be monitored by the developer and scrutinised by the Chief Engineer and Scientific Advisor. The survey quantified the physical structure and benthic cover at the sites to provide a baseline against which change could be measured, and to accurately determine spatial and temporal mitigation measures for construction activities (such as anchoring, rock cutting, dredging, armouring, rock dumping). The case study illustrates how good practice in Coastal Zone Management involves EIA with direct feedback monitoring underpinned by sound scientific data to determine realistic, usable criteria.

Towed-diver Surveys, a Method for Estimating Reef Fish Assemblages over a Large Spatial Scale: A Case Study at Swains Island and Rose Atoll, American Samoa

*Brian J ZGLICZYNSKI**, Robert E SCHROEDER, Stephani R HOLZWARTH, Joe L LAUGHLIN
2570 Dole Street, Honolulu, Hawaii, 96822-2396 United States of America
Brian.Zgliczynski@noaa.gov

A new method has been developed to assess reef fish assemblages at shallow to moderate depth (< 30 m) over large spatial scales. Two open-circuit SCUBA divers were towed behind a small boat while piloting towboards equipped with digital video cameras, survey data sheets, high precision temperature depth recorders, and timekeeping devices. A GPS was used to record the track of the small boat during the survey and a layback model was applied to georeference the position of the recorded data. The towed-diver fish observer recorded all fishes larger than 50 cm Total Length (TL) within a 10m wide swath approximately 2km long. Digital video recorded during the towed-diver surveys was analyzed by viewing 40% of each tape to assess fishes larger than 20cm TL and by viewing 100% of each tape to assess fishes larger than 50cm TL. The results of this study show that the towed-diver survey and digital video analyses are effective methods to evaluate reef fish assemblages of remote and/or expansive reef ecosystems. By comparing the two, the limitations of each method are identified and can be addressed for specific applications. An examination of the towed-diver survey methodology, including the analysis of digital video, is presented along with a case study of the results from 23 towed-diver surveys conducted at Swains Island and Rose Atoll, American Samoa February 17-26, 2002.

Spatial Distribution of Large Mobile Predators in the Northwestern Hawaiian Islands

*Stephani R HOLZWARTH**, Brian J ZGLICZYNSKI, Robert E SCHROEDER
1125 B Ala Moana Blvd., Honolulu HI 96814 United States of America
stephani.holzwarth@noaa.gov

Sharks (Family Carcharhinidae) and jacks (Family Carangidae) were surveyed using towed divers at the atolls and banks of the Northwestern Hawaiian Islands annually from 2000 to 2003. Divers were towed behind a small boat on a 60-m line at depths ranging from 1 to 30 m. Each tow transect was 10 m wide and approximately 2 km long. We compared abundance and biomass of these predators at banks versus atolls and at different habitats within atolls (forereef, backreef, channel, and lagoon), and mapped their spatial distribution. Neither abundance nor biomass of sharks differed significantly between the banks and atolls even though both appeared to be an order of magnitude higher at the banks. Both abundance and biomass of jacks were significantly higher at the atolls. Within atolls, significant differences between habitats existed. Both sharks and jacks were observed most frequently in forereef habitats and least often in backreef and lagoonal habitats, with biomass estimates showing the same pattern. Maps of shark and jack distribution within each atoll and bank show localized hotspots where large mobile predators are spatially or temporally concentrated. We conclude that towed-diver surveys can provide an effective way to identify coarse habitat associations of sharks and jacks.

Coral Reef Monitoring for Climate Change Impact in the Caribbean

Marcia M CHEVANNES CREARY*, Peter WILSON-KELLY, Sean GREEN, Leslie WALLING

13 Gibraltar Camp Way, Mona, Kingston 7, Jamaica WI Jamaica
marcia.creary@uwimona.edu.jm

The Caribbean: Planning for Adaptation to Climate Change (CPACC) project was developed by CARICOM countries in response to their growing concerns about the impacts of global climate change on their members states. Component 5 - Coral Reef Monitoring for Climate Change Impacts (one of the nine components of the CPACC project) was designed to establish a long-term monitoring program, which over time would be expected to show the effects of global warming factors (temperature stress, sea level rise, and hurricanes) on coral reefs, starting with three pilot countries (The Bahamas, Belize and Jamaica). The first year of monitoring (2000) was considered critical as the information and experience gathered was used to improve on the design and implementation of the programme. There are plans under the Mainstreaming Adaptation to Climate Change (MACC) project, the follow up to CPACC project, to expand the monitoring programme to the other CARICOM countries of the Eastern Caribbean. This report provides a summary of the results of the pilot monitoring exercise carried out in the Jamaica, Bahamas and Belize in 2000 and also the continuation of this monitoring in Jamaica over the four-year period 2000-2003.

Does Local Oceanographic Conditions at the Mexican Pacific Can Buffer the ENSO Effects on Coral Reefs?

Luis E CALDERON-AGUILERA*, Hector REYES-BONILLA

Km 107 Carretera Tijuana - Ensenada United Mexican States
leca@cicese.mx

Before the ENSO 1997-1998, it was thought that this event was not relevant to the coral reefs of the Mexican tropical Pacific compared to the devastating effects of 1982-83 ENSO had on coral reefs from Central America. However, unusually high sea surface temperatures from May to September 1997 caused severe bleaching all along the coast, but affected differently each locality. To test the hypothesis that upwellings and local oceanographic conditions marked that differences, given the occurrence of the 2002-2003 ENSO, we have been monitoring two coral reefs: La Entrega, Oaxaca (15°N) and Cabo Pulmo, at the tip of the Baja California Peninsula (23.5°N) from June 2002 to date, in order to compare with previous data. Coral cover was estimated through 50-m point-transect method (10 transects at Oaxaca and 18 transects at Cabo Pulmo), invertebrates through 50 X 1 m band transects and fish by stationary circular census of 5 m radius, following a random stratified sampling design. At Oaxaca, live coral cover was 71% in June 1998, but decreased to 23% in June 2002 and 24% in June 2003; on the other hand, death coral increased from 17% in June 1998 to 50% in June 2002 and 48% in June 2003. At Cabo Pulmo, live coral cover was 42% in December 1998, 20% in July 2002 and 12% in October 2003; respectively, death coral was 23%, 16% and 34% for the same dates in this location. Interestingly, the invertebrates and fish communities have not changed, which may be indicating a structural rather than a functional relationship with the corals.

Biodiversity on the Marginal Coral Reefs of South Africa: The Face of the Future?

Michael H SCHLEYER*, L CELLIERS, A KRUGER

P.O. Box 10712, Marine Parade, Durban 4056, Republic of South Africa
schleyer@ori.org.za

Southern African coral communities form a continuum from the more typical, accretive reefs in the tropics of Mozambique to the marginal, southernmost African distribution of this fauna in KwaZulu-Natal. The latter are limited in size, yet they provide a model for the study of many of the stresses to which these valuable systems are globally being subjected. Soft coral cover, comprising relatively few species, exceeds that of scleractinians over much of the southern reefs. The coral communities nevertheless attain a high biodiversity at this latitude on the East African coast. A long-term monitoring programme, involving image analysis of high resolution digital photographs of fixed quadrats, has revealed significant changes in community structure on the reefs in recent years, concurrent with consistent increases in mean and maximum temperature. Insignificant bleaching was encountered in the region during the 1998 ENSO event, unlike elsewhere in East Africa, but quantifiable bleaching occurred during an extended period of warming in 2000. Published projections on the long-term effects of climate change indicate that more reefs will become marginal as a result of global warming. The current monitoring on the South African reefs has thus been expanded to investigate the extent to which they will elucidate the future of more typical reefs. This paper will present a synopsis of the methods we have developed for our studies, our findings and their significance.

Recovery (or Not) of the Major Reef-building Species *Acropora palmata* (Elkhorn Coral) in National Parks in Florida and the Caribbean

Caroline S ROGERS, Richard C CURRY*

1300 Cruz Bay Creek, St. John, USVI 00830 Virgin Islands of the United States
caroline_rogers@usgs.gov

The major reef-building species *Acropora palmata* (elkhorn coral) is increasing in abundance in the US Virgin Islands following its devastation 20 to 25 years ago from white band disease and hurricanes. New colonies have developed both from fragments and from sexual recruits. Biologists from the US Geological Survey and the National Park Service are collaborating in studies of this species, now under consideration for listing on the Endangered Species List, in Virgin Islands National Park, Buck Island Reef National Monument, and Biscayne National Park. Spatial distribution, abundance, size frequency, and data on diseases and other causes of mortality are being collected, and photographs of selected colonies are being taken every month. A pilot study of 66 colonies at Haulover Bay, St. John, US Virgin Islands, from February - November 2003 showed the dynamic nature of the elkhorn population there, with 40 (61%) of the colonies exhibiting new growth, 25 (38%) losing tissue to white pox or patchy necrosis, 2 (3%) affected by white band disease, 5 (8%) losing more than 90% of their tissue, and 5 (8%) dying during this 9 month period. Although there are clear signs of new, actively growing colonies, further growth of existing colonies and future recruitment may not offset losses from diseases, predators (*Coralliophila* snails, fireworms, and territorial damselfishes), and physical breakage (from storms, swells, boats, snorkelers). Many colonies are growing in very shallow water close to shore and vulnerable to boat damage and to sedimentation from upland construction. Even without additional hurricanes, bleaching events, or new diseases, it would take decades for this species to become as abundant as it was in the 1970s and 1980s.

Monitoring Benthic Cover at Four Reefs' Forereefs around St. John, US Virgin Islands

Jeff MILLER, Jim PETTERSON, Rob WAARA*, Caroline ROGERS

1300 Cruz Bay Creek, St. John, VI, 00830 Virgin Islands of the United States
William_J_Miller@nps.gov

Long-term annual video monitoring for changes in benthic cover (e.g.: coral, gorgonian, sponge, algae, sand) at four coral reefs in and around Virgin Islands National Park (VINP), St. John, USVI has been undertaken since 1999. Twenty randomly selected transects were permanently placed for filming and subsequent video analyses at Newfound, Yawzi, Mennebeck and Haulover Reefs (the latter three being located within VINP). An innovative approach was used to apply statistically rigorous random sampling methods to each reef site. This protocol uses a SONAR-based mapping system whereby the reef area can be simply mapped with all potential sample points identified. This significant deviation from traditional "haphazard" sampling allows for a more valid application of results to the entire study site fore reef zone. Each reef is located within relatively undisturbed watersheds with good water quality. Study site depths range between 6 to 15 meters. *Montastraea annularis* (complex) is dominant at each reef and is found in 95% of transects sampled in 2003. Among the sites, coral cover ranged between 25.1% (± 16.4 SD) at Mennebeck in 2003 to 7.1% (± 5.7 SD) at Yawzi in 1999. Newfound Reef was the only study sites to show a statistically significant decrease in coral cover from 18.0% (± 6.3 SD) in 1999 to 12.2% (± 5.3 SD) in 2001 ($p < 0.01$). Additionally at Newfound Reef, as a pilot study, new random transects were located each year at Newfound Reef to compare with permanent random transects. This revealed that repeated sampling of permanently located random samples provides more statistical power and can reduce sample size by half when compared to non-permanent random sampling.

Comparative Assessment of Coral Reef Systems Located along the Insular Platform of St. Thomas, US Virgin Islands and the Relative Effects of Natural and Human Impacts

Steven E HERZLIEB*, Richard S NEMETH

2 John Brewer's Bay, St. Thomas, VI 00802 Virgin Islands of the United States
sherzli@uvi.edu

Most research on Virgin Islands reefs has been concentrated on shallow (5 - 30 m depth) near-shore fringing reefs less than 1 km from shore. On the insular platform off the south coast of St. Thomas, U.S. Virgin Islands, there are also extensive mid-shelf reefs located 2 - 10 km from shore (5 - 30 m depth) and shelf-edge reefs located 10 - 15 km from shore (>30 m depth). Very few descriptive or empirical studies have been done on these reef systems, especially shelf-edge reefs. Due to their similar depths, near-shore and mid-shelf reefs are exposed to similar levels of natural disturbance, while mid-shelf reefs are less susceptible to human induced stresses due to their greater distance from shore. Shelf-edge reefs are even less susceptible to anthropogenic stresses. Mid-shelf reefs, especially fringing reefs associated with undeveloped cays, provide an ideal control for measuring the effects of anthropogenic stresses on near-shore reefs. Baseline data of bleaching, disease, coral species composition and the percent cover of live coral, dead coral covered with turf algae, macroalgae, sponges, gorgonians, coralline algae, and non-living substrate are presented for near-shore, mid-shelf, and shelf-edge reefs south of St. Thomas. These are the first data of this kind to be presented for these shelf-edge reefs. Near-shore reefs had significantly lower percent cover of live coral and significantly higher percent cover of algae than both mid-shelf and shelf-edge reefs. No significant differences in levels of disease and bleaching were found between different reef systems. Continued monitoring of both mid-shelf and shelf-edge reef systems along with near-shore reefs may elucidate the synergistic effects of natural and anthropogenic stresses on coral reefs.

Coral Reefs off Former Navy Bombing Ranges: Destruction or Protection?

Ken J P DESLARZES*, Robert NAWOJCHIK, David J EVANS,
 Cheryl J MCGARRITY, Peter M GEHRING

550 East 15th Street, Plano, Texas 75074 United States of America
kdeslarzes@geo-marine.com

The Puerto Rican islands of Vieques and Culebra have been used as U.S. Navy bombing ranges from 1941 through 2003 and 1901 through 1975, respectively. The degree of collateral damage to adjacent coral reefs has been a point of contention for many years. Despite scientific studies to the contrary, the general perception has been of widespread damage to nearshore marine ecosystems. This study examines the relative health of various coral reef sites around both islands. Study sites were chosen to reflect varying degrees of military and civilian impact. Organisms examined include hard corals, other sessile benthic invertebrates, and fishes. Despite difficulties in categorizing "impacted" versus "non-impacted" sites, it was evident that those sites closest to the bombing ranges were not necessarily worse than other sites, and in some cases were healthier. This finding has been denoted as a "sanctuary effect" of enforced military protection (i.e., the security afforded to active military bases excludes civilian activities that are deleterious to the environment). Because of the transfer of military lands on Culebra and Vieques to civilian control, it is imperative that alternative management plans (with associated enforcement) be implemented as soon as possible to avoid overexploitation of the natural resources of these islands.

Juvenile Corals and Coral Diseases in Former Military and Civilian Waters of Vieques and Culebra Islands, Puerto Rico

Cheryl MCGARRITY*, Ken DESLARZES

11846 Rock Landing Drive, Suite C, Newport News, VA 23669 United States of America
cmcgarrity@geo-marine.com

The U.S. Navy recently vacated the Puerto Rican islands of Vieques and Culebra after several decades of military training. This provided a unique opportunity to study the effects of enforced exclusion of civilian and non-military activities on large coral reef areas surrounding these islands. As part of a larger study, we assessed abundances of juvenile corals and occurrences of coral diseases as a snapshot indication of reef condition at 18 sites surrounding Vieques and Culebra. Three site types were compared: sites near former military land-based live impact areas (military target sites), military non-target sites, and civilian sites. We identified, photographed, and counted juvenile corals in 45 quadrats (50 by 50 cm) haphazardly placed at each site, and evenly distributed around three sampling stations. All diseased corals encountered were photographed. We found higher densities of juvenile corals and higher numbers of juvenile coral genera at Culebra sites. Military target sites had the highest densities of juvenile corals, followed by civilian sites. Sites located on the western side of the Culebra contained higher densities of juvenile corals than eastern sites. At Vieques, highest density was at the military non-target sites, followed by civilian. The southern sites had greater densities of juvenile corals than northern sites. Coral diseases identified were: bleaching, black band (BBD) and white band disease (WBD), aspergillosis, and dark spots. Disease abundance was highest on Culebra overall. Dark spots disease was only witnessed in Culebra. Aspergillosis and WBD were more abundant on Culebra; BBD was more abundant on Vieques. Higher densities of disease were on the western side of Culebra than the eastern side. One western site on Culebra had as much as twice the density of diseases as compared to all others. Vieques had higher densities of disease on its southern side. Coral bleaching was found at all sites.

Reefs at Risk in Sabah - Assessment of Coral Reefs for Integrated Coastal Zone Management

*Annadel S CABANBAN**, *Lauretta BURKE*, *Gaim LUNKAPIS*

Sepangar Bay, Locked Bag 2073, 88999 Kota Kinabalu, Sabah Malaysia
annadelc@ums.edu.my

Mapping of coral reefs and assessing the risks these reefs from land-based sources of pollution are useful for identifying appropriate management options at the scale that managers can implement options. Studies showing these are few and we report here the application and utility of such approach. The Reefs at Risk in Sabah project digitized coral reef in Sabah at the scale of 1:50,000 and assessed the risks of these reefs from sedimentation, coastal development, and land-based sources of pollution. Data layers on these threats were gathered from various sources and analyzed following the protocols in the broader Reefs at Risk in Southeast Asia analysis. The results of the analysis in Sabah show where reefs are at risk and are considered and incorporated in the Statutory Planning for the Coastal Zone in Sabah. This assessment of risks is important in the integrated coastal zone management and in the conservation of coral reefs.

Mediterranean *Hippocampus* Mission: A Study on the Geographical and Ecological Distribution of Seahorses Carried Out in Collaboration with Recreational Scuba Divers

*Stefano GOFFREDO**, *Piccinetti CORRADO*, *Francesco ZACCANTI*

Marine Science Group, Via F. Selmi 3, I-40126, Bologna, Italian Republic
sgoff@tin.it

Seahorses (*Hippocampus*) live in both tropical and temperate waters, where they are vulnerable due to their life histories and habitat preferences. Habitat degradation and fishery overexploitation has led to drastic population declines on a global scale. Population monitoring is essential to assess their current status and manage their conservation. This is the first study conducted in Italian waters to determine the geographical and ecological distribution of the two Mediterranean seahorse species: *Hippocampus hippocampus* and *Hippocampus ramulosus*. Recreational scuba divers were recruited and trained to report sightings on a questionnaire. In this 3-year study, 2536 recreational scuba divers spent 6077 diving hours gathering data and completed 8827 questionnaires. 8% of the questionnaires reported seahorse sightings for a total of 3061 sighted specimens, 68% of which referred to *Hippocampus ramulosus*. The two seahorse species had overlapping geographic distributions. Seahorse abundance varied considerably around the coast of Italy: the northern Adriatic Sea had the greatest abundance of seahorses, followed by the central-southern Tyrrhenian Sea and seahorses were rare in the Ligurian and northern Tyrrhenian Seas. Preferred habitats were shallow areas with either sandy bottoms or *Posidonia oceanica* meadows. The seahorse distribution may be correlated with the degree of degradation of *P. oceanica* meadows. We have shown that resource users like scuba divers are willing to take part in biological monitoring and can contribute both in scientific terms by collecting considerable amounts of data over short time periods, and economic terms by indirectly part funding research. The greatest limitation with volunteers was the difficulty in obtaining a uniformly distributed sample across time and space. We conclude that recreational scuba divers can play an active part in the monitoring of the marine environment and that the "Mediterranean *Hippocampus* Mission" may be used as a model for biodiversity monitoring.

Dynamics of Reef Fish Assemblages on Coral Reefs Subjected to Different Management Approaches in the Abrolhos Bank, Brazil

*Ronaldo B FRANCINI-FILHO**, *Rodrigo L MOURA*

Av. Nazare, 451 Sao Paulo SP 04263-000 BRAZIL
rofilho@yahoo.com

Among several potential benefits, Marine Protected Areas (MPAs) are increasingly being recognized as effective tools for fisheries management. However, their optimal design and management is still challenging, despite recent encouraging developments. We present the results of an inter-annual monitoring program (2001-2003) that targeted reef fish assemblages in five areas within the Abrolhos Bank (~46,000km²), Brazil. These areas, separated by c. 80km, are subjected to different management regimes and restrictions levels, as follows: **1)** The fully-protected area (~4.5km²) of Itacolomis Reefs, within the Corumbau Extractive Reserve (CER); **2)** An area used and managed by traditional fishermen (~20km²), also within the CER; **3)** Timbebas Reefs (~110km²), a fully-protected area within the Abrolhos National Park; **4)** Paredes Reef (unprotected; ~300km²), the largest coral reef in the South Atlantic; **5)** Sebastiao Gomes Reef (unprotected; ~5km²). The fully-protected area of Timbebas Reef consistently presented higher abundances of large herbivores (parrotfishes) and lower level carnivores (particularly the yellowtail snapper, *Ocyurus chrysurus*). Temporal comparisons showed that total fish density tended to increase between 2001 and 2002 along the entire region, soon after an increase on enforcement levels of no-take areas in Timbebas and Itacolomis Reefs. However, this increase is strongly related to distance from deeper reefs and species' mobility, suggesting that regional-scale movements of fishes from deeper (less exploited) to shallower reefs played a major role. In 2003, the abundance of several target species decreased, except for that of large herbivores inside the fully-protected areas in Timbebas and Itacolomis Reefs. Despite signs of positive effects in local scales, the use of MPAs as a regional fisheries management tool is still dependent on a larger and articulated network of fully-protected and multiple-use MPAs in Abrolhos, with adequate enforcement and including several critical habitats such as mangroves, estuaries and deeper reefs.

Evaluating Management Effectiveness: The NOAA National Coral Reef Ecosystem Monitoring Program

*Ruth KELTY**

1305 East-West Highway, Silver Spring, MD 20910 United States of America
ruth.kelty@noaa.gov

Coral reefs ecosystems are under threat from multiple stresses that are overwhelming their natural resilience. In response, the U.S. Congress has appropriated over \$100M to support mapping, monitoring, restoration, research, management, and education for coral reef conservation. Responsible policymakers need to take an unbiased look at what we have achieved in return for this investment in coral reef ecosystems. Has our money been well spent? Is the state of the reefs improving? Is there something more we should be doing? The NOAA National Coral Reef Ecosystem Monitoring Program (Monitoring Program) is a tool for evaluating coral reef ecosystem management efforts and identifying the changing needs of coral reef ecosystems and their users. The goal of the Monitoring Program is to build a scientific basis and state and territory capacity to monitor the status and trends in the condition and function of U.S. coral reef ecosystems, and to use the state of the reef to evaluate the effectiveness of management. The Monitoring Program cumulates in the production of biennial State of the Reefs reports. In this presentation, I articulate the Monitoring Program goals and objectives, identify questions central to evaluating the state of coral reef ecosystems, and define critical program functions and corresponding performance criteria and measures. Applied examples for biological and socioeconomic monitoring are offered. The benefits of incorporating cellular diagnostics to forensically establish cause and effect, distinguish between natural and anthropogenic stresses, and provide prognostic capacity that can lead to timely policy decisions and effective environmental protection are emphasized.

A National Assessment of the Status of US Coral Reef Ecosystems

John D CHRISTENSEN, Christopher F G JEFFREY, Jenny WADDELL, Mark E MONACO*

1305 East West Highway SSMC-4, 9th Floor, Silver Spring, Maryland United States of America

John.Christensen@noaa.gov

NOAA and its partners have implemented a nationally coordinated, comprehensive, long-term program to assess, inventory, and monitor the condition of U.S. Coral Reef Ecosystems. Implemented in 2000, this program was requested by the U.S. Coral Reef Task Force in its National Coral Reef Action Strategy and is funded with Congressional appropriations for coral reef conservation. The program includes the long-term collection, analysis, and reporting of data to characterize three aspects of coral reef ecosystems: 1) benthic habitats (e.g., depth, habitat delineation, percent cover of benthic organisms), 2) associated biological communities or populations (e.g., abundance and size of fish and invertebrates), and 3) water quality (e.g. temperature, turbidity, sedimentation, and toxicity). This talk will describe a framework for the integration of now-disparate monitoring sites in U.S. federal, state, commonwealth, and territorial waters, into a coordinated national network for sharing monitoring information among managers and filling gaps in monitoring coverage of coral reef ecosystems nationwide. Additionally, examples and solutions to the problems associated with the synthesis of data sets collected through disparate methodologies will be presented in reference to determining the current health and status of coral reef ecosystems and setting baselines for comparisons with future estimates of coral reef conditions.

Managing through Rose-colored Glasses: The Need for Predictive Indicators of Coral Reef Health

*George P SCHMAHL, Emma L HICKERSON**

1200 Briarcrest Dr., Suite 4000, Bryan, Texas 77802, United States of America
george.schmahl@noaa.gov

Managers of coral reef protected areas are faced with the reality of the general worldwide degradation of coral reef resources. In areas where reefs are still doing well, a necessary concern is the ability to know when a coral reef is in trouble before it begins to show signs of serious decline. Most coral reef marine protected areas have some kind of research and monitoring program to gauge the health and vitality of the resource. Monitoring programs have proven to be excellent at documenting the demise of coral reef systems in great detail. However, the ability to provide an early warning system for potential coral reef decline is much less well developed. The Flower Garden Banks National Marine Sanctuary is located in the northwestern Gulf of Mexico and contains one of the northernmost coral reefs in the continental United States. By all traditional standards, these coral reefs are among the healthiest in the western Atlantic and Caribbean region. Living coral cover exceeds 50%, coral colony size is large, macroalgal cover is minimal, and the incidence of recognized coral diseases and bleaching is extremely low. However, by the time any of these common measures of reef health begin to show signs of significant decline, it may be too late to take any relevant resource management actions. At the Flower Garden Banks, careful observation has identified the occurrence of certain phenomena that may indicate early signs of possible decline. These include an increase in turf algae, the occurrence of unusual conditions in corals that may be precursors to disease and the apparent lack of coral recruitment. This paper will highlight factors that should be incorporated into coral reef monitoring programs to help identify when a coral reef may be in trouble, before it is too late.

Science and Technology: Serving Coral Reef Management

Cheryl M WOODLEY, Stephen C JAMESON, Craig A DOWNS*

Hollings Marine Laboratory, 331 Ft Johnson Rd, Charleston, SC 29412 United States of America

cheryl.woodley@noaa.gov

The last five years have seen the emergence of a new paradigm for coral health assessment. This paradigm embraces the use of science and technologies that can move us from a descriptive science (i.e. a phenomenon has occurred) into the realm of mechanistic science (i.e. how has the phenomenon occurred). It is only through understanding mechanisms of action (whether at a molecular, cellular, organismal or population level) by which organisms respond to their environment, that we can begin to understand the processes governing our coral reef resources and allow us to address questions such as: How does the resource respond to a changing environment? How can one determine when a system has exceeded its plasticity in responding to a changing environment and determine its fate? How can the factors affecting this change be identified? By adopting this new paradigm, coral reef managers are positioned to influence new directions in scientific research and environmental technology development. These advances will enable identification of "cause and effect" relationships so that recognition of the "smoking gun" of coral decline may give new insights for devising wise management options.

Building Ecosystem Approaches to Coral Reef Management: Effectiveness of the US Coral Reef Task Force

*Roger B GRIFFIS**, *Miguel A LUGO*

1305 East-West Hwy. SSMC4 Rm. 10201, Silver Springs, Maryland 20910
United States of America
roger.b.griffis@noaa.gov

The U.S. Coral Reef Task Force was established in 1998 by Presidential Order to lead U.S. efforts to protect and conserve coral reef ecosystems. Composed of the heads of twelve federal agencies, Governors of 7 states and territories and the Presidents of 3 Freely Associated States, the Task Force has developed "national-level" goals and strategies and taken other actions to help build ecosystem-based approaches to coral reef management. The Task Force efforts represent an interesting case study of a primarily government-driven effort to promote ecosystem management of marine resources. For example, in 2002 the Task Force launched an effort to develop 3-year Local Action Strategies to help link locally-based priorities and action to national-level plans and goals. This presentation will provide an assessment of the challenges, opportunities and effectiveness of Task Force efforts to facilitate ecosystem-based management of reef systems

Monitoring Changes in Fully Protected Marine Zones in the Florida Keys National Marine Sanctuary

*Brian D KELLER**

P.O. Box 500368, Marathon, Florida 33050 United States of America
brian.keller@noaa.gov

The Florida Keys National Marine Sanctuary is a 9,844-km² marine protected area that was designated in 1990. A comprehensive management plan was implemented in 1997 to protect and conserve marine resources. A key aspect of the management plan was the creation of a network of 23, mostly small, fully protected marine zones (marine reserves); the Tortugas Ecological Reserve was implemented in 2001 as the 24th fully protected marine zone, the largest (518 km²) in Florida coastal waters. An ongoing monitoring program is designed to determine effects of "no-take" protection on heavily exploited fishes and invertebrates, benthic communities, and human activities and perceptions. Data on the abundance of reef fishes and spiny lobster; spiny lobster size; benthic cover; and ecological processes are collected from fully protected marine zones and adjacent reference sites. Socioeconomic analyses are also being conducted. Preliminary reports indicate increases within fully protected marine zones in the number and size of heavily exploited species such as spiny lobster and certain reef fishes. Slower-growing benthic species such as corals and sponges have not shown significant changes within fully protected marine zones, possibly because the marine zones were implemented relatively recently. No strong, negative socioeconomic impacts of marine zoning have been determined, and a large majority of resident reef users support the existing network of fully protected marine zones.

Long-term Monitoring of a High-latitude Coral Reef System off Southeast Florida, USA

*David S GILLIAM**, *Kenneth W BANKS*, *Carl R BEAVER*, *Richard E DODGE*, *Louis E FISHER*, *Walter C JAAP*, *Jennifer L WHEATON*, *Paula ALLEN*, *Katherine ANDREWS*

8000 North Ocean Drive, Dania Beach, Florida United States of America
gilliam@nova.edu

Significant coral reef community development along the eastern shelf of the United States is often described as stopping north of the Florida Keys (Latitude 25° 30' N). However, this coral reef ecosystem continues northward (160+ km) through Miami-Dade, Broward, Palm Beach, and Martin Counties, Florida (to Latitude 27° N). These Southeast Florida high-latitude coral communities have approximately 30 species of stony corals, stony coral coverage of 2-3%, and a diverse assemblage of reef gorgonians, sponges, and fishes. NSU OC / NCRI is working with local county (BC DPEP) and state (FDEP and FMRI) resource managers on projects monitoring the Southeast Florida reefs. We have recently extended the Coral Reef Evaluation and Monitoring Project (CREMP) of the Florida Keys to Southeast Florida. Other pre-existing monitoring sites in Broward continue to be examined. This system lies within 3 km of the coast offshore a highly urbanized area comprising a population of 5 million people (the population of Broward County alone exceeds 1.6 million). Potential impacts include those from commercial and recreational fishing and diving, major shipping ports, sewer outfalls, canal discharges, ship groundings, and marine construction activities (fiber optic cables, channel dredging, gas pipe lines). These reefs are important economic assets: a 2001 economic assessment estimated the annual reef input for Miami-Dade, Broward, and Palm Beach Counties at 5.8 billion dollars. The unique features of this reef system as well as its proximity and value to the urban community of southeast Florida demand sustaining monitoring and increased investigations into the limiting environmental/ecological processes. This work complements the goals of the US National Coral Reef Monitoring Program to assess, inventory, and monitor coral reef ecosystems.

Coral Reef Fish Assemblages Offshore Broward County, Florida: A Baseline Data Set for Determining Need and Evaluating Effectiveness of Management Strategies

Fleur M FERRO, *Lance K B JORDAN*, *Paul T ARENA**, *Richard E SPIELER*

8000 N. Ocean Dr., Dania Beach, Florida United States of America
spielerr@nova.edu

We have recently completed an extensive inventory of the coral reef fishes in Broward County, Florida, USA. During a four-year period, 86,463 fish belonging to 211 species (52 families) were recorded (using a 15m diameter point-count) from 667 sites. Counts were performed at the crest and western and eastern edges of three reef tracts at quarter nautical mile intervals for a 21km section of coastline. The reef tracts are separated by sand and run parallel to the coast in sequentially deeper water. Significant differences ($p < 0.05$, ANOVA, SNK) in total abundance, species richness, and biomass were noted among the three reef tracts. The offshore reef tract had significantly greater species richness and abundance values than the Middle tract, with both tracts having significantly greater species richness and abundance values than the Inshore reef tract. The Offshore reef tract exhibited significantly higher biomass values than the Middle reef tract. Both had significantly higher biomass values than the Inshore reef tract. MDS plots of Bray-Curtis dissimilarity indices support the contention that substantial differences exist in fish assemblages among the three reef tracts. SIMPER analysis provided a breakdown of those species primarily responsible for the variability among the tracts and indicates that future management strategies (*e.g.*, MPAs, EFHs, HAPCs, etc.) should consider tract differences. For example, juvenile fishes (predominately grunts [Haemulidae]) were significantly more abundant inshore than offshore, indicating a potential nursery habitat. Larger adult fishes (>5cm TL) showed a significantly greater abundance offshore, an area presumably subject to greater fishing pressure. Findings of immediate management interest include a surprising scarcity of legal-size groupers (2) and snappers (198) over the entire survey area.

Vital Signs Monitoring in the South Florida / Caribbean Network of the National Park Service; Monitoring for Better Ecosystem Management

*Matthew E PATTERSON**

950 N. Krome Avenue, Homestead, Florida 33030 United States of America
matt_patterson@nps.gov

The South Florida / Caribbean Inventory and Monitoring Network is developing an ecosystem monitoring program which will track the status and trends of the "Vital Signs" of key environmental indicators for the National Park Service. The South Florida / Caribbean network includes seven National Parks including Big Cypress National Preserve, Biscayne National Park, Buck Island Reef National Monument, Dry Tortugas National Park, Everglades National Park, Salt River National Historic Site and Ecological Preserve and Virgin Islands National Park. These areas total more than 10,000 sq. kilometers and are made up of forested wetlands, non-forested wetlands, and marine ecosystems with significant coral reef resources. The "Vital Signs" monitoring program is expected to consist of a significant marine monitoring component, since the majority of the network parks are struggling with the difficult management conflicts that arise with the balance of protecting the resources unimpaired for future generations while still providing for the visitor to experience the natural wonders protected within these parks. These challenges are compounded by multi-agency fisheries management, enforcement difficulties, and traditional uses. The marine component of the monitoring program is expected to contain four major elements, including benthic systems, fisheries, water quality, and human use. Tracking these four components over time will help park managers assess how effective management actions are, or whether adaptive management is necessary. The data collected will be analyzed and compounded into a marine system overall metric, which will be transparent, allowing managers to understand how an overall score has shifted over time. This metric will be easily understood by both managers and the public to allow for easy communication of intensive monitoring. The metric can be exploded to show how each of the parameters feed into the overall score, with explanations on the assumptions made with the scoring and weighting defined.

MAREPAC-Palau Overview and the Ngaremeduu Conservation Area (NCA) Monitoring Program

*Alma RIDEP-MORRIS**

P.O. Box 359, Koror, Republic of Palau 96940 Republic of Palau
almarm@palaunet.com

Palau is one of nine Pacific Islands that make up the Marine Resources Pacific Consortium (MAREPAC). The MAREPAC-Palau's mission is to work cooperatively to achieve the conservation of coastal and marine environments and the sustainable use of marine resources for the benefit of the present and future generations of our islands. MAREPAC-Palau was formed in November 1999 to address issues relating to the marine environment. MAREPAC-Palau's goals are to promote wise, appropriate, and sustainable use of coastal and marine resources to ensure present and future generations enjoy the benefits; to better understand the status of our commercial and non-commercial marine resources in order to provide policy makers and private sector managers with up-to-date information so they can implement sustainable environmental practices; and to enhance communication and coordination between all stakeholders regarding Palau's marine resources. Among the many programs supported by MAREPAC-Palau, the Ngaremeduu Conservation Area Monitoring Program is designed to integrate modern monitoring techniques with traditional knowledge to effectively manage the protected area. The monitoring program, including coral reef monitoring, water quality monitoring, sedimentation monitoring and seagrass monitoring, are a means to enable the managers and local stakeholders to make sustainable coastal management decisions. This presentation will address issues and lessons from a community-based protected area management program.

An Organizational Model for an MPA Network Based on MPA Function, Representative Value and Jurisdiction for Stewardship

Stacey A TIGHE, Mark E ERDMANN, Yaya MULYANA*

Ratu Plaza Bldg, 18th Floor, Jl. Jenderal Sudirman 9, Jakarta 12070 Republic of Indonesia
satighe@aol.com

The Government of Indonesia is expanding its marine protected area system to include community sanctuaries, city, district and provincial sites and systems. To this end, a working group is tasked with defining a national network, and has chosen North Sulawesi to serve as a pilot location for developing a system of MPAs. The organizational system being developed links the function of the MPA (turtle nesting site, spawning aggregation site for groupers, community fishing reserve, tourism based on pristine habitat, etc) with the management actions that will need to be taken by the stewards (community, NGO, city government, national government, etc.). The management actions will depend on the representative value of the site (is it one of many or unique?), the outcome desired (more turtle hatchlings or sustainable recreational tourism) and the jurisdiction of the steward. For North Sulawesi, more than 20 sites ranging in size and function within the area are categorized and their role in an MPA network are defined.

Reef Fish Spawning Aggregations; the Need for Conservation and Management

*Yvonne SADOVY**, *Andy CORNISH*

Pok Fu Lam Road, Hong Kong

yjsadovy@hkucc.hku.hk

Many reef fishes, including a number of commercial importance, aggregate in large numbers to spawn each year. Increasingly, these aggregations are being found and exploited, sometimes to the point of depletion. This can severely compromise the reproductive capacity of affected populations. Despite their biological importance, vulnerability and appeal for fishing, the protection and management of spawning aggregations, with few exceptions, is not routinely practiced. Nor are they typically incorporated into the design of marine protected areas. The Society for the Conservation of Reef Fish Aggregations (SCRFA) was formed in 2000 to address such concerns, with the aim of documenting the current status and history of spawning aggregations around the tropics to more effectively promote and foster sound and appropriate management. Information has been collected from a wide range of published and unpublished literature and studies, including specially designed fisher interviews in the western Pacific, and a database is now available in the public domain for data entry and retrieval. The aim of the database is to assist managers, biologists, students, etc. who need to better understand the biology of aggregating species and the history of spawning aggregation exploitation to improve their protection. The database currently contains information on over 400 aggregations (=records), from 97 species in 19 families. The records are dominated (88%) by species of serranid, lutjanid, acanthurid, scarid and labrid. The Nassau grouper, *Epinephelus striatus*, is the single species with most records. Of 122 aggregations for which information is available, 70% have declined and 21% have disappeared. We will present the results of this project, summarize our major findings, identify key data gaps and discuss what these results reveal about options for reducing pressure on aggregations. We will also discuss what the management and exploitation of aggregations tells us about the wider context of reef fish fisheries.

The Occurrence of Spawning Aggregations of *Plectropomus areolatus* in a Marine Protected Area in the Republic of Palau

Jason KUARTEI, *Valentino KLOULCHAD*, *Julie BARR**

PO Box 1811, Koror, Palau 96940 Republic of Palau

jkuartei@yahoo.com, pcs@palaunet.org

The principle objective of this study was to monitor the occurrence of spawning aggregations of *Plectropomus areolatus* in a marine protected area in Palau in order to determine the annual frequency of occurrence of these aggregations. After four years of banning all access to this MPA, a management plan is being completed, which will allow for multiple use of the area, including sport fishing and scuba diving. The data from this study will help develop proper guidelines for multiple use of the area. The abundance of *P. areolatus* was monitored on a permanent transect at the mouth of a large channel in the MPA. Visual census was conducted on the 3rd and 4th day before the new moon every month. The fish were counted in two size categories: <40cm and 40cm>. The data show that *P. areolatus* forms a spawning aggregation at this site at least 8 months out of the year (Feb-Sep). The smallest aggregation occurred in February and by the start of the fishing ban in April it had increased by more than 50%. By July, the size of the spawning aggregation had declined by 40%. These fish continued to form a spawning aggregation at the site in August and September.

Spawning Patterns and Reproductive Output of the Halfspotted Hind, *Cephalopholis hemistiktos*, from the Fringing Reefs of Oman

*Jennifer L MCILWAIN**

PO Box 34, Al Khod, 123, Sultanate of Oman

mcilwain@squ.edu.om

Grouper or Hamoor are considered one of the most valuable fish groups in the artisanal fishery of Oman, second only to Spanish mackerel. They are heavily targeted by fishermen, using a variety of fishing gear such as baited fish traps, hand lines and bottom gill nets. Unlike kingfish though, there has been very little research effort or funding spent on even the most fundamental biology of groupers found in Omani waters. One of the most commonly caught grouper around the capital area, Muscat, is *Cephalopholis hemistiktos*. Age structure data reveal significant differences in maximum age and size range between Muscat and Musandam, approximately 700 km to the north. In Musandam, where *C. hemistiktos* is considered bycatch, fish live longer ($t_{max}=23$ years) and are smaller ($L_{min}-L_{max}=193-394$ mm) than Muscat ($t_{max}=11$ years, $L_{min}-L_{max}=142-461$ mm). Histological preparations of gonads from the Muscat population reveal the pattern of sex change was diandric protogynous hermaphroditism, with evidence of both primary males (derived from immature individuals) and secondary males (transition from mature females). Peaks in spawning was evident during the summer months (June and July) around the new moon period using indicators such as GSI and the presence of postovulatory follicles (POFs) in transverse sections of the gonads. Results from experimental fishing reveal no significant difference in Fork Length (FL) at different depths.

Is Fish Aggregation Size a Stock Assessment Index ? A Long Term Observation on the New Caledonian Stock of *Epinephelus cyanopodus*

*Claude A CHAUVET**

James Cook St., Noumea, New Caledonia

chauvet@univ-nc.nc

The *Epinephelus cyanopodus* stock in New Caledonia's south western lagoon has been studied since 1992. An assessment by diving visual census was done of spawning aggregations every spring and recruitment every summer. Moreover, fisheries are monitored by the Fishery Service. Data on commercial catches and fishing effort have been analysed and a demographic study has been carried out (samples in catches and otolith analysis). The results show firstly, a regular decrease of the aggregation size and a real collapse since 1998; secondly, a high variation in recruitment success (exceptional one in 1996 followed by a big one in 1997); thirdly, an adult stock demography dominated by one or two successful cohorts (the stock size increase in 1999 and the bigger sizes were in 2000 and 2001). The collapse in spawning aggregations could be the consequence of the disturbance caused by the fishermen (recreational fishing). However, it seems that the recruitment success could be linked with the ENSO climatic system, but 12 years observation is too short to draw conclusions. Stock size depends on variable recruitment (stochastic) and variations in stock size can be predicted by the previous recruitment knowledge. Therefore the size of spawning aggregations is not an index of the size of the stock.

Coral Reef Fish Spawning Periodicity and Habitat in New Caledonia: A Multi-faceted Approach in a Data-deficient Environment

Adrian J FLYNN*, Sebastien SARRAMEGNA, Michel KULBICKI
124 Camberwell Road, Hawthorn East, Victoria, 3123, Australia
adrian.flynn@enesar.com.au

An Environmental Impact Assessment (EIA) for a proposed mining project on the west coast of Northern Province, New Caledonia, required an understanding of coral reef fish spawning periodicity and habitat utilisation in New Caledonia in order to describe and mitigate the potential impacts of the development. A study was undertaken that encompassed literature review, analysis of catch data, analysis of gonad index data spanning some 18 years and interviews of commercial and subsistence fishers. Literature review highlighted the variation in spawning periodicity that occurs on a spatial scale of oceans to reefs. Spawning of key coral reef fish species is apparently concentrated in the spring and summer months in New Caledonia. Commercial fisheries production data supported this as production increased in spring and summer. The increase in production was not necessarily due to heightened fishing effort and was presumably as a result of increased catchability of fishes due to spawning aggregations. Interviews with village fishers also indicated spring-summer spawning of some species. Gonad index data indicated that spawning for many of the species analysed (*Epinephelus maculatus*, *Lutjanus* spp., *Diagramma pictus*, *Pomadasys argenteus*, *Lethrinus* spp., *Upeneus* spp. and *Nemipterus metopias*) occurred predominantly from September to March although it is likely that some species spawn throughout the year. Although annual spawning aggregations on the Great Barrier Reef have been documented for some species, the habitats utilised elsewhere do not necessarily apply to New Caledonia. Site-specific oceanographic conditions associated with the complex matrix of barrier reefs, channels and patch reefs in New Caledonia are likely to govern the spawning sites of pelagic broadcast spawners. Information obtained from interviews with local subsistence and commercial fishermen was generally consistent with other data sources and provided valuable site-specific data, particularly with respect to spawning habitats.

Preliminary Findings on Spawning Aggregations of Reef Fishes in Eastern Africa

Melita A SAMOILYS*, Julie CHURCH, Narriman JIDDAWI, Albogast KAMUKURU, Boaz KAUNDA-ARARA, Anapaola BALAO
P.O. Box 68200, Nairobi Republic of Kenya
mas@iucnearo.org

There is no published information on the occurrence of spawning aggregations of reef fishes in the Western Indian Ocean. Since this phenomenon occurs in many reef fish species in the Caribbean and Pacific Oceans, it is highly likely that this reproductive strategy occurs in certain species of reef fish in the Indian Ocean. As a first step in gathering data on reef fish spawning aggregations we identified focal scientists at research institutions in three mainland countries, Kenya, Tanzania and Mozambique, together with field researchers adept at conducting interviews with fishers. Having conducted a training workshop, an interview based questionnaire was designed by all participants. Fishers were interviewed in all three countries in locations where researchers were already conducting other reef fisheries research. Older fishermen were targeted and information was collected on known aggregation sites, species and timing, with a particular focus on three species: *Epinephelus polyphekadion*, *E. fuscoguttatus* and *Plectropomus* spp.. In some cases fishers did not appear to be aware of spawning aggregations. The results will be discussed in the context of building resilience into the design of marine protected areas. Recommendations for future research on spawning aggregations in Eastern Africa will also be presented.

Comparison of Seasonal vs. Permanent Closures for Protecting Red Hind Spawning Aggregations and Enhancing Fisheries in the US Virgin Islands

Richard S NEMETH*
2 John Brewer's Bay, St. Thomas, Virgin Islands of the United States
rnemeth@uvi.edu

Many commercially and ecologically important reef fish species form spawning aggregations, dramatic events where 1000's of fish gather annually at specific locations for reproduction. Grouper and snapper aggregations are often targeted by local fishermen making them extremely vulnerable to over fishing. In the US Virgin Islands, two red hind (*Epinephelus guttatus*) spawning aggregation sites (Lang Bank, St. Croix and Red Hind Bank, St. Thomas) were closed seasonally in 1990. The St. Thomas site was closed permanently in 1999. Tag and release studies and visual census on scuba were used to evaluate the recovery of the red hind spawning aggregation in St. Thomas from 1999-2002. Tag returns from St. Thomas indicated that red hind migrated 11 to 35 km after departing the aggregation to a ca 450 km² area. Compared with surveys conducted in 1997, the biomass of red hind increased over 500% in 4 years and the average size of spawning red hind increased 25% over 10 years. These findings suggest a substantial increase in reproductive output for this aggregation. This study provides one of the best examples of the effectiveness and positive benefits of marine protected areas in protecting spawning aggregation integrity, reversing the negative effects of over fishing and sustaining and increasing the productivity of local fisheries. These results are compared with biostatistical data from the seasonally protected St. Croix red hind spawning aggregation site and its associated fishery.

Use of Spawning Aggregations in MPA Design and Management: Cuba, South Florida and Quintana Roo, Mexico

Ken LINDEMAN*, Rodolfo CLARO, Tomas CAMARENA
14630 SW 144 Terrace, Miami, FL 33146 United States of America
klindeman@ed.org

Several clusters of MPAs containing no-take marine reserves exist within the northwest Caribbean. Around the insular shelf of Cuba, over 20 MPAs exist or are now proposed with at least 8 no-take areas. In South Florida, over 20 no-take areas exist within the Florida Keys National Marine Sanctuary. Along the Caribbean coast of Mexico, 8 federal MPAs exist with over 5 no-take areas. In each of these three areas, spawning aggregations of important reef fishes are contained within some of these no-take zones. Spawning aggregations of commercially important reef fishes represent particularly concentrated production sites in space and time. This has also led to their rapid overexploitation in some systems: a driving force behind their increasing use in MPA design and efforts to ensure connected population structure across wide geographic ranges. Spawning aggregation protection within these three areas has evolved under differing administrative structures and with variable levels of scientific input. We examined the biological, fishery and administrative attributes of snapper and grouper spawning aggregation protection or lack thereof within these areas and suggest traditional and MPA-based measures that may conserve spawning stock biomass. In Cuba, almost half of 21 known aggregation sites are proposed as new no-take zones or as seasonal spawning closure areas. In the Florida Keys, year-round no-take protection exists for the most upstream spawning site while almost all downstream sites remain spatially and seasonally unprotected. In Mexico, several significant spawning areas are within no-take zones, while others are not and enforcement is highly variable. In all areas, multi-species sites used by groupers during winter and snappers during summer deserve particular attention. Use of slotted size limits to protect older spawners off-site and protection of pre-spawning migratory routes before the spawning season can be key tools in addition to no-take reserves.

Conservation Status and Management of Reef Fish Spawning Aggregations in the Greater Caribbean

*Brian E LUCKHURST**

P.O. Box CR 52, Crawl CR BX Bermuda

bluckhurst@gov.bm

A total of 35 species are known to form spawning aggregations in the greater Caribbean region. The commercially important groupers and snappers are the dominant species groups at the majority of known spawning aggregation sites. The current status of documented reef fish spawning aggregations by country and species is presented for the region. There appears to be a general declining trend in the fishery landings from most exploited spawning aggregation sites. Several countries in the region have implemented conservation measures to protect spawning aggregation sites principally in the past 10 years. The majority of these measures involve seasonally or permanently closed areas and there have been positive effects demonstrated from active management of spawning aggregations. In December 2002, Belize permanently closed 12 spawning aggregation sites as a conservation measure to protect the decimated population of Nassau grouper. One year later (December 2003), the Cayman Islands closed all Nassau grouper spawning aggregation sites for eight years. A number of Caribbean spawning aggregation sites (principally those of Nassau grouper) have disappeared in the past 25 years and urgent management action is required to address increasing fishing pressure at unprotected sites. The elements of a regional conservation and management strategy for spawning aggregations are presented and linkages with MPA (Marine Protected Area) planning are suggested to help achieve both conservation and fishery management goals.

Spatial and Temporal Closures to Fishing to Protect Transient and Resident Reef Fish Spawning Aggregations on the Great Barrier Reef

*Martin W RUSSELL**

PO Box 1379 Townsville Queensland Australia 4810 Australia

m.russell@gbrmpa.gov.au

This paper discusses spatial and temporal fishing closures and catch and effort restrictions to protect transient and resident spawning aggregations of reef fish in the Great Barrier Reef Marine Park. Spatial and temporal spawning closures to fishing are essential as a minimum management strategy to protect reef fish species when they aggregate to spawn. The type of closure and the need for supporting catch and effort restrictions depends on the transient or resident nature of the spawning aggregations. The spawning behaviour of three commercially targeted reef fish species is discussed. In the Great Barrier Reef Marine Park, common coral trout *Plectropomus leopardus* is a transient aggregating fish on an individual reef scale, but a resident aggregating fish on a reef-wide scale. Red throat emperor *Lethrinus miniatus* is a transient aggregating fish, using multiple spawning sites. Spanish mackerel *Scomberomorus commerson* is a transient aggregating fish, using one known primary spawning site, and possibly several secondary spawning sites.

Spawning in the Humphead Wrasse, *Cheilinus undulatus*, in Palau: Physical and Biological Dynamics

*Pat L COLIN**

P.O. Box 1765, Koror, Palau 96940 Republic of Palau

rrf@palaunet.com

Cheilinus undulatus is a resident aggregating species of labrid found throughout the Indo-west Pacific. It aggregates and spawns during much of the lunar month, with a possible peak in one lunar phase. It may spawn every month of the year in Palau. It aggregates along the shelf edge reefs a few hours after high tide and spawns quickly, so that daily aggregations form and disappear in just over one hour. Large aggregations consist of several males and as many as 100 females. The males hold temporary territories that constantly shift and there is only mild aggression between males. Males spawn individually with females and the eggs move slowly off the reef on the falling tide. Through measurements of micro-oceanography environments on these reefs, some estimation of eggs and larval movement during the first 24 hours after spawning can be made.

Fine Scale Behavior and Habitat Use of Goliath Grouper (*Epinephelus itajara*) as Determined by Acoustic Telemetry

*Michael L DOMEIER**

901-B Pier View Way, Oceanside, CA 92054 United States of America

michael@pier.org

This study was intended to demonstrate the effectiveness of a new tool designed for releasing incidentally caught goliath grouper (*Epinephelus itajara*). The device sinks the fish back to the bottom and precludes the need to deflate the swim bladder. At a wreck site in the Gulf of Mexico, acoustic transmitters were placed on two goliath grouper caught and released in this fashion. The transmitters did in fact demonstrate the survival of each fish, but data gathered allowed for detailed analyses of the fishes behavior as well. The pressure coded tags transmitted swimming depth as well as the presence of the individual fish. Both fish remained in the vicinity of the wreck for the entire time the tags remained on the fish (36 and 73 days). Patterns were found that showed increased vertical activity at sunrise during the full moon period in July. This pattern may be indicative of spawning behavior.

Observations and Numerical Analysis of the Current in the Southwest of Okinawa Island as a Key Factor in Larval Dispersal

*Youchi SUZUKI**, Kazuo NADAOKA, Yasumasa MIYAZAWA, Hitoshi TAMURA, Shinnitirou KAKUMA, Takeshi MATSUOKA, Kenji SATOU, Satoshi FUJII, Syouitirou KOJIMA

2-12-1, Oookayama, Meguroku, Tokyo Japan

suzuki@wv.mei.titech.ac.jp

For the restoration of damaged coral reefs, it is important to understand the processes governing larval transport. Planulae of corals and *Acanthaster planci* are dispersed by the surface ocean current. We have made field measurements in the southwest of Okinawa Island to reveal the flow structure, which governs the processes of the larval transport and supply from the Kerama Islands and Okinawa Island, Japan. We have analyzed the data of the field surveys to find the typical patterns of the ocean current, using an HF ocean radar system, newly developed GPS-installed drifters and moored buoy system equipped with current meters and thermo meters. We have also examined the numerical simulation results of ocean current to clarify more detailed features of flow structure. In addition, we analyzed SST data of the NOAA and SSH data of the TOPEX/POSEIDON to understand possible connections with the Kuroshio current and meso-scale eddies. We found characteristic patterns in ocean surface current distribution on the shelf region in which the Kerama Islands are located. The current on the shelf region is governed mainly by tide. On the other hand, the east or northeast current is dominant in the northern area beyond the shelf edge where the water depth is over 300m. The data of the field measurements and the satellite data suggested that offshore influences such as Kuroshio current spread to the shelf region and the northern area. The result of particle tracking simulation suggests that coral planulae from the Kerama Islands can reach the west coast of Okinawa Island. In addition, we will discuss the possibility of the dispersal from the far distant areas such as Sekisei Islands which is located in the most southern area of Japan.

Ontogenetic Changes in Coral Larval Buoyancy and Vertical Swimming Behavior: Implications for Dispersal and Connectivity

*Alina M. SZMANT**, Melissa G MEADOWS

5600 Marvin K. Moss Ln, Wilmington NC 28409 USA

szmanta@uncw.edu

Many hermatypic corals are broadcast spawners. Little is known about the dispersal potential of their planktonic larvae. Settlement can begin 2-3 days after fertilization, but competency may last for a month or more. Hydrographic models can be used to estimate larval dispersal, but they require information about the swimming behavior of the larvae during transport, including buoyancy and vertical swimming behavior. Coral eggs are positively buoyant when released, but with time larvae become less buoyant and acquire the ability to swim downwards. The time-course of such ontogenetic changes are needed to couple with hydrographic data to model dispersal curves. Such data are presented here for the major Caribbean hermatype, *Montastraea faveolata*. Larval buoyancy was measured as ascent rate in a volumetric pipette, and measured every 6 hours for 56 hours post-fertilization (HPF). Vertical swimming behavior was measured as their vertical distribution within 2 L graduated cylinders, placed on a shaker table, measured every 6 hours from 40 to 205 HPF. Newly fertilized eggs (non-swimming) had an ascent rate of 1.82 mm s⁻¹, and this decreased linearly to 1.04 mm s⁻¹ by 56 HPF, by which time larvae were swimming and no further measurements could be made. Over 80 % of the embryos and larvae remained within the top 4 cm of the 40 cm-tall cylinder over the first 60 HPF. Diel vertical migration became apparent at ca. 70 HPF (down in dark, up in light), and became stronger over time. Even at 200 HPF, less than 20 % of larvae were at the bottom of the cylinder at the end of the dark period. These results show that while some larvae of this species can settle within a few days, most do not develop bottom seeking behavior until much later, and could be dispersed far from their site of origin.

Undisturbed Swimming Behaviour and Nocturnal Activity of Coral Reef Fish Larvae

*Rebecca FISHER**, David R BELLWOOD

Townsville, Australia 4811 Australia

rebecca.fisher@noaa.gov

Larval dispersal is shaped by the interaction between oceanographic processes and larval behaviour. To evaluate the potential impact of larval behaviour, we quantified the undisturbed swimming speeds and nocturnal swimming activity of five reef fish species, throughout their larval phase. We used video techniques to obtain undisturbed observations of swimming behaviour in captive bred larvae. The results conclusively demonstrate that larvae maintain relatively high swimming speeds throughout development. Speeds were consistent among three anemonefish species (Amphiprioninae), which swam an average of 3.9 and a maximum of 8.4 body lengths per second. However, differences may exist among taxa in the undisturbed swimming speeds of larvae. Highest speeds were recorded in the damselfish *Pomacentrus amboinensis* (Pomacentridae) and the slowest speeds in the cardinalfish *Sphaeramia nematoptera* (Apogonidae). The results support short duration experimental and in-situ evidence of high sustained swimming speeds. However, it is striking that larvae routinely swim at such speeds without external stimuli. The proportion of time larvae spent swimming at night increased rapidly towards the end of the larval phase in all five species examined. In addition, the undisturbed swimming speeds of larvae were significantly greater at night than during the day. Patterns of nocturnal activity appear to relate to the active nocturnal settlement behaviour of larvae. The pattern of swimming, and speeds achieved, suggest that an active behavioural mechanism for self-recruitment is well within the capabilities of the reef fish larvae examined.

Experimental Assessment of the Importance of Behaviour on the Swimming Performance of Reef Fish Larvae

*J.Derek HOGAN**, Camilo MORA

401 Sunset ave., Windsor, Ontario, Canada

hoganh@uwindsor.ca

The extent to which behaviour affects patterns of larval dispersal in coral reef fishes has been a topic of major discussion among reef fish ecologists. In this study we assessed the importance of behavioural choice in the context of larval swimming. Here we measure swimming performance of late-stage larvae of *Abudefduf saxatilis* in an extended swimming chamber that allowed larvae the option to either swim against the current, with the current or not swim at all (drift). Overall most larvae tended to face the current but were increasingly overcome by its strength as current speeds increased in the chamber. Previously determined U_{crit} swimming speeds indicate that larvae of this species can swim faster than currents at which they were tested in this experiment, suggesting that when given the choice larvae do not use their swimming abilities to the fullest potential. This also suggests that conclusions drawn from previous estimates of sustained swimming in reef fish larvae may over-estimate their importance for preventing advection. Under a wide spectrum of current regimens, drifting could be an energy saving behaviour used by reef fish larvae to increase survival in and after the pelagic period.

The Importance of Sound for Navigation at Settlement in Coral Reef Fishes

*Stephen D SIMPSON**, Mark G MEEKAN, Andrew JEFFS, Hong Y YAN
PO Box 373, York, YO10 5YW United Kingdom of Great Britain and Northern Ireland
simpsonstephen@hotmail.com

Recent work has highlighted the active movement of settlement-stage coral reef fishes as they navigate to suitable settlement sites. We have used several approaches to investigate the importance of sound to this process. First, we attached sound systems playing reef sounds to some light traps, and compared the catches of fishes to those from silent traps. We found significantly greater numbers of fishes from many reef fish families in the traps coupled with noise. Second, we compared recruitment of fishes at patch reefs with speakers broadcasting reef noises, with recruitment at silent reefs. We were able to enhance recruitment using noise and examined the importance of high and low frequency noises. Third, we studied the response of clownfish embryos to noise and found that these fishes would experience reef noises during their development on the reef before entering the pelagic phase. Fourth, we used electrophysiological methods to determine the hearing capabilities of larval clownfishes, and from the measured thresholds we calculated that larval fishes may hear reefs at distances of 100s of m. We conclude that sound is vital for successful navigation and settlement of larval coral reef fishes. Our findings not only have major implications for how we model recruitment, but may also offer some potential management tools for reef systems.

Swimming Speed of Late-stage Reef-Fish Larvae Measured in the Laboratory and in the Field: A Comparison of Critical Speed and *in Situ* Speed

*Jeffrey M LEIS**, Rebecca FISHER
6 College St, Sydney, NSW, 2010 Australia
jeffl@austmus.gov.au

Recently, it has been shown that larval coral-reef fishes near the end of their pelagic stage are strong swimmers. This finding is important for understanding dispersal and connectivity in reef-fish populations. Information on swimming abilities of larvae is needed to model dispersal realistically. Two measures of swimming speed in reef-fish larvae (critical speed [U-crit] and *in situ* speed) show that larvae of many species swim at relatively fast speeds. U-crit is determined using laboratory swimming flumes, whereby speed is increased incrementally until the larva can no longer maintain position. U-crit is a maximum performance measure of swimming speed that is particularly useful for comparisons among different species and developmental stages. However, its relationship to the actual swimming speeds of larvae in the field remains unclear. *In situ* speed is chosen by the larva in the field, and is measured by SCUBA divers following the larva. *In situ* speed can be difficult and labour-intensive to measure, but it represents the only available method for estimating swimming speed of larvae in the water column. Using late larvae from light traps, we compared U-crit to *in situ* speed for several families of coral-reef fishes, including Acanthuridae, Apogonidae, Chaetodontidae, Lethrinidae, Lutjanidae, Nemipteridae, Pomacentridae, and Pomacanthidae. We found a strong, significant correlation between the two measures of swimming speed. At the family level, mean *in situ* speed is about half that of mean U-crit. This relationship can be used to estimate swimming speed of late-stage larvae in the field from a convenient laboratory measure. The relationship will also be useful for those taxa that can be measured using one method, but not the other.

Genetic and Demographic Perspectives on Dispersal and Recruitment Dynamics of a Coral Reef Fish

*Jacob P KRITZER**, Margaret F DOCKER, Daniel D HEATH, Peter F SALE
401 Sunset Avenue, Windsor, Ontario, N9B 3P4, Canada
kritzer@uwindsor.ca

Historically, the dominant focus of the ecological study of coral reef fishes has been on rates of recruitment to the benthic population. Over the past decade, however, there has been a shift in focus toward patterns of pelagic larval dispersal. However, effective inter-population connectivity is determined by both dispersal and successful recruitment to the destination population. Therefore, we combine data on genetic population structure as a proxy for inter-population connectivity with age frequency data as a proxy for long-term recruitment trends in order to more comprehensively examine replenishment dynamics. We analyze genetic and demographic data for ten populations of the dusky damselfish, *Stegastes adustus*, distributed from the southern Yucatan Peninsula and Banco Chinchorro, Mexico, through the Belizean Barrier Reef and Turneffe Atoll, to Roatan Island, Honduras. With this composite data set, we examine a series of questions related to dispersal and recruitment dynamics. Firstly, at what spatial scale are cohort sizes, and therefore recruitment fluctuations, correlated? Secondly, does genetic similarity among populations reflect an isolation-by-distance effect? Thirdly, is within-population genetic variability, as an index of proportional self-recruitment (i.e., low genetic variability means high self-recruitment), positively or negatively correlated with inter-annual recruitment variability? And, finally, are there any patterns in genetic similarity of distinct cohorts either within or among populations? We examine these questions in the context of metapopulation structure of coral reef fishes.

A Comparison of Seagrass-Fish Assemblage Structures in Open Oceanic and Coastal Bay Areas in the Ryukyu Islands, Japan

*Yohei NAKAMURA**, Masahiro HORINOUCI, Takuro SHIBUNO, Hiroyuki KAWASAKI, Mitsuhiro SANO
1-1-1 Yayoi, Bunkyo-ku, Tokyo, Japan
yo-hei@minos.ocn.ne.jp

In the Ryukyu Islands, reef-associated seagrass beds are utilized by both seagrass-resident fishes and coral-reef fishes which use seagrass beds as nursery. To reveal whether differences exist in the structure of fish assemblages between open oceanic and coastal bay seagrass beds, visual censuses were conducted at three *Cymodocea serrulata*-dominated sites at Ishigaki and Taketomi islands. Among these sites, two were situated within an exposed, oceanic area, whereas the other one was located within a sheltered bay with streams. The numbers of fish species and individuals observed were not significantly different among the three sites. However, cluster analysis, based on the number of individuals of each fish species, demonstrated clear separation in fish assemblage structure between the oceanic and bay sites, although overall similarity among the three sites was relatively high. SIMPER analysis showed that *Lethrinus atkinsoni* and *L. harak* contributed greatly to similarities within the oceanic and bay sites, respectively. The number of juveniles of the former species, which is known as a reef fish utilizing seagrass beds as nursery, was significantly higher in the oceanic sites than in the bay site. On the other hand, all size-classes of the latter species, which is known as a shallow inshore fish, occurred abundantly in the bay site.

Experimental Assessment of Sensory Abilities of Coral Reef Fish Larvae in the Detection of their Settlement Habitat

*David LECCHINI**, *Rene GALZIN*

Universite de Perpignan, 66860 Perpignan France, Metropolitan
lecchini@univ-perp.fr

One of the great mysteries of coral reef fish ecology is how larvae locate the relatively rare patches of coral reef habitat on which they settle. The answer must lie partly in the sensory abilities of fish because it seems unlikely that successful settlement is solely a matter of chance. The present study attempts to estimate, by experiments in aquaria, the sensory abilities of coral reef fish larvae when they search for a settlement habitat. Larval recognition of settlement habitat may involve the detection of conspecifics or of shelter characteristics determined by emissions of visual, chemical and mechanical cues. These cues could be recognized by five senses of fish larvae: visual cues by sight, chemical cues by smell or taste, and mechanical cues by hearing or vibratory sense. For this study, larvae were captured with crest nets and were then introduced into experimental tanks that allowed testing of each sense separately. Among the 19 species studied, 15 chose their settlement habitat due to the presence of conspecifics and not based on shelter characteristics, and 4 species did not migrate toward their settlement habitat. Among the different senses tested, only sight, smell and vibratory sense were used in the recognition of conspecifics. Some species (*Parupeneus barberinus*, *Ctenochaetus striatus*) used three senses, others used two (*Myripristis pralinia*, *Lutjanus fulvus*) or one sense (*Gymnothorax* sp., *Chrysiptera leucopoma*) and some species (*Pomacentrus pavo*, *Canthigaster janthinoptera*) apparently used no sense. These results demonstrate that many coral reef fish larvae have the ability to discriminate species-specific sensory cues and could in practice use these sensory cues for successful integration into settlement habitat (connectivity between larvae population on reef crest and juveniles population on settlement habitat).

Shifting Currents, Shifting Sources: Using DNA Fingerprinting to Identify Changes in Larval Dispersal Pathways for a Reef Fish

*Kimberly A SELKOE**

University of California, Santa Barbara, 93106 United States of America
selkoe@lifesci.ucsb.edu

Many aspects of marine larval dispersal are poorly understood due to the challenges of tracking marine larvae in the plankton. Without diverse approaches to determining the scale and variability of dispersal pathways, our ability to understand basic population dynamics or design successful networks of MPAs will remain limited. In this study I used microsatellite marker analysis to indirectly assess the dynamics of larval dispersal for a reef fish, *Paralabrax clathratus*, with a 30 day planktonic phase. By examining shifts in the genetic signature of pulses of incoming juveniles collected biweekly over 2 settlement seasons at 5 sites 15-50 km apart, I found that abrupt genetic differences occurred sporadically among sites and within sites over the 2 year period. These genetic shifts do not appear to be caused by high genetic drift, selection or localized reproduction. Rather, I found that the timing and location of genetic shifts correspond to shifts in the regional circulation pattern, indicating that changes in larval source were the cause of the genetic changes. Comparing circulation patterns, patterns of adult abundance across the region, and data on the biweekly variation in recruitment numbers for the 2 year period suggests that recruitment levels were highest when larvae originated from populations at the northern range edge, despite very low adult abundance at the northern edge and the species affinity with southern, warmer water fauna. These results provide evidence that larval dispersal pathways can vary over small spatial and temporal scales for high dispersal species, and that small, peripheral populations can be important larval sources for large, central populations. This study has broad applicability to understanding the dynamics of connectivity for high dispersal species associated with patchy habitat types such as coral reefs, and to designing MPA networks to protect them.

Connectivity of Coral Reef Fish Populations: Testing a Larval Source Hypothesis

*Domingo G OCHAVILLO**, *Porfirio MALINO*, *Edgardo D GOMEZ*, *Gerald BAKUS*
Velasquez Street, Diliman, Quezon City Republic of the Philippines
ochavill@yahoo.com

It has been hypothesized that a group islands, cays and shoals in the South China Sea, collectively known as the Spratly's and whose ownership is currently contested by several countries, is a larval source for coral reef-associated organisms in the surrounding coastal states. We tested this hypothesis by analyzing the patterns of the sequence variation of the mitochondrial DNA control region of the rabbitfish *Siganus argenteus*. We used this fish species as a model because it spawns pelagic eggs and its larvae have been recorded offshore of coral reefs. The results indicated that the fish recruits collected in a Philippine reef hundreds of kilometers from the Spratly's are genetically related to that reef's sampled adult population. However, the recruits were also genetically related to other nearby sampled Philippine reefs. These imply that there may be active larval exchange among these reefs including the Spratly's. So this group of islands may be both a crucial larval source and sink of the coral reefs in the region.

Estimating Self-recruitment and Connectivity in Reef Fish Populations from Genetic Paternity Analysis

*Serge PLANES**, *Geoffrey JONES*, *Simon THORROLD*

Avenue Paul Alduy, 66860 Perpignan Cedex, France, Metropolitan
planes@univ-perp.fr

One of the most important problems facing marine ecologists and managers is to determine how far larvae disperse (i.e. connectivity). The degree to which juveniles are retained within or transported among populations determines the processes that drive local population dynamics. In practical terms, it sets the scale at which management strategies for exploited marine species as well as for biodiversity conservation need to be applied. The design of an effective strategy for quantifying connectivity between marine populations is obviously contingent upon the availability of appropriate technology to trace the origins of larval fish. At present we lack quantitative data on demographic connectivity. In the present work we are reporting the use of paternity analysis to trace genealogy of families of fish and therefore identify self-recruitment within a population. While theoretically simple, this approach requires populations of small size that can be entirely screened without damaging the individuals while being able to collect new recruits. The focus of this study will be on the anemonefish species, *Amphiprion polymnus* (family Pomacentridae) that complies number of characteristics that will facilitate the application and success. A total of about 80 adults were fin-clipped and screened for 13 microsatellites loci and all new recruits settling over a period of 4 months (about 60) were collected and screened for the same microsatellites loci. In parallel we develop a specific statistical analysis that estimates the number of loci require according to the adult population size, assigns paternity with a probability attached and takes into account potential miss-scoring of microsatellite allele. Such paternity assignment provides empirical estimates of self-recruitment that can be also measured through time by looking at genealogy among older individuals within the adult and sub-adult population, and also inform on the individual contribution to local renewal of the population.

Coral Reef Diseases Revisited*Garriet W. SMITH**, *Ernesto WEIL*471 University Parkway, Aiken SC 29801, United States of America
smithres@usca.edu

Attention to coral diseases has increased greatly over the past few years. New diseases have been described, the pathogenic agents of a number of known diseases have been identified, and progress on understanding the pathogenic mechanisms and vectors of a few diseases has been made. The purpose of this presentation is to summarize recent observations and advances and to put into perspective what needs to be done. The distribution of known diseases globally has increased. For example, researchers have reported significant occurrences of coral disease at reefs in the Philippines and the Great Barrier Reef. Skeletal-eroding disease and brown band have been shown to be caused by protozoans, and PUWS is most likely caused by a *Vibrio* species. Disease outbreaks have also been reported in the Indian Ocean, but the Caribbean remains the hotspot of coral disease activity. Recently, white pox (patchy necrosis or acroporid serratiosis) was found to be caused by the bacterium *Serratia marsescens*, the source of the pathogen is still unknown. New tools have been developed to determine the occurrence, spread and vectors involved with white plague caused by *Aurantimonas corallicida*. Host ranges for some diseases have increased, for example *Aspergillus sydowii* is now known to affect at least 5 other octocoral species from different genera. White plague is reported to affect 39 coral species and possibly, a crustose algae. Although much remains to be done, research is underway to (a) develop probes to identify the presence of the same pathogen (s) in different species, (b) determine the pathogenic agent (s) of white band, dark spots, yellow band and other important syndromes, (c) assess geographic distributions, prevalence, species-specific rates of mortality including spatial and temporal variability, vectors, reservoirs, and to (d) determine local and geographic impact of diseases on coral reef communities.

Current Status of the Coral Disease White Plague Type II*Laurie L. RICHARDSON**, *Deetta K. MILLS*, *Elizabeth REMILY*, *Joshua D. VOSS*

Biology Department, Florida International University, 11200 SW 8th St., Miami, Florida 33199 United States of America

Laurie.Richardson@fiu.edu

White plague, first discovered on reefs of Florida in 1977, has increased in virulence to become perhaps the most devastating of all Caribbean coral diseases. Since its first appearance, now designated as white plague type I (WPI), it reemerged in the 1990s in a much more virulent form termed white plague type II (WPII). The two forms of the disease are distinguishable by different patterns of tissue loss and rates of tissue degradation. In the last decade WPII has spread to a Caribbean wide distribution, commonly exhibiting epizootics with prevalence values of >30%, and is responsible for ongoing and severe coral mortality. It has been reported to infect more than two thirds of Caribbean scleractinian coral species. WPII is caused by the bacterial pathogen *Aurantimonas corallicida*, recently described as a new genus and species. We have developed a species specific molecular probe designed and constructed based on the 16S rRNA gene sequence of the WPII pathogen. Application of the probe to field samples of diseased coral tissue, in conjunction with fluorescent in situ hybridization analyses, has revealed that this pathogen is associated with WPII on reefs of both the Florida Keys and the Bahamas. Additionally, samples collected from corals infected with WPI also yielded positive probe results, indicating that these two forms of the disease are caused by the same pathogen and are both currently present on Caribbean reefs. Long-term quantitative studies of the effect of a WPII epizootic have revealed that this disease has restructured the size-frequency distribution pattern of one of the most susceptible coral species, *Dichocoenia stokesi*. Application of the pathogen specific probe on a region wide basis, together with continued quantitative monitoring of the recovery of affected populations, promises to provide insight into the current and long-term role of this coral disease on coral reef degradation.

The Molecular Microbial Ecology of White Band Diseased *Acropora palmata* Colonies*Olga PANTOS**, *John C. BYTHELL*Department of Biology, United States of America
olga_pantos@hotmail.com

Since the first documented cases of coral disease, attempts have been made to identify the causal agents involved. White band disease (WBD) is characterised by the loss of tissues from the coral skeleton exposing the underlying white aragonite skeleton. In branching acroporids the degraded necrotic tissues slough off the skeleton at a uniform rate around the branches, exhibiting a sharp demarcation between apparently healthy coral tissues and bare skeleton. WBD has been seen to have a devastating impact on two of the most important framework-building species of Caribbean reefs, *Acropora palmata* and *A. cervicornis*, playing an important role in reef ecology. The aetiology of this disease however, remains unresolved. Previous studies have identified differences in the bacterial community associated with the surface mucopolysaccharide layer of healthy and diseased tissues. Bacterial cells have also been identified within these tissues. These bacteria have not yet been identified phylogenetically and there is little evidence to suggest that they are directly involved in the disease process or are responsible for tissue necrosis. With the use of a range of 16S rDNA molecular based techniques, the microbial communities associated with the healthy and white band diseased tissues of *A. palmata* colonies collected from Barbados have been identified. Sequence data of the bacterial community of diseased tissue and those from unaffected colonies showed a difference in the bacterial group diversity. A holistic response to the presence of disease by the coral colony is also evident. Striking similarities were also seen between sequences associated with the diseased tissues studied here and those previously reported in association with black band disease and a white plague-like disease in coral. Similarities include the presence of a potential pathogen, an α -proteobacterium identified as the causal agent of juvenile oyster disease.

Fungal Disease in Caribbean Gorgonian Corals: Pathogen Population Genetics*Krystal L. RYPIEN**, *G. W. SMITH*, *C. D. HARVELL*

Department of Ecology & Evolutionary Biology, Corson Hall, Cornell University, Ithaca NY 14853 United States of America

klr32@cornell.edu

An epizootic of aspergillosis caused by the terrestrial fungus *Aspergillus sydowii* is currently affecting gorgonian corals in the Caribbean. Prevalence of aspergillosis is as high as 90% in some areas, with a recent study in the Florida Keys documenting a uniform prevalence of 43%. I am currently investigating the origins and geographic variation in virulence of *A. sydowii*. To determine if there are geographically distinct pathogen isolates that induce differential host responses, clonal replicates of *Gorgonia ventalina* (common sea fan) were infected in the laboratory with eight strains of *A. sydowii* isolated from diseased sea fans throughout the Caribbean, one genetically modified strain, and one non-pathogenic strain. Several aspects of sea fan response to infection were quantified, including the change in proportion of purple sclerites (calcium carbonate structures in the coenenchyme), and the antifungal properties of crude extracts. The results of this experiment demonstrate that there is variation in the host response induced by different pathogen isolates, and emphasize that this is a general stress response. Autosomal microsatellite markers were developed for *A. sydowii* to identify whether genetically distinct strains of the pathogen exist, and to see if these strains exhibit any patterns with regard to geography or magnitude of host response induced. An examination of allele distribution among sites in the Florida Keys and the Mesoamerican barrier reef system will reveal whether there are multiple pathogen strains in the environment, and may identify the origin of *A. sydowii* in coral reef ecosystems.

Enemy within? Observations of Virus-like Particles in Reef Corals

Simon K DAVY*, Sarah G BURCHETT, Amy DALE, Joanne E DAVY, William H WILSON

PO Box 600, Wellington, New Zealand

simon.davy@vuw.ac.nz

Previously, we have demonstrated that symbiotic dinoflagellates (zooxanthellae) in the temperate sea anemone *Anemonia viridis* may harbour a latent virus, which enters into a lytic cycle at elevated temperatures and contributes to the degeneration of its zooxanthella host. However, evidence for viruses in tropical zooxanthellae and their hosts, such as reef corals, has been lacking. Here, we screened for viruses in reef corals, which were heat shocked before thin sections were prepared for transmission electron microscopy (TEM). TEM revealed numerous hexagonal virus-like particles (VLPs) both in the zooxanthellae and in the coral tissues. Furthermore, seawater from around bleaching coral (*Acropora formosa*) was sampled and analysed by Flow Cytometry (FC) for the presence of VLPs. After staining with SYBR Green I, FC showed a distinct group of low side-scatter fluorescing particles that did not appear in seawater from around non-bleaching *A. formosa*. TEM showed many of these VLPs to be droplet shaped, though hexagonal, rod shaped and rounded VLPs were also observed. Therefore, corals and their zooxanthellae are associated with a number of types of VLP. Current attempts to isolate and further characterise coral VLPs will be described and the potential role of viruses in determining the health of reef systems in the face of global climate change will be discussed.

New Light on Black Band Disease - Coral's Oldest Disease

Meir SUSSMAN*, David BOURNE, Cathie PAGE, Holly BOYETT, Bette WILLIS

James Cook University, School of Marine Biology and Aquaculture, Townsville, Qld 4810, Australia

meir.sussman@jcu.edu.au

For the past 30 years it has been thought that Black Band Disease (BBD) is caused by a consortium of microorganisms dominated by the gliding, filamentous cyanobacteria *Phormidium coralyticum*. However, recent studies based on the molecular analysis of BBD-infected corals sampled in the Caribbean, have identified a totally different cyanobacterium within the black band. This uncultured cyanobacterium is related to *Oscillatoria cf. corallinae*. Here we report for the first time of the successful isolation of this species from infected colonies of *Acropora spp.* at Lizard Island on the Great Barrier Reef. It is not only the first successful attempt to cultivate this newly suspected pathogen, but also the first proof of its world wide distribution. In our laboratory at the Australian Institute for Marine Science (AIMS), we were able to culture this cyanobacterium and confirm its taxonomic identity by sequencing its 16S rDNA. Further more; we have managed to infect healthy corals with this species and re-isolate it from infected colonies, thus fulfilling Koch's postulates. This is the first time that healthy corals have been successfully infected with black band disease from a pure culture. In our study, we have not identified the alleged consortium previously thought to be involved in causing the BBD. Nevertheless, we conclude that infections must be aided by a primary agent or stress causing lesions in the coral tissue. It is therefore highly conceivable that infections in nature are initiated by a predator which is also a vector. It thus may mean that similar symptoms of black band disease are caused and transmitted in many ways, depending on region and species infected.

Differential Response of Zooxanthellae to Toxins that Produce Bacterial Bleaching in Stony Corals

Diego L GIL-AGUDELO*, Xavier HERNANDEZ, Yael BAN-HAIM, Eugene ROSENBERG, Roberto IGLESIAS-PRIETO, Garriet W SMITH

603 EWS Building, University of South Carolina, Columbia, SC, 29208 United States of America

gilagude@mcsi.sc.edu

Bleaching of reef organisms has been one of the most important stressors of coral reefs during the last two decades. Bleaching has been associated with the death of significant amount of corals in different parts of the world and its consequent impact in marine ecosystems and human economy has been significant. Although bleaching has been mainly related to changes in the environment (increase of water temperature, sedimentation, and changes in water salinity, among others), evidence of bleaching caused by bacteria has been found on at least two occasions, one in the Mediterranean Sea and another in the Red Sea. In the Caribbean Sea, probably the region most affected by bleaching, no conclusive evidence of bleaching causing bacteria has been found. This study evaluated the potential effects that *Vibrio shiloi*, a bacteria found to cause bleaching in corals of the Mediterranean Sea, might have in Caribbean corals. To reach our objectives, zooxanthellae extracted from several coral species were exposed to the supernatant of a three day old *V. shiloi* cultures. A decline in the Quantum Yield (QY) of zooxanthellae showed disruption of the photochemical abilities of the cell, which is one of the signs of bleaching. Zooxanthellae extracted from *Oculina patagonica* showed a decrease in QY of more than 60% (from 0.6 to 0.2) in less than 10 min. Meanwhile, zooxanthellae isolated from other Caribbean corals such as *Montastraea annularis* and *M. faveolata*, also showed significant decreases in the QY (30% and 15% respectively) during the same period of time. *Porites astreoides* showed no visible effect to the bacteria toxins. Results showed differential response of zooxanthellae extracted from different coral species to the toxins contained in the supernatant, but only in *O. patagonica* were the effects extreme. None of the Caribbean corals evaluated seems to be bleached by *V. shiloi*.

Etiology and Histopathology of the White Pox Disease of the Caribbean Elkhorn Coral *Acropora palmata*

Kathryn P. SUTHERLAND*

1033 Green Street, Athens, Georgia 30602 United States of America

kathryn@uga.edu

White pox is a lethal disease of *Acropora palmata*. Annual photographic monitoring at eight reef sites in the Florida Keys showed that *A. palmata* populations with white pox signs sustained losses averaging 87% between 1996 and 2002. The etiology of white pox was determined through examination of surface mucopolysaccharide layers (SML) from white pox-affected and -unaffected corals. Metabolic profiles of pure bacterial strains isolated from SML were used to identify potential pathogens. Potential pathogens were experimentally inoculated onto healthy *A. palmata*. Corals inoculated with isolate PDL100 showed white pox signs, and PDL100 was reisolated from these corals (satisfying Koch's postulates). 16S rDNA gene sequence analyses of PDL100 demonstrated 100% identity to the enterobacterium *Serratia marcescens*. The source of the *S. marcescens* strain that causes white pox is uncertain. This study begins the search for the origin of the white pox disease pathogen through the examination of seawater samples collected within the Florida Keys. Bacterial isolates obtained from seawater samples were characterized biochemically and genomic DNA from presumptive *Serratia* and seven *Serratia* controls was extracted, amplified, and subjected to restriction analysis. Six bacterial isolates were identified as presumptively belonging to the genus *Serratia*. White pox-affected and apparently healthy tissues were collected from white pox-diseased colonies of *Acropora palmata* in the Florida Keys. Tissues were processed for histopathology with light microscopy. Cellular and tissue degeneration was observed in both apparently healthy and diseased tissues. Lesions observed in the white pox-diseased colonies of *A. palmata* are different in this disease than in other coral diseases. White pox is associated with rounding of granular gland cells, necrosis, and atrophy. There was no significant difference in the number or type of abnormalities present in diseased versus apparently healthy specimens. These similarities may indicate that colonies affected by white pox sustain a whole-colony reaction to infection.

Bacteria, Viruses and Rising Sea-Water Temperature as Links to Yellow Band Disease

James M. CERVINO*, Raymond HAYES, Thomas GOREAU, Shawn POLSON, Sarah POLSON, Robert MARTINEZ, Garriet SMITH

117-20 5th Ave. College Point New York NY 11356 United States of America
cnidaria@earthlink.net

The factors contributing to Yellow Band Disease, also known as yellow blotch (YBD), which affects the major reef-building Caribbean coral *Montastrea annularis* have been identified. Bacteria associated with YBD were isolated and the 16S rRNA gene was sequenced. All associated bacteria from YBD were found to belong to the genus *Vibrio*. Inoculating healthy corals with these *Vibrio* caused YBD symptoms. Elevating the water temperature notably increased the rate of spread of YBD and induced greater coral mortality. Results suggest that when corals are exposed to elevated water temperatures they become more susceptible to these pathogens. Histological sections of *Vibrio* inoculated coral tissue indicated the presence of Virus-like particles (VLP) in the zooxanthellae. However the functional role of these VLPs is not known, and warrants further investigation. This is thought to be the first known case of a symbiotic algae disease in Caribbean corals.

Fungi Infection in the Caribbean Sea Fans (*Gorgonia* sp.)

Carlos TOLEDO-HERNANDEZ*, Paul BAYMAN, Alberto SABAT

UPR, Department of Biology, PoBOX 23360 Rio Piedras PR, 00931-3360
 Puerto Rico
donq65@hotmail.com

Aspergillosis is a disease affecting the Caribbean sea fans *Gorgonia ventalina* and *G. flabellum*. The saprophytic fungus *Aspergillus sydawii* has been proposed as the causal agent. This study reports for the first time several other species of fungi on sea fans (*Gorgonia* sp.) with signs of Aspergillosis. For this study, twelve sea fan colonies showing signs of Aspergillosis were selected per site at eight coral reefs in Puerto Rico. From each colony, one tissue sample from the diseased area, and one tissue sample from a visually healthy area were collected. Samples were surface sterilized before cultivation in standard medium for marine fungi (GPYA). *Aspergillus* species were identified using microscopic and morphological features. Identification was confirmed by PCR amplification and sequencing of the nuclear ribosomal ITS regions and the D1-D2 region of the 28S nuclear ribosome gene. *Aspergillus niger*, *A. flavus*, and *A. terreus* were isolated from afflicted and healthy tissue, in addition to several species of *Penicillium* and *Trichoderma* and an unknown number of unidentified fungi. *A. terreus* was the most common fungus found in diseased and healthy tissue, followed by *A. niger*. *A. flavus* was not isolated on healthy tissue. Similarly several species of *Trichoderma* and *Penicillium* were isolated from diseased and healthy tissue. Curiously, no *A. sydawii* was found in any tissue sample. It is possible that these fungi might be pathogenic, since some are known to produce mycotoxins and be opportunistic pathogens of humans and animals.

Environmental Modulators of Seafan Inducible Resistance to Fungal Disease

Drew HARVELL*, Jessica R WARD, Nancy L DOUGLAS, Gerardo VASTA, John BRUNO, Kiho KIM

Corson Hall, Cornell University, Ithaca, New York United States of America
cdh5@cornell.edu

Because *Aspergillus* is typically a pathogen of immune suppressed hosts, we hypothesize that one driver of the Aspergillosis outbreak in Caribbean gorgonian corals is compromised host resistance. Seafans produce potent antifungal compounds, that can affect progression of fungal infections. Field and lab inoculation experiments demonstrate induced coral resistance (production of anti-fungal chemistry including melanin) and sensitivity of resistance to environmental conditions. We have developed assays for chitinase and phenylloxidase to explore inducible resistance to *Aspergillus* infections. Demographically, incidence of aspergillosis is highest in largest, most fecund colonies, which are also lowest in anti-fungal chemistry; these large hosts also become reproductively suppressed by fungal infections. Aspergillosis prevalence has declined significantly over the last three years. Hypotheses for the decline include change in availability of susceptible hosts. We discuss progress in developing a biosensor for *Aspergillus* to aid monitoring of infected hosts and dynamics of the epizootic.

An Integrative Analysis of Environmental Factors, Coral Population and Community Structure, and Microbial Community Composition Associated with Coral Diseases near Lee Stocking Island, Bahamas

Joshua D VOSS*, Deetta K MILLS, Laurie L RICHARDSON

FIU Dept. of Biological Sciences, OE 167, Miami, FL 33199 United States of America
joshua.voss@fiu.edu

The number of coral diseases, coral species they infect, number of reported cases, and range over which they are distributed have all increased dramatically in the past three decades, posing a serious threat to coral reef ecosystems worldwide. While some published studies provide data on the distribution of coral diseases at local and regional levels, few studies have addressed the factors that may drive these distributions. We recorded coral disease incidence, prevalence, and severity along with 11 environmental factors and 4 coral community and population composition factors over two consecutive summers on reefs near Lee Stocking Island in the Bahamas Exuma Chain. Similar to other reports, relatively large, framework species including *Siderastrea siderea*, *Colpophyllia natans*, and *Montastrea annularis* sp. comp., along with the smaller *Dichocoenia stokesi*, were the most susceptible species. Recurring infections on individual colonies from 2002 to 2003 were more likely for black band disease than for either white plague or dark spots syndrome. Additionally, while white plague and dark spots demonstrated clumped distributions, black band was randomly distributed on these reefs. Utilizing a PCR-derived analysis of amplicon length heterogeneity within the 16S rRNA gene sequence, we examined variation in the composition of the black band microbial community and the microbiota associated with coral surface mucopolysaccharide of both black band infected and healthy corals with respect to time, coral species, space, and environmental conditions. Detailed microbial community analyses of healthy and diseased corals combined with environmental and community level studies may provide insight into the drivers of black band (and other) coral disease incidence and the relationship between environment and coral reef health.

Investigation of Coral Disease on the Reefs of the Hawaiian Archipelago

*Teresa D LEWIS**, *Greta S AEBY*, *Thierry M WORK*, *Steve L COLES*,
Jo-Ann C LEONG

P. O. Box 1346, Kaneohe, HI 96744 United States of America
tdlewis@hawaii.edu

The Hawaiian Archipelago encompasses the majority of coral reef area within the United States. Although considered to be relatively healthy, Hawaii's reefs are not immune to the conditions that have led to the decline of other reef systems. Extensive coral bleaching occurred in September 1996 in Kaneohe Bay, Oahu, and more recently, a mass-bleaching event was recorded in September 2002 on the reefs of the Northwestern Hawaiian Islands (NWHI). Coral diseases and tumors have also been documented in most major reef-building coral species in the main Hawaiian Islands and have recently been reported in the NWHI. A combination of field surveys and laboratory investigations are currently in progress to document disease in corals in Hawaii. Hawaii is in the unique position of not having suffered major catastrophic declines of reefs due to disease. As such, we are very well placed to develop a baseline assessment of the health of the reefs of the Hawaiian Archipelago. Here we report on our progress, to date, in identifying coral health and disease in the Hawaiian Archipelago using a variety of laboratory techniques, including traditional and molecular microbiological techniques as well as histology. Research support provided by NOAA/HCRI-RP grant #NA03NS4260044.

Information of Coral Tumor-like Structure in *Acropora* species in Okinawa Southern Japan

*Akiyuki IRIKAWA**, *Hideyuki YAMASHIRO*, *Michio HIDAKA*
3-34-17Yafuso, Urasoe City, Okinawa 901-2127 Japan
a.irikawa@eac-oki.co.jp

Many coral tumors appearing on the surface of *Acropora* spp were observed on the reefs of Kerama Islands, Okinawa, Japan. In the larger colonies of *Acropora cytherea*, *A. florida*, and *A. valenciennesi* etc., tumors were distributed mainly on the surface and around the center of the colony. Tumor was recognized as a bleached (less number of zooxanthellae) and hemispherical mass. Generic or species-specific structures were mostly disappeared or lost in the tumors. Although polyps were observed even in tumor region, polyps and their calyx were gradually covered as tumors grew. Rate of photosynthesis was lower in tumors than that of ordinary parts. In the tumor, P/R ratio was less than 1.0, and the electron transport rate vs irradiance intensity was also lower. Kerama Islands are not affected human disturbances, assigned as natural protected area because of having healthy coral reefs, and thought to be the important site for providing planula larvae to Okinawa Island, where most coral reefs have been damaged. Our results suggest that tumors on *Acropora* are in malnutrition without being supplied photosynthetic products from zooxanthellae. Tumor formation will result in lowering net production and reproductive output of the whole colony, and finally give negative effect to the community of coral reefs.

Coral Reef Guinea Pigs: Culture of Research Clonal Lines for the Coral Disease and Health Consortium

*Eric BORNEMAN**

Department of Biology, 4800 Calhoun Rd., Science and Research Bldg. II,
Houston, Texas 77204 United States of America
eborneman@uh.edu

To investigate normal coral biology and disease states using modern scientific techniques, it is necessary to identify and develop model species, and make them routinely available for research. Model laboratory species share well-known desirable characteristics, including ease of culture, high growth and fecundity rates, and relatively simple genetics. Model corals will enable rapid advances by focusing research on fundamental biological concepts broadly applicable across the taxon. Model corals must be representative of coral diversity, and include Indo-Pacific and Caribbean species, autotrophs and heterotrophs, branching and boulder growth forms, species with different calcification rates, and with different algal symbionts. They also must be susceptible to bleaching and disease and include taxa that are resistant to bleaching and disease. Developing a living stock collection for model corals will provide infrastructure critical for basic research by providing well-characterized and documented experimental organisms to domestic and international researchers; an area deemed imperative in the study of coral disease in order to gain efficacious results to ameliorate pathologies causing rapid and severe coral mortality and resultant ecosystem damage. The Coral Health and Disease Consortium (CHDC) has determined coral culture of key species to be integral in furthering the study of coral disease by allowing: 1) to identify and develop model coral species (analogous to *laboratory rats*) that are well characterized and suitable for laboratory culture; 2) to establish a culture facility able to supply model species for scientific research. These coral lines will take several years to establish in terms of broodstock, fragmentation and grow-out times, but the costs of each fragment will be significantly less than what it costs to acquire the same corals from the field unless the research facility has very proximate access to coral collections.

Lesion Formation on *Acropora palmata* and the Coral's Ability to Heal

*Erinn M MULLER**, *Caroline S ROGERS*, *Rob Van WOESIK*

150 W. University Blvd. Melbourne, FL 32901 United States of America
emuller@fit.edu

Coral colonies are often damaged by at least one of many agents, which include heavy wave action, fresh water, extreme temperature fluctuations, sedimentation, and disease. Yet, corals also have the ability to regenerate lost or damaged tissue over a relatively short period of time. *Acropora palmata* is currently being affected by lesions from diseases such as white band and white pox on reefs in Florida and the US Virgin Islands. The survival of individual colonies may rely on the coral's ability to heal these wounds. Sixty tagged colonies of *A. palmata* located in Haulover Bay, Virgin Islands National Park, have been monitored and photographed on a monthly basis for one full year. In February 2003, at the start of the study period, 13% of the colonies displayed signs of fresh white pox lesions (no algae present), and 13% displayed signs of old white pox lesions (algae present). After six months of monitoring 44% of the affected colonies had either partly healed or completely regenerated the lost tissue. In contrast, 31% of the affected colonies exhibited either an expansion of the lesion and/or death. The colonies that died were often the smaller corals (less than .30 m). Over the one-year time period the white pox disease infected a total of 63% of the 60-tagged colonies, and some corals experienced multiple lesions throughout the year. The greatest occurrence and size of white pox lesions was visually determined to take place during October and early November, when the sea surface temperatures were at a yearly high. Monitoring continues in order to analyze the new lesions and assess the relationship between lesion healing of *Acropora palmata*, other life-history parameters, and environmental setting.

The Role of Reef Fish in the Transmission Dynamics of Black-Band Disease in the Florida Keys

*Greta S AEBY**, *Deborah L SANTAVY*

1151 Punchbowl St., Rm 330, Honolulu, Hawaii 96813 United States of America

greta@hawaii.edu

Transmission of black-band disease has been shown to occur by direct contact and transference by prevailing currents. We propose reef fish as vectors or stressors that aid in the transference and establishment of black-band disease on tropical reef-building corals. We examined whether the local coral-feeding butterflyfish, *Chaetodon capistratus*, was involved in the inter-colony transfer of black-band disease. We also assessed the role stress caused by injury and/or elevated temperature had on the ability of black-band disease to invade coral and examined whether injury caused by nesting damselfish might pre-dispose corals to disease. In aquaria, the presence of *C. capistratus* increased the rate at which black-band spread from affected to unaffected fragments of *Montastrea faveolata*. Corals, both protected from and exposed to, fish predation contracted the disease. Hence, either direct oral transmission of the pathogen from colony to colony and/or indirect fecal transmission could be occurring. Under laboratory conditions, *P. coralliticum* was able to successfully invade all injured but no uninjured fragments of *M. faveolata* irrespective of temperature regime. A field survey of 31 sites throughout the Florida Keys found nesting damselfish to be ubiquitous and abundant and 83% of black-band disease incidence on reefs was associated with damselfish nests. This suggests that damselfish damage may be one mechanism allowing black-band disease to establish on corals. The activities of both butterflyfish and damselfish might offer further insight into the transmission dynamics of black-band disease and in the distribution of infected colonies on the reef.

Corallivorous Snails as Coral Disease Vectors in Caribbean Acroporids

*Dana E WILLIAMS**, *Margaret W MILLER*

SEFSC 75 Virginia Beach Drive, Miami, FL USA 33149 United States of America

dana.williams@noaa.gov

A rapidly progressing die-off of *Acropora cervicornis* (staghorn coral) was recently observed over a wide geographic range (>200 km) in the Florida Keys. Original observations made at White Bank Dry Rocks revealed one-third of *A. cervicornis* colonies with tissue rapidly sloughing from multiple areas. Random surveys suggested that this syndrome was clumped and spreading among the colonies at the rate of 5% per week. Field experiments demonstrate that the syndrome causing the die-off is transmissible not only via direct contact between affected and healthy staghorn coral tissue but also via a predator vector (the corallivorous snail, *Coralliophila abbreviata*). The condition was also transmissible, though less effectively so, to the congener *A. palmata* (elkhorn coral). No transmission was observed in indirect contact treatments designed to simulate diver interaction/touch. Transmissibility implies that the condition is indeed a biotic disease and the demonstration of effective vector transmission suggests that predation may exacerbate disease outbreaks in remnant Caribbean acroporid populations to further impede their recovery.

Temporal Variation in Tissue Mortality of *Montastraea faveolata* with Yellow Blotch Syndrome at Morrocoy National, Venezuela

*Aldo CROQUER**, *Ernesto WEILL*, *David BONE*

Sartenejas., Caracas, Miranda Republic of Venezuela

croquer@telcel.net.ve

Yellow Blotch (YBS) is a wide-spread Caribbean coral syndrome mainly affecting colonies of *Montastraea annularis* and *Montastraea faveolata*. At Sombrero Key, in Morrocoy National Park (10° 52 N-59° 16W), this syndrome is very common with prevalence ranging from 14 to 16% and mainly affecting *M. faveolata*. Goals of this work were to determine the rate of s of tissue mortality produced by YBS and to test if these rates varied on a temporal scale. A total of 30 colonies of *M. faveolata* with YBS were tagged by carefully hammering nails between healthy and necrotic tissues. Each colony was monitored 3 times (every four months) for one year by measuring the distance between the initial marks and the new position of the band. Tissue mortality across time periods was compared with a Repeated-Measure Analysis of Variance. Total tissue removed by YBS significantly decreased from 6.23±0.21cm (2000-2001) to 4.43±0.20cm (2001-2002). The rate of tissue mortality was extremely variable within years. The highest values of tissue mortality were recorded during May and July 2001 (0.7±0.2 cm/month). These rates significantly (p<0.001) decreased to 0.1±0.02 cm/month between August and October, the lowest for the period of study. Finally, the rates of mortality significantly increased (p<0.01) up to 0.8±0.24 cm/month between February and May 2002. These results show that mortality rates by YBS on *M. faveolata* are extremely variable within and across years. Further studies must be done to determine the factors (environmental or biological) that regulate this temporal variability of tissue mortality as well as the epidemiological significance (if any) of this trend.

Temporal Changes in Susceptibility to Dark Spot Syndrome in the Caribbean Coral *Siderastrea siderea*

*Deborah J GOCHFELD**, *Julie B OLSON*, *K Erica MARSH*, *Marc SLATTERY*

P.O. Box 1848, University, Mississippi 38677 United States of America

gochfeld@olemiss.edu

Scleractinian corals appear to be increasingly susceptible to pathogenic diseases, yet it is poorly understood why certain individuals, populations or species are more susceptible to diseases than are others. Clearly an understanding of mechanisms of disease resistance in corals is essential to our understanding of patterns of disease incidence and virulence. A survey of Bahamian corals identified selective antimicrobial activity in some, but not all, of the species tested. One of these species, *Siderastrea siderea*, exhibits variability in susceptibility to Dark Spot Syndrome (DSS), a disease of unknown origin that can result in tissue necrosis. We monitored colonies of *S. siderea* affected by DSS, as well as their nearest neighbor controls, for over two years, and found temporal variability in the incidence of this disease. Colonies of *S. siderea* exhibited a marked decline in extent of DSS infection in October of both years, and previously necrotic tissue exhibited remarkable regenerative capacity. The surface microbial community structure also varies among diseased vs. healthy colonies, suggesting that phenotypic plasticity in antimicrobial activity may impact microbial settlement and/or survival on coral surfaces. To assess whether changes in chemical defenses were responsible for the observed temporal variability in DSS incidence, we have sampled *S. siderea* for quantitative and qualitative analysis of chemical and antimicrobial variability between resistant and susceptible colonies of *S. siderea*.

Spatial Trends in Coral Disease Prevalence and Distribution of Disease Types on the Great Barrier Reef

Cathie A PAGE*, Cathie A PAGE, Bette L WILLIS

School of Marine Biology and Aquaculture Australia

cathie.page@jcu.edu.au

It has generally been assumed that coral disease occurs only rarely on the Great Barrier Reef (GBR). This perception is due to a lack of research focused on coral disease in this region. Data collected annually since 1998 by the AIMS Long Term Monitoring Program indicate that White Syndrome (WS), a disease category that may encompass a number of diseases including skeletal eroding band, has increased in both distribution and abundance over 5 years of surveys. Recent surveys revealed the presence of a number of additional disease types previously undetected on the GBR, however, the distribution of these disease types throughout different latitudinal sectors and cross-shelf positions of the GBR is unknown. In the summer of 2003/2004 surveys of coral disease prevalence were conducted in two latitudinal sectors of the GBR to examine spatial patterns in coral disease prevalence and the distribution of disease types. In each sector, surveys of coral disease were conducted on reefs located in each of three cross-shelf positions (inner-, mid- and outer-shelf) to examine the relationship between terrestrial run-off (the main source of anthropogenic pollution on the GBR) disease prevalence and the distribution of disease types on the GBR. These surveys represent the most comprehensive surveys of coral disease prevalence and disease types on the GBR to date.

Seasonal and Taxonomic Patterns in the Prevalence of Coral Disease on the Great Barrier Reef

Bette L WILLIS*, Cathie A PAGE, Elizabeth A DINSDALE

Townsville, Queensland, 4811 Australia

Bette.Willis@jcu.edu.au

Diseases of coral reef organisms have been escalating in the past few decades, but little is known about the prevalence of disease on the Great Barrier Reef (GBR) or throughout most of the Indo-Pacific. As part of the WB/GEF Working Group on Coral Disease, we surveyed prevalence of coral disease at sites in the northern and southern sectors of the GBR Marine Park. We identified six disease states that affect scleractinian corals and one that affects gorgonians. Disease prevalence (combined for all disease states) ranged from $7.2 \pm 1.06\%$ to $10.7 \pm 0.76\%$ for scleractinian corals and up to $16.6 \pm 4.5\%$ for gorgonians in January 2003. Disease prevalence was greatest in pocilloporid and acroporid corals at all sites ($n=8$), peaking at 16.8% of pocilloporid corals at Lizard Island sites. Overall, white syndrome (WS) and skeletal eroding band (SEB) were the two most common disease states. Black band disease (BBD: comprising a group of unidentified cyanobacterial syndromes), brown band (BrB) and tumors were also present on all reefs. Disease prevalence increased dramatically between winter 2002 and summer 2003 surveys on Lizard Is reefs (northern sector), increasing by fifteen-fold in acroporids, twelve-fold in faviids and doubling in pocilloporids. In particular, the number of cases of WS, SEB and BBD was greatest in the austral summer, suggesting a link between higher temperatures and disease incidence. Given 1) putative links between disease outbreaks and both elevated temperatures and deteriorating water quality, and 2) that current trends in global climate change and intensity of human-related activities predict escalating levels of stress for reef corals, studies such as this one on the Great Barrier Reef are important for establishing global baselines against which to judge whether background levels of coral disease are increasing.

Coral Diseases and Syndromes Affecting Coral Reefs in the Philippines

Laurie J RAYMUNDO*, Clarissa T REBOTON, Kathryn B ROSELL, Longin KACZMARSKY

Silliman University Marine Laboratory, Bantayan Beach, Dumaguete City 6200 Republic of the Philippines

lauriejr@dgte.mozcom.com

While it is assumed that Indo-Pacific reefs are unaffected by diseases, limited data suggest a number of diseases and syndromes which are poorly quantified. This report presents results of a survey of coral diseases in two regions in the Philippines: Central Visayas and Lingayen Gulf. Eight reefs were surveyed, four in each region. On each reef, three 20m x 2m belt transects at shallow and deep portions of the reef quantified the following data: benthic community composition, a count of all diseases within the belt, identification of host species and counts of infected colonies, hard coral diversity along five 2m segments bisecting each 5m point along the transect, and colony counts of all species of *Porites*, as the genus *Porites* was particularly impacted. Mean total disease prevalence was $14.2\% \pm 2.8\%$ (Mean \pm SE; $n = 8$ reefs), with Central Visayas reefs showing higher prevalence ($17.6\% \pm 3.9\%$; Mean \pm SE; $n=4$ reefs) than those of Lingayen Gulf ($11.1\% \pm 3.9\%$; Mean \pm SE; $n=4$ reefs). Six diseases/syndromes were described, three of these: *Porites* Ulcerative White Spot Disease (prevalence= $8.96\% \pm 2.2\%$; Mean \pm SE), Neoplasia (prevalence= $1.0\% \pm 0.5\%$) and Pink Line Syndrome (prevalence = $0.5\% \pm 0.2\%$) occurred frequently in both regions and targeted the genus *Porites*. Black Band and White Band Diseases, previously recorded from this area, were not observed. Correlation between reef diversity and disease prevalence was positive but insignificant ($r^2=17.8$; >0.05), with weak to zero correlation between the number of *Porites* colonies per reef and disease prevalence ($r^2=0.1$, >0.05) and total live coral cover and disease prevalence ($r^2=0$; >0.05). *Porites* is a major reef builder in the Indo-Pacific, comprising 30% of hard coral on surveyed reefs, and is generally thought to be a hardy, long-lived genus. Diseases targeting this robust group present an as yet unquantified risk to Philippine reefs and could result in major changes in reef structure and biodiversity.

Dynamics of Coral Diseases and Syndromes in the Central Philippines: Prevalence, Distribution, Progression Rates, Host Ranges, Anthropogenic Links, and Experimental Evidence of Pathogen Involvement in Coral Neoplasia

Longin T KACZMARSKY*

P.O. Box 287, Cliffwood, New Jersey 07721 Virgin Islands of the United States
solonnie@hotmail.com

It is widely thought that coral disease is not a major threat to Indo-Pacific reefs. The results of this quantitative research suggest otherwise. Field surveys were conducted from November 2002 to August 2003. Sites included the islands of Palawan, Cebu, Bohol, Siquijor, Panglao, Olango, Mactan, Sumilon, Bantayan, Pescador, Balicassag and Negros. Two syndromes occurred in the Philippines at a high prevalence locally. One of these syndromes, neoplasia, is newly documented for the Philippines. These syndromes mainly affected species of the genus *Porites*, a dominant reef-forming group. 10026 *Porites* colonies were examined in 154 belt transects covering 3080 m² of reef. Neoplasia occurred as high as $38.8\% \pm 5.0$ SE among massive *Porites* and *Porites* ulcerative white spot syndrome (PUWS) as high as $41.2\% \pm 7.8$ SE among massive and branching species. Tagging 116 colonies showed that both syndromes progressed slowly and exhibited low mortality over an eight-month period. Along an anthropogenic impact gradient on Negros, 15 shallow sites were examined (6 permanent transects each, depth 1 to 3 m). Correlation analyses revealed patterns that link higher disease prevalence and severity to anthropogenic influence and a unique geomorphology that affected local water movement. Survey results from an additional 13 sites within the region strengthened this conclusion. Transfection experiments revealed a newly observed transmission pattern for coral neoplasia suggesting the involvement of a pathogen. Several additional syndromes new to the Philippines were also observed and quantified including a severe outbreak of the coral-killing sponge *Terpios hoshinota* affecting most of the shallow corals on the island of Balicassag. A high prevalence of black band disease was also recorded in one Palawan site. Expanded host ranges and new characterizations of the disease and syndromes are described. This study provides much-needed baseline coral disease data and the most comprehensive to date for the Philippines.

Coral Diseases Outbreak and the Changing Face of Indian Coral Reefs*R. JEYABASKARAN**, *S. RAGHUKUMAR*

Dona Paula, Goa - 403 004 Republic of India

jeybas@hotmail.com

In India, coral reefs are found in 4 regions namely Andaman & Nicobar, Gulf of Kachchh, Gulf of Mannar, and Lakshadweep islands. Recent survey results showed the presence of 55% live coral coverage at Andaman & Nicobar Islands. Coral diseases like dark band, white band and tissue necrosis were observed in these reefs. The Gulf of Kachchh live coral coverage was only 3 to 5% at reef flat and 15 to 25% at reef slope. These corals are degrading fast due to diseases and industrialization. Corals were severely affected by tissue necrosis, sedimentation, white pox and Dark band and bleaching. Gulf of Mannar islands consisted of 12 to 17% live coral coverage. Among these, coral diseases such as white band, bleaching, tissue necrosis and pink line syndrome affected 53% of branching corals and 41% of massive corals. The live coral coverage was varied from 5.5 to 32.5% in Lakshadweep islands. The disease outbreaks were higher in reef flats 70% and lower in reef slopes 15%. A newly emerging disease Red Plague Syndrome was spreading very fast (10 to 15 cm a day). In Kavaratti Island, 90% of *Porites* sp and *Montipora* sp colonies were affected by these disease. The etiology of diseases, human influences and status of each island reefs have been proposed in this paper.

Macroalgal Recruitment on Coral Reefs: Dynamics and Roles of Ecological Processes

Guillermo DIAZ-PULIDO, Laurence J MCCOOK*

A.A. 1122, Santa Marta Republic of Colombia
guillermo.diaz@unimag.edu.co

The recruitment of algae is a critical process during algal colonisation and invasions, particularly in coral to algal phase shifts. Despite algae are widely assumed to colonise and kill corals, there is very little known about the recruitment dynamics of coral reef algae, or the effects of ecological processes on such dynamics. To address these issues, we combined descriptive and experimental data from the Great Barrier Reef (GBR), Australia, focusing on two dominant macroalgae: *Sargassum* and *Lobophora variegata*. Recruitment abundance varied across the GBR, between habitats, species, and through time. *Sargassum* propagules recruited throughout the year but peaked during summer/autumn in inshore reefs, whereas, at offshore reefs, recruitment was nil. Reef slopes had lower densities of *Sargassum* recruits than reef flats. Contrary to *Sargassum*, *L. variegata* recruited across the entire GBR, being more abundant in inshore reefs and slopes. Adult *Sargassum* populations were highly seasonal and were related to algal recruitment, suggesting an important role of adult phenology in recruitment dynamics. We tested: 1) the ability of algal propagules to settle and grow on healthy coral tissue, 2) the relative importance of nutrient supply to and herbivory on recruits, and 3) the effects of herbivory and habitat on algal recruitment. Healthy corals were able to prevent attachment or survival of recruits of these macroalgae and variation in recruitment appeared related to the amount of turf algae or crustose algae on the plates. Herbivory strongly reduced both density and growth of recruits for both taxa, whereas nutrient supply had minor effects on growth of *L. variegata* recruits and no detectable effects on *Sargassum* recruits. Herbivory varied between species, habitats, and locations. These results emphasize the critical roles of coral disturbances to coral - algal phase shifts, and the importance of herbivores to the protection of coral reefs against algal overgrowth.

Stock-Recruitment Relationship Predicts a Slow Recovery of an Isolated Reef System Following a Catastrophic Bleaching Event

Luke D SMITH*, Andrew HEYWARD, James GILMOUR, Max REES

PO Box 83 Australia
Lsmith@jcu.edu.au

In April 1998 a major coral bleaching event occurred in the Scott Reef region in north-western Australia as a result of elevated sea-surface temperatures. We quantified changes in percentage cover of benthic organisms at the Scott Reef system four years before, and three years after, the mass coral bleaching in 1998. The relative abundances of corals and other benthic organisms changed little over the years prior to the bleaching. The hard corals were the dominant benthic organisms, at approximately 40% cover, and the soft corals occupied approximately 10% cover. Elevated water temperatures (greater than 32 °C) in 1998 caused mass bleaching of almost all corals, resulting in catastrophic mortality across the entire Scott Reef system. The percentage cover of hard and soft corals decreased to approximately 15% and 2%, respectively. The coral communities at the Scott Reef system show no signs of recovery following the catastrophic bleaching and the community has shifted from one dominated by corals to one dominated by algae. The bleaching event had a dramatic effect on coral recruitment rates, which decreased by 96% in the years following the bleaching. There was an average of 39.6 coral recruits plate⁻¹ (range 7.9 to 168.9) in the two years before the bleaching, compared with only 1.35 rec. plate⁻¹ (range 0.8 to 2.2) over four years after the bleaching. Rates of recovery of the resident coral communities at the Scott Reef system of reefs are likely to be extremely slow, because of the extent and severity of the bleaching event, and the reproductive isolation of the system. Predictive models indicate that bleaching events around the world will become more frequent, and the coral communities at Scott Reef may not have sufficient time to recover before the next bleaching event.

Cross-shelf Coral Assemblages on the Great Barrier Reef: The Importance of Disturbance History

Abbi MCDONALD*

JCU, Townsville, QLD, Australia, 4811 Australia
abbi.mcdonald@jcu.edu.au

Ecological systems are largely influenced by disturbance operating at various spatial and temporal scales. Over the last few decades the frequency and intensity of large-scale disturbances have increased on coral reefs, causing concern for their future status. The heterogeneous nature of disturbance across the Great Barrier Reef (GBR) means that histories of individual reefs are often unique. This hampers the study of multiple disturbances, limiting the understanding of how increasing disturbance will affect the GBR. The aim of this study was to investigate the variation in multiple disturbances on the GBR and to determine if the disturbance history of reefs is reflected in the current adult and juvenile coral assemblages. Reefs in the Townsville sector, central GBR were studied. Disturbances were defined as either pulse (cyclones, coral bleaching, and *Acanthaster planci* outbreaks), or press (sedimentation) impacts. There was little variation in the history of pulse disturbances between inner-shelf reefs. These reefs were better distinguished by their depth, and proximity to the coast, which was used as a proxy of the press impact of sedimentation. In contrast, mid-shelf reefs were rarely affected by sediment plumes and/or resuspension, but were highly variable in their history of pulse disturbances. The assemblage structure and abundance of both adult and juvenile corals reflected the disturbance history of the reef on which they occurred. Cross-shelf patterns were also apparent. The results from this study suggest that the history of disturbance on the GBR is highly relevant to the current status of both adult and juvenile coral assemblages. Future studies comparing reef assemblages would benefit from taking into account the history of individual reefs, rather than generalising by region and/or shelf position.

Response of Host and Symbiont Pigments from Three Distinct Colour Morphs of the Scleractinian Coral *Montipora monasteriata* to Stress

Sophie DOVE*, Juan Carlos ORTIZ, Roberto IGLESIAS-PRieto, Susanna ENRIQUEZ, Ove HOEGH-GULDBERG

St Lucia 4072 QLD Australia
sophie@uq.edu.au

Growing evidence suggests that reef-building corals that have heavy host pigmentation are more susceptible to thermal than less pigmented con-specifics. Pocilloporins, a family of all protein chromophore (GFP-like proteins) are responsible for both fluorescent and non-fluorescent pigmentation associated with host tissue. GFP mRNA is unstable for corals heated to 32°C for 6 h. Heavily pigmented corals heated to 32°C both experimental and in the field show significant decreases in photosynthetic efficiency and loss of symbionts leading to high mortality. In this study, brown, purple and red morphs of *Montipora monasteriata* were collected at a depth of approximately 5 m from Wistari Reef (southern Great Barrier Reef, Australia). Corals were exposed to 32°C for 6 h in a controlled experiment on an overcast day where irradiance levels did not exceed 250 $\mu\text{M Quanta m}^{-2}\text{s}^{-1}$. GFP-like proteins, Mycosporine-like Amino Acids (MAAs) and photosynthetic pigments were analyzed by gel filtration and reverse phase chromatography. Control and thermally stressed corals were then exposed to a day of high irradiance (max. 1800 $\mu\text{M Quanta m}^{-2}\text{s}^{-1}$) with and without UV-radiation. The effect of added UV stress on host and symbiont pigments were then analyzed by chromatography and by a comparison of GFP-mRNA concentrations. The level of UV protection offered by pigments and symbionts to host DNA was also determined. The results of this study indicate complex interactions between environmental variables, host pigmentation and stress, and the acclimation state of the symbionts.

Ecological Effects of Climate Change and Human Perturbations: What Can We Learn from Communities near their Physiological Edge?

Juan M JIMENEZ*

Department of Biology and Biochemistry, University of Houston, SR 2 room 369, Houston, TX, 77204 United States of America
jjimene@mail.uh.edu

This paper argues about the importance of experimentally studying the nature of the coral-algae-herbivore interactions in naturally extreme environmental conditions (such as in the Eastern Tropical Pacific or the Red Sea). These studies can provide key information to understand the on-going and future changes on coral reefs in other parts of the world and can be used to improve existing models. Global climate change and habitat fragmentation are disrupting interactions among species producing major changes in community structure, biodiversity, and ecosystem functioning worldwide. To improve the predictive accuracy of community structure models, scientist should examine species interactions under conditions near the edges of their physiological tolerances. Most models are based on very limited data sets and generally exclude communities that live under extreme conditions. Thus, in general, models are incomplete and have low predictive accuracy for the major ecological changes to come. Benthic community structure models on coral reefs have been recently challenged because their fundamental assumptions are not true in many cases. These basic assumptions should be tested under naturally extreme environmental conditions (i.e. high sedimentation rates, low light penetration, eutrophic waters, periodic thermal stress). Coral reefs are experiencing degrading conditions due to global climatic change and anthropogenic perturbations. Reefs will tend to become monotypic, be exposed to turbid waters with high nutrient concentration and high sedimentation rates and periodic temperature stressful events. Test the existing models on reefs that are already under such conditions can significantly improve their predictive accuracy.

Size Matters: Bleaching Dynamics of the Coral *Oculina patagonica*

Noa SHENKAR*, Maoz FINE, Yossi LOYA

Ramat Aviv 69978, State of Israel

levinn@post.tau.ac.il

Global patterns of coral bleaching have been studied extensively, though little is known on bleaching patterns on the individual colony and population levels. To clarify the yearly dynamics of the bleaching process of the encrusting coral *Oculina patagonica* continuous photographic monitoring of a fixed tagged population was conducted during two annual bleaching events. Results showed that the extent of percent bleached surface area within each colony was correlated to water temperature. Surveys showed that during the peak of bleaching season non-bleached colonies were small colonies averaging 4.6 cm in diameter. In colonies undergoing bleaching, the perimeter of the colony was affected first and as water temperatures rose, bleaching progressed toward colony center. No differences were found in either the density of the zooxanthellae population or the chlorophyll content between the edge of non bleached colonies and their center. During the summer months, partial mortality occurred in the perimeter region of bleached colonies in 22% of the tagged colonies. 25% of the tagged colonies died during the research period. Most of the colonies that died belonged to the largest size group. The partial mortality caused an average decline of 46% in the average colony size, resulting in a shift to a smaller size group. The high mortality of large colonies, high survivorship of the small colonies and the decline in colony size, due to partial mortality, suggest that in the case of bleaching in populations of *O. patagonica*, small colony size is an advantage. In this species colonies as small as 2 cm in diameter are reproductive. Hence, bleaching may have a lesser effect on the reproductive fitness of the small size groups in the population. This may prove to be true also in other massive and encrusting coral species that the onset of their reproduction starts at a small size.

Post-bleaching Development of a Northern Maldivian Reef (1998-2002)

Helmut SCHUHMACHER*, Karen LOCH, Wolfgang LOCH, Wolf R SEE

Universitaetsstrasse, 45117 Essen Federal Republic of Germany

h.schuhmacher@uni-essen.de

The development of the reef flat and upper slope on Komandoo (Lhaviyani atoll) is under observation since the bleaching event of 1998. We report here on specific losses, recolonization by coral larvae and regeneration of partly damaged (massive) colonies over the period from 1999 to 2002. Recruitment was quantitatively recorded along transects over the reef flat, on dead *Acropora*-tables at the reef slope and on partly destroyed large *Porites*- and *Diploastrea*-colonies. The damage of the reef structure by hydrodynamics and bio-erosion, as well as the overall status of the reef community were qualitatively assessed. Soon after the bleaching recruitment was more pronounced than in the following years, *Pavona varians* being a main constituent of regeneration. The temporal recolonization pattern points at an emergency-spawning of local *Scleractinia* just prior to the bleaching, whereas during the following years the number of fertile colonies was reduced as evidenced by a sharp decrease of young settlers in 2001 and 2002. The dominant species in the coral community shifted from acroporids and pocilloporids to agariciids. The skeletal deposition of recovering *Diploastrea heliopora* is equivalent to that before the bleaching; it is one third of that of neighbouring *Porites lobata* colonies. The slow and scattered formation of new reef substance is more than outweighed by the collapse of dead protruding and spacious colonies (e.g. *Acropora* tables). Four years after the bleaching the formerly irregular (three-dimensional) structure of the reef flat and upper slope is converted into a levelled field of rubble. The cover of filamentous algae (including cyanobacteria) has increased, whereas the amount of herbivorous Acanthuridae has decreased slightly and that of Chaetodontidae even more. Considering the recurrence of bleaching events (1987, 1998) and the results of the present study one may assume a cascading deterioration of the status of the reef for the future.

Recovery of Coral and Fish Following the 1998 El Nino Event at Aldabra Atoll, Southern Seychelles: A Site with Minimal Anthropogenic Influence

Nigel DOWNING*, Ben STOBART, Raymond BUCKLEY, Kristian TELEKI

Ashcroft, Rotherfield Peppard, Oxfordshire RG9 5LB United Kingdom of Great Britain and Northern Ireland

mukiwa@netcomuk.co.uk

The Aldabra Marine Programme was established in 1999 to monitor reef changes at Aldabra following the 1998 coral bleaching event. Aldabra is a remote atoll, lacks permanent inhabitants, and is protected by UNESCO World Heritage status. It is therefore an ideal place to study reef recovery "free" of anthropogenic disturbances. Mortality of coral at Aldabra following the bleaching event was estimated to be approximately 30-40%. Video transects were used to survey the benthos along permanent transect lines, while fish were surveyed by visual census. Five years after the bleaching there are signs of hard coral recovery at some locations, but in spite of several years of high coral recruitment signs of overall recovery are not significant. Over the study period, average hard coral cover change was only 0.3% at 10m depth and -1.4% at 20m. Over the same period there has been a considerable increase in soft coral cover, reaching 33% at one location, while more commonly ranging from 7-10%. Soft coral increase has been dominated by the genus *Rhytisma*. Macro algal cover did not increase following the bleaching event. There have been no further events leading to large-scale coral mortality at Aldabra since 1998. Fish abundances and diversity were found to be high at Aldabra. The diversity of fishes, both in terms of species and families, appears to have remained relatively stable over the study period and probably represents pre-bleaching community structure. Significant positive correlations have been detected between densities of fishes, or the number of species, for the reef associated serranids, chaetodontids, pomacentrids, labrids and holocentrids, and percentage of live coral habitat. With over 221 species and 45 families identified to date, Aldabra is a biodiversity "hot spot" for reef fishes in the southern Seychelles.

Reef Regeneration at Alphonse Atoll, Western Indian Ocean, Following the 1997-98 Ocean Warming Event

*Annelise B HAGAN**

Dept. of Geography, University of Cambridge, Cambridge. CB2 3EN United Kingdom of Great Britain and Northern Ireland
abh28@cam.ac.uk

Considerable debate on reef survivorship has focussed on possible near-future changes in coral bleaching frequencies, driven by a global environmental change signal embedded within increasingly frequent El Nino ocean warming events. Such questions require a better appreciation of rates and characteristics of reef recovery following catastrophic bleaching yet few studies extend beyond the immediate post-bleaching period. Indian Ocean reefs were particularly badly affected by the global 1997-98 ocean warming event, suffering up to 90% coral mortality. Repeated quantitative reef surveys (Video Transects and Line Intercept Transects) have been conducted at up to 30 sites around Alphonse Atoll, Seychelles (7°01'S; 52°44'E) in 1998, 1999 and 2001-2003. Data has been analysed to show changes in percentage cover for 7 benthic categories (sand, rubble, bare substrate, calcareous algae, scleractinia, non-scleractinia and macroalgae). One year after the bleaching event, scleractinia cover was greatly reduced (10%) but macroalgal cover increased (up to 27%). This high level of macroalgae has not persisted and scleractinia cover has been progressively increasing, reaching 23% by 2003. At the same time, substrate coverage of calcareous algae has increased from 10% (1998) to 40% (2003). However, there has been no associated increase in coral diversity, with much of the percentage increase being attributed to colonisation by opportunist species of *Pocillopora* and *Acropora*. Alphonse reefs appear to be in the early stages of recovery following the 1997-98 bleaching. The results suggest that it may take up to 10 years for these reefs to re-gain their pre-bleaching level of scleractinia cover, but possibly over 30 years to regain their generic diversity.

Spatial and Temporal Dynamics of Arabian Gulf Coral Assemblages (U.A.E.) in Response to Temperature-forcing

*Bernhard M RIEGL**, *Samuel PURKIS*, *Kevin KOHLER*, *Richard E DODGE*

Oceanographic Center, 8000 N. Ocean Drive, Dania Florida 33004 United States of America
rieglb@nova.edu

We analyzed spatial and temporal patterns of coral communities in the southeastern Arabian Gulf (Abu Dhabi, Dubai, Sharjah) in response to temperature variability in one of the most extreme coral environments. We used Ikonos and Aster satellite imagery combined with 8 years of ecological monitoring data (line transects and photo-squares) and sea-surface temperature data (CoADS, HadISST1, NCAR). Analysis of SST confirms that the area is subjected to recurrent and cyclic temperature anomalies. We explore whether unusually low or high temperatures are the main forcing factor of coral mortality and whether links to ENSO via the Indian Ocean Zonal Mode/Dipole exist. Temperature extremes occur more frequently in the western area between Qatar and Abu Dhabi than in the eastern area between Abu Dhabi and Musandam. The spatial expression of coral assemblages near Jebel Ali (Dubai) on IKONOS imagery is consistent with what would be predicted if reef development was repeatedly 'reset' on a decadal time-scale by recurring episodes of coral mass mortality induced by severe positive or negative SST anomalies. Furthermore, a combination of remotely-sensed habitat mapping and bathymetric digital elevation model analysis revealed no evidence of any reefal framework development, suggesting that the cycle of temperature-induced mortality has been operating for a considerable time. We therefore suggest that the environment in the entire southeastern Arabian Gulf has not been conducive to biohermal framework production and that all coral areas have been subject to frequent mortality episodes. Increased global temperatures are likely to increase the frequency of extreme positive SST excursions and indeed the area has experienced bleaching events in 1996, 1998 and 2002, which is the fastest recurrence rate recorded on any reef system. While some evidence for phenotypic adaptation was observed (reduced bleaching in *Acropora*), further degradation of the system is expected.

Ecological Indicators for Coral Reef Resilience to Climate Change, from the Kiunga Marine Reserve, Kenya

*David O OBURA**

P.O.BOX 10135, Mombasa Republic of Kenya
dobura@cordio.info

The Western Indian Ocean has experienced one major and several minor bleaching events in the last decade; in 1998, some reefs suffered 90-95% bleaching and mortality of corals with a regional average of about 30%. The resilience of coral reefs to increasing severity and frequency of warming events will be critical to whether they can survive and adapt to changing conditions, and can be broken down into properties of avoidance of warming conditions, resistance to bleaching and mortality, and recovery following mass mortality. Investigation of reef resilience to mass bleaching depends on the identification of suitable indicators, and comparative analysis of these indicators at sites exhibiting different avoidance, resistance and recovery properties. Potential resilience indicators include coral species composition, species number accumulation curves, recruitment rate, percent cover, size class structure, bleaching and mortality rates and life history parameters, measured over time. Data will be presented from the Kiunga Marine Reserve, northern Kenya (S 2o 00', E 41o 30') to illustrate the utility of these indicators for measuring reef resilience and recovery from mass bleaching and mortality. For example, at the individual site level, coral species number decreased from 142 to 101 from 1998 to 1999 (*Acropora* spp. 44 to 12, non-*Acropora* 98 to 89), then increased progressively from 2000 to 2002 (in 2002; 153 species total, 11 *Acropora*, 142 non-*Acropora*) though this is in part due to improved identification and discrimination of non-*Acropora* species. Recruitment was almost absent in 1999 (0.16±0.09m⁻²), increasing but remaining consistently low in subsequent years (2001 2.2±2.35 m⁻²; 2002 1.01±0.62 m⁻²), and dominated by *Pocillopora* spp. (31%, mainly *P. verrucosa*), *Porites* spp (11%), *Coscinaria* (9.1%) and *Favites pentagona* (8.3%). Full analysis of data to 2004 will be conducted comparing species by site variation, to raise hypotheses of resilience and recovery of sites from mass coral bleaching.

Resilience of Corals to Bleaching Stress: An Experimental Study

*Shakil M VISRAM**, *Angela E DOUGLAS*, *David O OBURA*

Department of Biology, University of York, PO Box 373, York, YO10 5YW, UK United Kingdom of Great Britain and Northern Ireland
shakilvisram@yahoo.co.uk

Resilience, i.e. capacity to recover, after bleaching is a crucial but little-studied aspect of coral responses to bleaching stress. To investigate coral resilience, *Porites cylindrica* was subjected to different durations of different bleaching stressors (elevated temperature and darkness). Coral resilience, as assessed by pattern of recovery of zooxanthella populations, was strongly influenced by the nature of the bleaching stressor. The impact of prior experience of bleaching on zooxanthella phylotype and susceptibility to a further bleaching stress was also investigated. Results were related to field observations of coral responses to bleaching stress in the natural environment. The contribution of coral responses (including acclimation) and zooxanthella responses to the resilience of corals to bleaching are considered

Response of Coral Reefs to Protected Area Management Spanning the 1998 ENSO*Tim MCCLANAHAN**

P.O. Box 99470 United States of America

tmclanahan@wcs.org

The effects of global climate change and the predicted increase in the intensity of warm ENSO events on coral reef diversity is predicted to extirpate many coral reefs but may depend on local reef management systems. A thirteen year study of eight Kenyan reefs divided among fished and unfished management systems across the extreme 1998 ENSO indicated that reefs recovered coral diversity within five years and that heavy fishing was a stronger effect than the 1998 ENSO. Heavily fished reefs had decreased herbivory, coral cover, and diversity of corals and fish and the ENSO increased frondose algae abundance and diversity on these but not the unfished reefs. Community structure of corals changed largely due to a loss in the dominant fast-growing species but the changes in fish community were considerably less and difficult to detect apart from the effects of fishing. Fish catches remained constant across the event and the effects were also difficult to distinguish from changes in gear management.

Reduction of Coral Calcification from CO₃²⁻ Decreases by the Mid-21st Century

Chris LANGDON*, Marlin J ATKINSON

Palisades, NY 10964 United States of America

langdon@ldeo.columbia.edu

Laboratory and mesocosm studies have demonstrated that lowering the [CO₃²⁻] and hence the aragonite saturation state (Ω_{arag}) of seawater by addition of acid or CO₂ causes a reduction in coral calcification. Light intensity and water motion have tended to be low relative to natural conditions in these studies. It is pertinent to ask whether corals that are energy replete and subject to minimal mass transport limitation of crucial ions will exhibit the same strong dependence on ambient [CO₃²⁻]. Colonies of *Porites compressa* and *Montipora capitata* were collected from Kaneohe Bay, HI and placed in a 24-m long by 0.4-m wide flume to form a bottom with an area of 2.32 m². Fresh seawater was circulated at a rate of 20 cm s⁻¹. Experiments were conducted in pairs, where calcification was measured with normal seawater from 1030-1200 h and then acid was added to drop the [CO₃²⁻], an amount equivalent to the drop expected by the year 2065, and then the response of the corals was observed from 1230-1400 h. After establishing the response at ambient nutrient levels a second course of experiments were conducted where the corals were first exposed to a spike of 0.3 M NH₄ and 0.024 M PO₄ for five hours the previous afternoon. We found that under ambient nutrient concentration, full sunlight and natural turbulence level there was a strong, positive correlation between calcification and Ω_{arag} (mmol CaCO₃ m⁻² h⁻¹ = 9.10 * Ω_{arag} - 7.96, r²=0.70, n=14). Based on this response a doubling in CO₂ would cause a 45% decrease in coral calcification. Brief exposure to elevated NH₄ and PO₄ concentrations had no significant effect on the rate of calcification but did have the effect of decoupling the dependence on Ω_{arag} (mmol CaCO₃ m⁻² h⁻¹ = 0.31 * Ω_{arag} + 12.92, r²=0.03, n=10). The mechanism of this decoupling is not known.

Concomitant Impact of Carbon Dioxide and Temperature on Coral Metabolism: Case of the High Latitude Reef of Bermuda

Alexandra AMAT*, Nick R BATES

Ferry Reach St Georges GE01 BERMUDA

alexandra.amat@laposte.net

Rates of calcification by reef builders are predicted to significantly decline in the future due to the increase in atmospheric CO₂. When considering the response of reefs to the present climate change, temperature effects should also be taken into account. Here, we investigate the simultaneous impact of CO₂ and temperature on the high-latitude Bermuda coral reef system (32°N, 64°E) through a series of *in situ* studies at several reef sites and *in vitro* aquarium experiments. The *in situ* seasonal variability of seawater properties such as temperature, pCO₂, [CO₃²⁻] were determined by time-series observations from a CARIOCA buoy and water column sampling. Growth rates for *Diploria labyrinthiformis* grown *in situ* were measured at 4 reef sites. Photosynthesis and calcification-irradiance measurements were also conducted every four months. In aquarium, three species of Scleractinian corals (*Porites astreoides*, *D. labyrinthiformis*, *Madracis mirabilis*) were acclimated for three months at 20°C (winter temperature) and 27°C (summer temperature) in water equilibrated with atmospheric pCO₂ levels of 400 ppm (control) and 700 ppm (elevated). Growth was assessed by buoyant weight techniques during the acclimation period. Rates of photosynthesis, respiration and calcification were measured at the end of this period using respirometric chambers. Photosynthesis mainly remains constant or increases under high CO₂ conditions. The results of the integrated calcification measurements confirm the hypothesis that an increase in CO₂ induces a decrease in calcification. However photosynthesis can be enhanced when CO₂ is unfavorable for calcification suggesting that a biological control of calcification through photosynthesis could prevent a large drop in the calcification potential. Buoyant weight results indicate that the CO₂ impact could be less detrimental under lower temperature. This result is compared with the instantaneous calcification measurements in the chambers that display different behaviors under light or dark conditions and the *in situ* coral growth and metabolism assessments conducted seasonally.

In-Situ Diel Cycles of Photosynthesis and Calcification in *Acropora eurystoma* under Variable pH Values

Kenneth Haim SCHNEIDER*, Oren LEVY, Zvy DUBINSKY, Jonathan EREZ

Edmond Safra Campus, Givat Ram, Jerusalem State of Israel

Kenneth@vms.huji.ac.il

The increase in atmospheric CO₂ levels, causes a decrease in the upper ocean pH, and has a negative effect on the calcification of marine ecosystems such as corals reefs. The in-situ response of hermatypic corals to pH changes was measured using a submerged respirometer measuring continuously pH, O₂, temperature and PAR. pH was controlled by injecting HCl or NaOH in to the respirometer chambers. The alkalinity changes (A_T) due to coral calcification were calculated from oxygen and pH (Barnes 1983), and were verified with A_T samples obtained every two hours. For this calculation a PQ ratio (CT / O_2) needs to be assigned and for *Acropora eurystoma* the PQ ratio was 0.89. Calcification was calculated from A_T data, net photosynthesis and respiration rates were calculated from O₂ data. In natural seawater the diel cycles of calcification and net photosynthesis followed the light intensity cycle with significant hysteresis in both. While calcification was strongly affected by seawater pH, net photosynthesis and respiration did not respond to pH changes. Calcification rates in acidified seawater (pH = 7.8) decreased significantly and even skeletal dissolution was observed at night as well as daytime. In alkaline seawater (pH = of 8.5) calcification rates increased 1.6 to 4.3 fold relative to normal seawater. The CO₃²⁻ concentration changed between 110 $\mu\text{mol kg}^{-1}$ and 460 $\mu\text{mol kg}^{-1}$ while that of ambient seawater was $\sim 300 \mu\text{mol kg}^{-1}$. Calcification and photosynthesis were positively correlated at ambient and high pH, while at low pH they were negatively correlated.

The Effects of Increasing Temperatures on Variations the Calcification Rates of *Montastraea faveolata*; Perspectives under Possible Environmental Scenarios

Aime RODRIGUEZ-ROMAN*, Roberto IGLESIAS-PRieto

Prolongacion Ninos Heroes S/N, Quintana Roo, Mexico

aimee@mar.icmyl.unam.mx

The interactions between coral metabolism and calcification are poorly understood in the context of climate change. It has been postulated that the most dramatic effect would result from a reduction in the aragonite saturation constant expected from increases in the concentration of CO₂ dissolved in seawater. Elevated temperatures are one of the most important stressors of reef corals. Photosynthetic rates of symbiotic dinoflagellates are negatively affected at temperatures above 30°C. This loss in photosynthetic function have been identify as the initiation point of coral bleaching. Considering that photosynthetic rates are related to calcification rates, as this last process appears to be light enhanced, we investigated effects of temperature (23-33 °C) on the respiratory, photosynthetic and calcification rates of the Caribbean stony coral *Montastraea faveolata*. To accurately reconstruct the effects temperature on coral physiology, we determined the post-illumination and dark-adapted respiratory rates, and photosynthetic rates by two methods: oxygen evolution and changes in the fluorescence yield of Chl a. Our results indicate that the post-illumination respiration rates have a Q10 of 2.1 consistent with a kinetic limitation, on the other hand dark adapted respiratory rates are independent of temperature suggesting that they are not kinetically limited probably due to the hypoxic conditions prevalent inside the animal tissue. Photosynthesis showed a non-linear behavior as a function of temperature, with dramatic losses at temperatures above 30 °C. Analyses the changes in the photosynthesis to respiration ratio, indicate that at temperatures above this point the contribution of photosynthesis to animal metabolism is reduced. As a result of this non-linear behavior, the optimal temperature for calcification in this species is 27 °C. Using this information, we estimate the effects of increasing temperatures on variations the calcification rates of *Montastraea faveolata* under various possible environmental scenarios.

Coral Calcification Associated with Aragonite Saturation State of Seawater*Mirza M M HOSSAIN**, *Shigeru OHDE*1 Senbaru, Nishihara, Okinawa Japan
mozaffar44@hotmail.com

Calcification of calcareous organisms is potentially one of significant processes, because it is associated with carbon budget of the oceans. In this study, calcification rates of a massive coral were observed through laboratory experiments. It is assumed that coral calcification rate decreases with the decrease of aragonite saturation state of seawater. In order to elucidate the relationship between coral calcification and aragonite saturation state of seawater, we have measured calcification rates of *Porites lutea* using seawaters of different aragonite saturation conditions at 25°C. We observed that calcification rate of *P. lutea* increased with increasing the aragonite saturation state of seawater. A linear correlation ($r^2 = 0.95$) was observed between coral calcification and aragonite saturation state of seawater. The coral samples also calcified during nighttime experiments and the rate increased less significantly with increasing aragonite saturation state of seawater. Daytime experimental results suggest that calcification rates of *P. lutea* strongly depend on aragonite saturation state of seawater. Since atmospheric CO₂ increases due to anthropogenic activities, aragonite saturation state of seawater is likely to decrease and coral calcification will possibly decrease in future.

Effect of Early Marine Diagenesis on Coral Reconstructions of Surface-Ocean ¹³C / ¹²C and Carbonate Saturation State*Anne MULLER**, *Michael K GAGAN*, *Janice M LOUGH*Steele Building, St. Lucia, Qld 4072, Australia
a.muller@earth.uq.edu.au

Recent research suggests that future decreases in the carbonate saturation state of surface seawater associated with the projected build-up of atmospheric CO₂ could cause a global decline in coral reef-building capacity. Whether significant reductions in coral calcification are underway is a matter of considerable debate. Multi-century records of skeletal calcification extracted from massive corals have the potential to reconstruct the progressive effect of anthropogenic changes in carbonate saturation on coral reefs. However, early marine aragonite cements are commonly precipitated from porewaters in the basal portions of massive coral skeletons and, if undetected, could result in apparent non-linear reductions in coral calcification toward the present. To address this issue, we present records of coral skeletal density, extension rate, calcification rate, ¹³C, and ¹⁸O for well preserved and diagenetically altered coral cores spanning ~1830-1994 AD at Ningaloo Reef Marine Park, Western Australia. The record for the pristine coral shows no significant decrease in skeletal density or ¹³C indicative of anthropogenic changes in carbonate saturation state or ¹³C of surface seawater (oceanic Suess effect). In contrast, progressive addition of early marine inorganic aragonite toward the base of the altered coral produces an apparent ~25% decrease in skeletal density toward the present, which misleadingly matches the non-linear 20th century decrease in coral calcification predicted by recent modeling and experimental studies. In addition, the diagenetic aragonite is enriched in ¹³C, relative to coral aragonite, resulting in a non-linear decrease in ¹³C toward the present that mimics the decrease in ¹³C expected from the oceanic Suess effect. Taken together, these diagenetic changes in skeletal density and ¹³C could be misinterpreted to reflect changes in surface-ocean carbonate saturation state driven by the 20th century build-up of atmospheric CO₂.

Latitudinal Trends and Limits to Coral Reef Accretion: Effects of Temperature on Coral Growth*Daria SICILIANO**, *Donald C POTTS*, *James E MARAGOS*, *Christina A RAVELO*1156 High Street, Santa Cruz, CA 95064 United States of America
daria@biology.ucsc.edu

The subtropical, remote Northwest Hawaiian Islands archipelago (NWHI) spans 1750 km and 8° latitude, and provides a unique natural laboratory to investigate responses of reef-building corals to changes in sea-surface temperatures (SST) in the absence of confounding effects from direct anthropogenic activity. Knowledge of carbonate production in marginal, subtropical reef environments is critical for understanding controls on reef development and distribution globally, and for assessing the influences of global change (e.g. rising SST) on the health of coral reefs. Sixty coral colony and core samples (up to 55 cm in length) were collected during 2001-2003 throughout the NWHI at a variety of habitats and depths to compare annual growth rates across the archipelago and between various habitats. We examined seasonal and annual variations in skeletal density from X-radiographs of coral slabs, and used ¹⁸O isotope measurements to assess the effect of latitudinal variations in SST on coral growth rates. We also looked for temporal trends in growth rates and ¹⁸O thermometry from coral cores, recording variations in SST from the mid 1900s to the present. The observed spatial trend in coral growth rates indicates strong inter-habitat variability: a decrease in growth rates with latitude is observed only in samples from exposed habitats. Temporal trends from isotopic analyses coupled with changes in skeletal extension rates in selected samples from oceanic environments suggest an increase in growth rates related to an increase in SST over the past several decades. The results are discussed in the context of factors controlling carbonate production, reef development and distribution on regional (NWHI) and global scales, and the response of reefs to global climate change.

Coral Reef Calcification in Response to Increased Atmospheric CO₂ : Lessons from *in-situ* Measurements on a High Latitude Reef, Northern Red Sea*Jacob SILVEMAN**, *Boaz LAZAR*, *Jonatan EREZ*Faculty of Natural Sciences, Edmond Safra Campus, Givat-Ram, Jerusalem, Israel, 91904 State of Israel
jacobs@vms.huji.ac.il

Laboratory studies have demonstrated the negative impact of increased atmospheric pCO₂ on coral reef calcification. In this study we report on changes in community calcification (G) during a two-year study (3/2000-3/2002) on a coral reef in the Northern Gulf of Eilat, Red-Sea (30°N). During this period diurnal cycle studies were carried out on a monthly basis and G was assessed as a function of depletion of total alkalinity and rate of water exchange between the reef and the open sea. Diurnal average G varied annually between 70 and 31 mmole C m⁻²day⁻¹, where G was on average higher by a factor of 2 during summer than during the winter. There appears to be a significant positive correlation between G and diurnal average temperature in the reef (R² = 0.74, n=17). However most of this dependence is probably caused by temperature related changes in σ_{org} in an open system (R² G to σ_{org} = 0.87). Under high nutrient conditions, caused by deep winter mixing, G is further suppressed by ~40-50% and thus de-couples the dependence of G on σ_{org} and temperature. Based on the observed relation between G and σ_{org} under low nutrient conditions (R² = 0.98, n = 11) it is possible to extract future changes in G as a function of SST and atmospheric pCO₂. Global warming associated with atmospheric CO₂ increase will have a moderating effect on σ_{org} . Nonetheless, even if we assume a 2 ° C increase in SST for pCO₂ doubling (560 ppm) there is an expected 80% decrease in community calcification relative to extrapolated G at pre-industrial pCO₂.

Formation Process of the Carbonate System through Biological and Physical Factors in a Subtropical Coral-Seagrass Dominated Ecosystem

*Atsushi WATANABE**, Hajime KAYANNE, Tatsuki TOKORO, Hitoshi TAMURA, Kazuo NADAOKA

7-3-1 Hongo, Bunkyo, Tokyo Japan
atsushi.watanabe@eps.s.u-tokyo.ac.jp

Formation process of the seawater carbonate system and the biological community metabolisms (photosynthesis and calcification) estimated from it have been studied using simple physical conditions such as "slack-water period" or "flow- respirometry method". However, such simple conditions are rarely met in coral reefs, and it has not been clearly demonstrated how mixture of seawater and freshwater and/or mixture of communities (corals, seagrass etc) would be projected on an alkalinity (TA) - dissolved inorganic carbon (DIC) diagram, and how we can compare diagrams obtained from different physical conditions and sites. Our study therefore aims at revealing the formation process of the seawater carbonate system and the associated community metabolisms in a subtropical reef environment where seagrasses and corals co-dominate, with measurements of the carbonate system (TA, DIC, PCO_2) and physical (velocity, salinity, and temperature) parameters. Surveys conducted at Fukido (Ishigaki Island, Okinawa) for three periods (twice in summer and once in winter) showed no significant differences in the carbonate system formation between the seagrass meadow and reef flat. Judging from the physical parameters, the carbonate system could be formed from the residence time of seawater as well as the community metabolisms. Normalizing by the residence time, TA- DIC diagrams clearly illustrated the community metabolisms with their magnitudes and ratio. The calculated metabolic rates were about the mean value of those reported separately for reef flats and seagrass meadows: gross production and respiration 440 mmol/m²/d, and calcification 70 mmol/m²/d. Higher seawater temperature enhanced the respiration by 10% comparing the two summer results, and the winter metabolic rates were slowed down by 40% those of the summers. This study demonstrated that the combination of the measurements of the carbonate system and physical parameters enabled us to estimate the community metabolisms in much wider reef environments than before.

South Florida Coral-Reef Sediment Dissolution in Response to Elevated CO_2

*Robert B HALLEY**, Kimberley K YATES, John C BROCK

USGS, 600 4th St. S., St. Petersburg, FL 33701 United States of America
rhalley@usgs.gov

Here we report the results of *in situ* elevated CO_2 experiments on "live" reef sand between patch reefs in Biscayne National Park. These aragonitic sands begin to dissolve at night as respiratory CO_2 induces slight changes in seawater characterized by a pH of 8.2, pCO_2 of 325 μ atm, and aragonite saturation index of 3.9. Two experiments used artificial additions of CO_2 to increase pCO_2 to 800 and 1000 μ atm respectively, and decrease pH and carbonate saturation. But within 24 hours, these induced changes begin to revert to lower pCO_2 , increased pH, and elevated carbonate saturation. These changes are accompanied by the accumulation of alkalinity in the overlying seawater, indicating that they are the result of carbonate dissolution in a medium normally considered supersaturated with respect to carbonate minerals. After 48 hours, pCO_2 was reduced by approximately 15% in both experiments compared to expected (modeled) values without dissolution. Concurrently, pH increased by about 0.07 pH units and the aragonite saturation index increased by 0.3. Although saturation state is routinely used as a proxy for dissolution and precipitation, it may not be appropriate for understanding dissolution in the complex environment of coral reefs. Dissolution, in seawater supersaturated with $CaCO_3$ minerals, may result from highly soluble magnesian calcite, extremely small particle sizes, biological dissolution, and recrystallization. The experiments suggest that carbonate reef sediments should not be considered as metastable, largely inert sediments immersed in supersaturated solutions. Rather, they are in dynamic dissolution/precipitation disequilibrium, continually reacting in response to subtle changes in the seawater chemistry. The effective solubility of *in situ* shallow-water carbonate sediment is initially greater than that of sediments removed to the laboratory. Changes in pCO_2 affect both dissolution and calcification and are biologically mediated through processes that are not yet well characterized.

Coral Rubble Primary Production in Kaneohe Bay and in Controlled Mesocosms (Biosphere 2 Center): Impact of Eutrophication and Increasing pCO_2 with Special Reference to the Boring Micro-flora, its Role and Significance

*Aline D TRIBOLLET**, Christopher LANGDON

HIMB Coconut Island PO BOX 1346 46-007 Lilipuna Rd 96744 Kaneohe, HI United States of America
at2137@columbia.edu

Increasingly coral reefs are threatened by various environmental factors such as eutrophication, rising pCO_2 and sedimentation. These factors are contributing to rising rates of coral mortality. Thus, dead coral substrata for colonization by epilithic and endolithic organisms and grazers are increasing. The dominance of soft algae and bioerosion exceeding bioaccretion in disturbed reefs may ultimately lead to physical loss of reefs. Here, we studied *in situ* the effects of eutrophication on primary production and bioerosion processes of coral rubble communities composed by epiliths (turf algae, encrusting calcareous algae, bivalves, etc) and endoliths (micro-flora, polychaetes) at three sites experiencing different levels of terrigenous inputs at Kaneohe Bay (Hawaii). Coral rubbles were experimental blocks cut from dead heads of *Porites lobata* and were exposed six months to colonization. The effects of eutrophication and increasing pCO_2 on the same processes in the same dead substrata were also investigated in tanks under controlled conditions at Biosphere 2 Center during three months. Chambers incubation, chl a extraction and image analyzes were used to quantify net production and bioerosion rates, and the participation of the boring micro-flora in both processes. Differences between sites at Kaneohe Bay were significant with a highest net production at the offshore site than at inshore and mid sites. Net production rates were dominated by the endoliths (>60 %). Under controlled conditions, net production rates were highest in tanks held under high nutrients and high pCO_2 followed by high nutrients and low pCO_2 and lowest in tanks held under low nutrients and low pCO_2 . Endoliths were responsible of 25% of the primary production in eutrophic tanks because of the explosion of turf algae growth. We conclude that eutrophication and elevated CO_2 both have a significant impact on the composition and metabolic activity of the community colonizing coral rubbles.

How Does Carbonate System of Coral Reef Respond to Global Environmental Change?

*Tamotsu OOMORI**, Yukio KITADA, Hiroyuki FUJIMURA, Ryuko TOKESHI, Mutsumi MORI

1-Nishihara, Okinawa 903-0213 Japan
oomori@sci.u-ryukyu.ac.jp

Coral reef is a typical ecosystem with high organic and inorganic carbon productions in tropical-subtropical marine environments. In order to understand how the carbonate system of coral reef responds to global environmental change, systematical observation on carbonate system has been carried out at Sesoko-jima (Okinawa) through recording parameters such as pH, DO, salinity and temperature in every 15 minutes, and measuring precisely alkalinity, TCO_2 , pH and DO in every month, as well as PCO_2 and air-sea CO_2 flux in every seasons, for 3 years. Time-series observation of carbonate system in coral reef have showed clearly the diurnal, monthly and seasonal variation of organic and inorganic carbon production, PCO_2 in seawater and air-sea CO_2 flux. Relatively high CO_2 exchange rate was obtained. Isotopic distribution of $\delta C-13$ and $\delta C-14$ along the growth band of sclerosponge carbonate skeleton revealed the intensive subduction of anthropogenic carbon dioxide into surface seawater particularly after 1950's. Dynamic relation of carbonate system in coral reef to global environmental change during several decades will be discussed.

Human Impacts on Lakshadweep Atolls, India

*R. JEYABASKARAN**

Dona Paula, Goa - 403 004 Republic of India

jeybas@hotmail.com

The Lakshadweep (Laccadive) islands are situated in the Arabian Sea about 225 to 450 km from the southwest coast of India. There are 27 islands in Lakshadweep covering total land area of 28.54 km². Of which, 11 islands are inhabited and have a land area of 26.89 km², while the 16 uninhabited islets are 1.65 km². Most of the islands are located within the 12 atolls. These islands are the most densely populated islands in India with more than 60,000 people living on 28 km² of land. The annual rainfall is about 1600 mm, the sole source of ground water recharge in these islands. There are about 660150 trees in all the islands harvests about 28 million coconuts per year. There are about 6200 fishermen engaged in fishing using 900 boats. These islands situated 1 to 2 meters above mean sea level has a very thin lens of fresh water floating over the seawater. Almost all fresh water sources are contaminated due to seawater intrusion. The drinking water wells contain excessive nitrate concentration originating from septic tanks, other human wastes and fertilizers used in garden. All drinking water sources show positive bacterial (faecal coliform) count exceeding the normal level. Increasing population pressure (2600 people / km²) leading to the accumulation of more diseases in corals. The newly emerging disease Red Plague Syndrome is spreading very fast in these islands. The anthropogenic impacts on coral reefs are discussed in the paper in detail.

The Relationship between the Prehistoric Fishing Activity and the Coral Reefs Diversity in Ryukyu Islands

*Yayoi NAJIMA**

2-3-1-304 Deiki Kanazawa-ku Yokohama Kanagawa, Japan

naji@d4.dion.ne.jp

The people living in Ryukyu Islands have done fishing on coral reefs. From archaeological research, they have caught reef fish since 6000-5000yBP and the methods were angling, spearing, and netting. However we do not know the relationship between the prehistoric fishing activity and the geomorphological diversity of fishing ground. Then to clarify the relationship, the author analyzed fish remains assemblage from archaeological sites and compared the result with the study of the geomorphological change. By statistical analysis of the fish remains assemblage (%MNI) of 30 archaeological sites from 6000yBP to 1000yBP in each site, I divided three patterns (A, B, C). Pattern A is Scaridae is the main fish and the others few. Pattern B is Labridae or Lethrinus is the main fish and the others are few. Pattern C contains various fishes equally. From 6000yBP to 3500yBP there is obvious change from pattern A to C, but after 3500yBP minor change. The period of obvious change corresponds to the period of the most remarkable reef development. About geographical distribution of those patterns, it is clear that pattern C distributed only in northern area of Amami Island. Reefs of the area are so narrow that most of them have no lagoon. So there are few points for net fishing called "oikomi" to get fishes coming into lagoon (the main is Scaridae). This is a particular character of the area. Now I should consider the relationship between the patterns and coral reefs diversity more concretely, through analysis of fishing gears, shells, and the other animal remains, and reference to local knowledge concerned with fishing.

Suitable Conditions for Prehistoric Human Settlement on Pacific Atolls - Archaeological and Geomorphological Investigations on an Islet of Majuro, the Marshall Islands -

*Toru YAMAGUCHI**, Masashi CHIKAMORI, Hajime KAYANE, Hiroya YAMANO, Hiromune YOKOKI, Yayoi NAJIMA

2-15-45 Mita, Minato, Tokyo 108-8345 Japan

toru38@flet.keio.ac.jp

In the trade wind zone are scattered a number of coral atolls, the most precarious landforms in the central Pacific realm. Their islets (*motu*) of foraminifera sand and coral shingle accumulated on reef flats are often no more than 2 - 3 meters in elevation and a few hundred meters wide. There is also no running surface water and are some atolls frequently suffering from droughts. The recent archaeological studies of the Marshall Islands in the Eastern Micronesia have revealed that, even in such a severe atoll environment, the prehistoric human settlements were back to ca. 2000 years ago, just after the period of late Holocene reef emergence. It does not mean, however, that all islets in the same atoll were settled at once. The present variety of islets in size and shape indicates there is the diversity of geomorphological conditions, which should be associated with the establishment and continuity of prehistoric human occupation on an islet. The islet of Laura in Majuro Atoll, the Marshall Islands, provides us with the information on its deposits and groundwater lens as well as our archaeological one. Focusing on this islet, the suitable conditions for early prehistoric settlements in the atoll environment will be discussed. This investigation would be also to locate the starting point of consequent interaction between physical and human agencies that constructed the present landscape.

Numerical Calculations of Wave Transformations in the Lagoon of Majuro Atoll, Marshall Islands for Estimating the Natural Topographic Change Processes due to Waves and Currents

*Hiromune YOKOKI**, Hiroya YAMANO, Hajime KAYANNE, Daisaku SATO, Yosuke MINAMI

4-12-1 Nakanarusawa, Hitachi, Ibaraki, 316-8511 Japan

yokoki@mx.ibaraki.ac.jp

Topographic changes in Majuro Atoll, Marshall Islands, are caused by various natural and artificial processes, for example, sediment transport induced by waves and currents, sediment supply from coral reefs, and the existence of construction structures along shoreline. In the present paper, numerical calculations of the wave transformations in the lagoon of Majuro are carried out, and the wave energy fluxes, which are the potentials of alongshore sediment transports, are also estimated, in order to distinguish the topographic changes due to waves and currents from that due to others. To verify the calculation results, these are compared with the bottom velocity data along the shoreline in the lagoon side, which were obtained by the field survey carried out in Majuro in September 2003. The contribution of waves and currents to topographic changes in Majuro are estimated by comparison with the process of past topographic change, which is, for example, obtained by satellite images.

Geomorphological and Ecological Interactions between Atoll Islands and Coral Reefs

*Hajime KAYANNE**, *Shoji YAMAMOTO*, *Hiroya YAMANO*, *Hiromune YOKOKI*, *Silvia PINCA*, *Toru YAMAGUCHI*, *Masashi CHIKAMORI*

Hongo, Toko 113-0033 Japan

kayanne@eps.s.u-tokyo.ac.jp

Atoll islands, low-flatted land with a maximum altitude of several meters, are under the threats of sea level rise and local environmental stress. Their formation is determined not only by physical but also by biological processes. Coral reefs offshore the islands form a natural breakwater and provide bioclastic materials as sand to the islands. Not much study has been conducted in their interaction. In Majuro Atolls in the Marshall Islands, coral reef flat was formed by 3500 yrs B.P., which served as the foundation for atoll islands. The islands have been formed at least 1500 yrs B.P. Formation process has been governed by storm derived coral debris in their seaward edge and longshore current and regular sedimentation in their landward part. Human settlement initiated just after the formation of the islands resulting in soil formation. Maintenance of vegetation by inhabitants also contributes to formation and maintenance process of the islands. Modernization and urbanization of atoll islands leads to degradation of coral reefs and collapse of vegetation maintenance process in recent years. For sustainable utilization and development of atoll islands, it is fundamental to evaluate the interaction between natural and human processes and to establish diagnosis procedure of the present states and future response of atoll islands to environmental changes. In this mini-symposium, we would like to discuss further into formation and maintenance processes of atoll islands in relation to geology, physical oceanography and biology; vegetation history; settlement history; resources evaluation; and land-human interactions. Based on the interdisciplinary discussion, we will propose their appropriate adaptation strategy against global changes.

Are Coral Reefs on the Slippery Slope to Slime?

*Jeremy B C JACKSON**, John M PANDOLFI, Nancy BARON, Roger H BRADBURY, Hector M GUZMAN, Terence P HUGHES, Carrie V KAPPEL, Fiorenza MICHELLI, John C OGDEN, Hugh P POSSINGHAM, Enric SALA
University of California, San Diego, La Jolla, California 92093-0244 United States of America
jbcj@ucsd.edu

Everywhere coral reefs are in decline but there is no clear policy for reversing this trend. The history of coral reefs tells us three new things that challenge business as usual. First, we should stop arguing about the relative importance of different causes of coral reef decline: overfishing, pollution, disease, and climate change. Instead we must simultaneously reduce all threats to have any hope of reversing the decline. Second, the scale of management of coral reefs has been too small. Reefs must be managed as entire ecosystems. Third, an impediment to progress has been a lack of clear goals. Historical ecology reveals a common trajectory of reef degradation and provides a way to assess the success or failure of management for recovery. This leads us to a new goal of reversing the decline. For too long, single actions - monitoring, making a plan, reducing fishing, reducing sources of pollution, or conserving a percentage of the system - were viewed as goals. In contrast, history tells us that the goal is to reverse the trajectory of decline regardless of the current state of degradation, and actions are just ways of achieving this goal. Historical ecology does not demand a return to a Garden of Eden or any other particular ecosystem state. Nor is it likely that the path of recovery will retrace the exact path of decline: the community of species will not reassemble in the same way that they fell apart. But it is not too late for key components of reef ecosystems to return, such as large grazers upon algae, mature forest-like stands of corals, and a diverse suite of large predators that maintain the food web in a more stable state. This sequential return of all the functional components is what actually constitutes success.

Targets and Tactics for Reversing Unsustainable Resource Use on the Semporna Island Reefs, Sabah, Malaysia

*Elizabeth M WOOD**, Muhammad S SULIANSIA, Irwanshah B MUSTAPA
Hollybush, Chequers Lane, Eversley, Hook, Hants RG 27 0NY United Kingdom of Great Britain and Northern Ireland
ewood@globalnet.co.uk

A survey and monitoring programme for the Semporna Island reefs shows high habitat and species diversity but low abundance of food fish such as snappers, sweetlips, emperors and groupers. For example, no large groupers have been recorded, and the density of *Cephalopholis* and small serranids is less than 2 per 100m². The population density of edible invertebrates is also low, and the largest species of giant clam (*Tridacna gigas*) has been made locally extinct. Heavy pressure combined with habitat destruction caused by fish blasting means that resource use is unsustainable if it continues at the existing level, using the same techniques. There are three main user groups for reef resources a) the local island communities, b) fishermen who come to the area from the mainland or neighbouring islands and c) nomadic Bajau Laut (sea gypsies). The traditional sea-faring lifestyle of the Bajau Laut means that they rely particularly heavily on marine produce both for their own consumption and to sell or barter for staples such as rice. Income of fishers is generally at or below the poverty level and they currently have few opportunities to diversify. The management aims for the Semporna area are to safeguard livelihoods, promote reef recovery and ensure sustainable use of marine resources. The strategy that has been adopted is first to reduce direct use of reef species by providing user-groups with alternative livelihoods, and then gradually to establish no-take zones, so that populations of fish and other heavily exploited species can recover. The alternative livelihoods currently being developed are culture and ranching of invertebrates such as giant clams, sea-cucumbers, abalone and top-shells. This paper describes progress, problems and prospects of success of this strategy.

Towards the Use of Size Spectra Analysis for Ecosystem Fisheries Management on Coral Reefs

*Nicholas A J GRAHAM**, Nicholas K DULVY, Aileen C MILL, Simon JENNINGS, Nicholas Vc POLUNIN
School of Marine Science & Technology, Ridley Building, University of Newcastle, Newcastle-upon-Tyne, NE1 7RU, UK United Kingdom of Great Britain and Northern Ireland
n.a.j.graham@ncl.ac.uk

Indicators of fishing impacts are needed to underpin the ecosystem approach to fisheries management (EAFM). However, the data requirements and resources needed to develop indicators are often lacking, particularly for coral reef fisheries. Size spectra, relationships between log-transformed abundance by body-size class and body size, can be calculated from simple size-abundance data and may provide a useful indicator of fishing effects on reef fish communities. Both the slope and the mid-point height of the relationship can be compared at different fishing intensities. We test the use of size spectra for assessing fishing effects on reef fish communities across a gradient of fishing pressure, based on body size- abundance data collected by underwater visual census from ten fishing grounds across a gradient of fishing intensity in the Kadavu Island group (selected families), and thirteen grounds in the Lau Island group (all non-cryptic families), Fiji. In both cases slopes of the size spectra became steeper (Kadavu; $F_{9,99} = 3.20$, $p < 0.01$; Lau; $F_{1,11} = 5.0$, $p < 0.05$) and height declined, though not significantly at Lau (Kadavu; $F_{9,99} = 15.78$, $p < 0.001$; Lau; $F_{1,11} = 1.5$, $p = 0.25$), with increasing fishing intensity. Regressions of numbers of individuals per size class across grounds were negative for all size classes in Kadavu, whereas release of smaller fish in the community was detected in Lau. Response to exploitation of size category mid-points demonstrated greatest responses for larger sized fish. Steepening of the slope with increasing fishing intensity largely resulted from reductions in the relative abundance of large fish and, in Lau, limited ecological release of small fish following depletion of their predators. The slope and height of the size-spectrum appear to be a good indicator of fishing effects on reef fish communities. Further development of this technique may prove useful in identifying reference points for an EAFM on coral reefs.

Universal Minimum Size Limits for Managing Trade in an Entire Genus of Fishes Listed on CITES Appendix II

*Sarah J FOSTER, Amanda C J VINCENT, Mary CASHMAN**
2204 Main Mall, Vancouver, BC, V6T 1Z4 Canada
s.foster@fisheries.ubc.ca

Creative approaches are needed when managing fisheries that are very data poor, particularly when conservation concern has arisen. Seahorse fisheries for traditional medicines, ornamental display and curiosities remain largely unstudied, despite marked population declines. Nonetheless, the international trade in seahorses came under international management in May 2004. In a landmark decision, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) added all seahorses (at least 33 species) to Appendix II, requiring the 164 signatory Parties to regulate their international trade in a precautionary manner. The global community must now find means to manage these data poor fisheries such that their trade does not become detrimental to wild populations. Any management measures will need to be easily implemented by Customs officers and enforcement agencies faced with multispecies shipments, with difficult taxonomy. As an interim means of moving towards this goal, we propose that a universal minimum size limit of 10 cm height might be applied to trade in all seahorse species. This single size limit should serve to reduce the probability of recruitment overfishing in most species, as it lies above their height at maturity but below their maximum height. The smaller species, with maximum heights below 10 cm, are seldom traded. As further knowledge becomes available, Parties could adjust this proposed limit through adaptive management, or adopt new means of making the non-detriment findings required by CITES.

Where Have All the Groupers Gone? The Philippine Fishing Experience

*Samuel S MAMAUAG**, Cleto L NANOLA, Porfirio M ALINO

Velasquez St., University of the Philippines, Diliman, Quezon City 1101
Republic of the Philippines
smamaug@upmsi.ph

The Philippines is the hottest of the hotspots among the reefs in the world especially in its prevalence and degree of overfishing. Suggestions of fishing down the food chain have been reported worldwide and yet reef fisheries impact on top reef predators have not been well investigated. Based on the underwater fish visual census estimates, six grouper species *Plectropomus leopardus*, *Cephalopis cynostigma*, *C. boenak*, *C. argus*, *C. urodeta* and *Epinephelus fasciatus* were assessed. Their size distribution, abundance in densities per 500 square meters, and overall biomass per area were analyzed in the six biogeographic regions of the Philippines. *P. leopardus* had the lowest abundance while *C. urodeta* and *C. argus* had the highest abundance. These suggest that the larger apex predator such as *P. leopardus* have already been extirpated in many areas with some sites (e.g. Bolinao in Lingayen Gulf) having no records of size reaching sexual maturity (not greater 20 cm TL). The level of regulation of fishing pressure suggests that *C. urodeta* and *C. argus* can attain larger sizes in the Marine Protected Areas (MPAs) such as in Tubataba, Cauayan, Negros Occidental and El Nido, Palawan. Aside from the level of fishing pressure, other patterns of distribution were confounded by the habitat preferences of the species (i.e. *C. boenak* and *E. fasciatus* are associated to reef type and depth) and their biogeographic location range. These findings suggest that bigger no-take areas need to be established in grouper spawning aggregation sites (e.g. in Northern Palawan and the Surigao Strait marine corridors) since there are still records of high abundance despite the high fishing pressure.

Demographic and Life History Characteristics of a Large Serranid, *Epinephelus fuscoguttatus*, from the Great Barrier Reef and the Implications for Sustainable Harvest Limits and Size Regulations

*Rachel J PEARS**, J Howard CHOAT, Bruce D MAPSTONE, Gavin A BEGG

Townsville, QLD 4811 Australia
rachel.pears@jcu.edu.au

This paper presents new biological information on a large exploited serranid, synthesizes ecological and life history characteristics for the species and examines the applicability of this information to establishing sustainable harvest limits and size regulations. We investigated age-specific demographic and reproductive variables of *Epinephelus fuscoguttatus* from the Great Barrier Reef and then synthesized available information to provide a biological summary for the species. Age determination using sectioned sagittae allowed us to estimate growth rate, longevity, and the relationship between age and female sexual maturity and between age and the recruitment of males into the study population. The material examined was obtained primarily from the commercial fishery on the central GBR. Validation using both tetracycline marking and marginal increment analysis demonstrated that a single annulus formed each year. The maximum age recorded was 42 years, with mean age of the oldest 10% of the population 36 ± 0.2 , suggesting that this species can be long-lived. Most growth was achieved early in the life span with the growth trajectory approaching an asymptote after 15 years. Females ranged from 320 to 855 mm FL and from 2 to 42 years (n=184). Males ranged from 683 to 925 mm FL and from 11 to 40 years (n=28). The size and age distribution strongly suggested protogynous hermaphroditism in this species. The presence of old females suggests that only a proportion of females transform to males. The case of the reef line fishery on the GBR is used to evaluate the applicability of the biological information to management of large serranids such as *Epinephelus fuscoguttatus*. The relatively long lifespan and the possibility that older members of the population remain female and contribute disproportionately to reproduction have important implications for the sustainability of the fishery for this species, including the suitability of current size regulations.

Harvesting a Caribbean Gorgonian: An Interim Assessment of Procedures, Effects and Sustainability

*Howard R LASKER**

Dept. of Biological Sci, 635 Hochstetter Hall, University at Buffalo, Buffalo, NY 14260
hlasker@buffalo.edu

The Caribbean gorgonian *Pseudopterogorgia elisabethae* contains natural products with anti-inflammatory properties and is harvested in the Bahamas for those compounds. Harvesting is conducted by cropping colonies, leaving an approximately 10 cm central branch and associated side branches. Areas are reharvested after 2-3 years of recovery. The harvest is limited by the combined effects of an export quota established by the Bahamas Dept. of Fisheries, a limited number of trained collectors, product demand, seasonal regulatory restrictions on the use of scuba and surface supplied air for collecting, seasonally adverse weather conditions and competing fisheries that are at times more profitable to the collectors. A formal assessment of the effects of the harvest has not been conducted. Collectors have been able to profitably collect from some sites up to three times, and yield per unit collecting effort has been relatively stable during the last three years of collecting. Factors controlling long-term sustainability include the survival and growth of cropped colonies and the effects of harvesting on recruitment rates. Colony growth models and field experiments have shown how different harvest regimes affect regrowth and the yield of individual colonies. Those individual models can be integrated into population scale models that predict the effects of harvesting on population growth and survival. The scale of larval dispersal and the effects of the harvest regime on colony fecundity will also affect recruitment and the long-term maintenance of local populations.

Sea Cucumber Fisheries: Assessing Resource Status for Better Management in the Tropical Pacific

*Kim J FRIEDMAN**, Tim SKEWES, Mecki KRONEN

BP D5 - 98848 NOUMEA CEDEX, New-Caledonia
kimf@spc.int

Despite being active for over two centuries, sea cucumber fisheries in the tropical Pacific are not well documented or understood. Heavy fishing pressure has depleted stocks of valuable species and places a greater need for management based on reliable stock estimates. However, visual surveys of sea cucumbers generate estimates of stock size and structure with varied effectiveness. The precision of assessments can be improved markedly when the multispecies nature of stocks, their low density, spatial aggregation and habitat specificity is accounted for in survey design. In addition, socio-economic assessments of these fisheries can provide a complimentary understanding to the instantaneous evaluation of stock size supplied by in-water surveys. Socio-economic assessments of the actual level of resource exploitation take account of variations in the commercial structure of these fisheries, and the presence, absence and/or fluctuations in regulations, marketing, and prices. Research agencies in Australia and the Pacific Islands have developed various approaches to assess the status of sea cucumber fisheries through resource and socio-economic assessment on a number of spatial scales, using tested and novel survey techniques. These approaches are compared and contrasted within the current understanding of sea cucumber stocks, to identify practical and reliable strategies for assessing these fisheries, and to build a framework for integrating current knowledge into advanced assessment techniques.

Predicting Social Resilience within the Great Barrier Reef's Commercial Fishing Industry

*Nadine A MARSHALL**

School of Tropical Environment Studies and Geography, James Cook University, Townsville 4811 Australia
nadine.marshall@jcu.edu.au

Changes in legislation are a common management approach to protect our natural resources. However, these changes may have a significant social impact on resource-dependent communities. This study aims to provide a better understanding of how resource-dependent people respond to change in resource policy, with particular reference to the commercial-fishing industry in Queensland. This paper specifically sets out to identify the mechanisms by which fishers in Queensland respond to changes in fisheries policy, and in particular, to identify which factors significantly influence the ability of these people to be resilient. This study has adopted a combination of qualitative and quantitative social science research methods. One-hundred fishing families in 5 coastal communities in northern Queensland were interviewed for 2-3 hours and were asked to complete a structured survey of 220 questions relating to their business, their background, their family, their relationship with fisheries managers and the fisheries resource, and their community. A response rate of 100% was achieved. Results show that the level of dependency on the fisheries resource, the way policies are interpreted and certain personal and family characteristics are important in determining how resilient a fishing family might be to a change in fisheries policy that affects their use of, or access to, the fisheries resource. Qualitative data was used to assist in the interpretation of the quantitative analysis. The management implications of these results include that understanding people's practices, values, beliefs and circumstances are more likely to develop into acceptable, successful and less disruptive policies. This study illustrates how developing management strategies to effectively maximize conservation goals can be achieved whilst minimizing social impact

Towards a System Where Coral Reef and Humans Co-exist: Involving Local Community in Coral Reef Monitoring and Research for Management

*Vineeta HOON**

160 Sivananda Road, Gillnagar Ext 2 Choolaimedu, Chennai 600 094 Republic of India
vhoon@vsnl.com

For Coral Reef Management and monitoring programs to have long-term sustainability it is necessary to involve the Indigenous community and make them feel a sense of ownership of the program. The local communities especially the indigenous people, fishermen, reef gleaners who are dependent on the coral reef resources for their survival, income are stakeholders, best geared for managing and monitoring reef resources because of their immediate presence and intimate knowledge of the area. This paper presents key learnings from two on going projects to assess the human dependency on coral reef resources and monitoring of reef related activities, in the Lakshadweep Islands, India. Taking the examples of Agatti Island and Minicoy Island we see how stakeholder clout can change with time. The paper discusses the process building procedure for involving the various stakeholders and building their capacity from data gatherers and providers to analyzers and action takers. The aim is to help in the creation of a new generation of islanders who will grow up conscious of the possibilities and limitations of the island environment. They will in future be part of evolving a viable, sustainable, survival strategy for the islands and themselves.

Attributing Importance to Key Features of Coral Reefs that Contribute to High-quality Environmental Experiences for Live-Aboard SCUBA Divers: Towards Sustainable Use and Management of Important Coral Reef Resources

Dean K MILLER, R Alastair BIRTLES, Peter S VALENTINE*

Office T0 003 Tourism Program, Western Campus, James Cook University, Townsville, QLD 4811, Australia.
dean.miller@jcu.edu.au

Recent conflicts between users of coral reef resources have arisen due to extractive industries collecting in areas also used by tourism. SCUBA diving tourism is growing worldwide, and is economically important to reef-based communities. Maintaining the environmental quality of coral reefs for the attraction of visitors and the experiences they receive is paramount. If features of dive sites significant to divers experiences are removed, the overall value of the dive experience is decreased. Such impacts might cause a downward shift in the demand and visitation to a site. Little research has been done to assess the social and economic value of viewing wildlife for SCUBA divers. This project investigates the diversity of species that exist on dive sites important to tourism through biological audits of coral reef resources. Key coral reef features contributing to environmental experiences for SCUBA divers are also examined. This is achieved through on-site self-administered questionnaires exploring expectations before, and perceptions after the diving experience. Over 400 SCUBA divers visiting the Great Barrier Reef and Coral Sea on live-aboard dive boat operations have been surveyed. This paper investigates how the expectations, importance, and enjoyment of coral reef features contribute to high-quality dive experiences. These features can be monitored and used as indicators of change in the environmental quality of dive sites as they are of highest importance to dive tourists. These research findings will contribute to the sustainable management of coral reef resources for dive tourism both locally and in other areas. Key Words: Sustainability, live-aboard SCUBA diving, coral reefs, key features, management.

Status of Reef and Lagoon Resources in the South Pacific - The Influence of Socioeconomic Factors

Mecki KRONEN, Kim FRIEDMANN, Eric CLUA, Samasoni SAUNI, Laurent VIGLIOLA, Franck MAGRON, Pierre LABROSSE, Jocelyne FERRARIS, Michel KULBICKI, Gerard MOUTHAM*

B.P. D5, 98848 Noumea Cedex New Caledonia
meckik@spc.int

Fishing pressure is one of the most important factors that determine status of marine resources. However, in the South Pacific, exploitation levels vary substantially according to fishing strategies, and these vary due to differences in socioeconomic characteristics amongst fishing communities. Thus, the better understanding of the interplay between intrinsic socio-cultural and external market economy is believed to be crucial for the development of successful management strategies. We have developed an integrated approach that combines socioeconomic, anthropological and ecological arguments to better understand which factors, the role they play and which interactions are decisive in the choice of target species, and exploitation level. We have selected examples for fin-fisheries and invertebrate fisheries from four island countries and territories in the South Pacific. Questionnaire-based socio-economic and underwater resource assessment for fin-fish (SCUBA) and invertebrates were conducted in 4-6 coastal communities each for Fiji, Tonga, Vanuatu and New Caledonia. The importance and the effects of major socioeconomic determinants are highlighted and evaluated against complementary marine resource data collected in the fishing grounds of each community concerned. Our analysis takes into account intrinsic (demography, religion, socio-cultural) and external factors (marketing, prices, urbanization), and their interfaces.

Molecular Phylogeography and Systematics of the Scleractinian Genus *Pocillopora*

*Jean-Francois FLOT**, *Simon TILLIER*

43 rue Cuvier, 75005 Paris French Republic
jfflot@mnhn.fr

Most taxonomical studies on corals have been hampered by the huge amount of morphological variation found among closely related individuals. The plasticity of corals in response to their environment makes it necessary for researchers to combine morphological data with other types of information that are supposedly not affected by environmental parameters, such as DNA sequences and chromosome organization. We present here the first results of a large-scale phylogeographical study on the keystone reef-building genus *Pocillopora*. Our project aims at combining molecular data from several nuclear and mitochondrial loci with cytological information such as chromosome numbers and shapes in order to test the species boundaries inferred from morphological observation in the genus *Pocillopora* and to obtain a phylogenetic tree of the revised species of this genus.

Geographic Differences in Species Boundaries among Members of the *Montastraea annularis* Complex Based on Molecular and Morphological Markers

*Nancy KNOWLTON**, *Hironobu FUKAMI*, *Ann F BUDD*, *Don R LEVITAN*

9500 Gilman Drive, La Jolla, California 92093-0202 United States of America
nknowlton@ucsd.edu

The three members of the *Montastraea annularis* complex (*M. annularis*, *M. franksi* and *M. faveolata*) are dominant reef-builders in the western Atlantic whose species status has been controversial for over a decade. We compare the three taxa genetically and morphologically in Panama and the Bahamas, widely separated locations spanning most of their geographic ranges. In Panama, analyses of three AFLP loci, a non-coding region of the mitochondrial genome, and ITS sequences reveal that *M. faveolata* is strongly differentiated genetically. Discriminant function analysis also indicates no overlap with the other two species in the fine structure of the corallites that comprise the colony. Genetic analyses of larvae from interspecific crosses between *M. faveolata* and the other two taxa confirmed the hybrid status of the larvae, but no examples of the most probable F1 genotype were observed in the field. Although *M. annularis* and *M. franksi* were more similar, they also exhibited strong frequency differences at two AFLP loci and in the mitochondrial non-coding region, as well as distinct corallite structure. In the Bahamas, in contrast, the three taxa exhibited overlapping morphologies. *Montastraea franksi* and *M. annularis* were indistinguishable genetically, and *M. faveolata* was distinct at fewer genetic loci. Once again, however, the most probable F1 genotype involving *M. faveolata* was not observed. Geographic differences between Panama and the Bahamas explain why past studies have come to different conclusions concerning the status of the three species. In general, the genetic and morphological data suggest a north to south hybridization gradient, with evidence for introgression strongest in the north. Reproductive data, however, show no such trend; at both sites *M. faveolata* is isolated by gametic compatibility, and *M. franksi* spawns approximately 90 minutes before the other two taxa.

Ecological Speciation in the Coral Genus *Favia*?

*David B CARLON**, *Ann F BUDD*

2538 McCarthy Mall, Honolulu, Hawaii 96822 United States of America
carlon@hawaii.edu

In the Bocas del Toro Archipelago of the Atlantic Coast of Panama, we found two morphotypes of the scleractinian coral *Favia fragum* with opposing depth distributions. One morphotype (Morph 1) fit the classical description of *Favia fragum* and was most abundant at 3 m depth. A second morphotype (Morph 2), was distinguished by raised corallites and was restricted to <1 m depth. The two morphotypes overlapped in distribution at 1 m depth. Multivariate analysis of polyp-level characters (shape and distribution of septa within corallites) divided samples into two groups corresponding to initial qualitative observations of colony shape and corallite relief. To determine if reduced gene flow maintains morphological variation, we measured the frequencies of alleles at five allozyme loci in both morphotypes at three sites 1-2 km distant. While there were significant differences in allele frequencies between the morphotypes within sites, there were also frequency differences between sites 1-2 km distant at most loci, with the exception of nearly fixed alleles at the *PGM* locus. Extremely low heterozygosity permitted us to use haplotypes to compare genetic distance between morphotypes and among sites. Comparisons between haplotype data and a null model assuming gene flow between morphotypes showed that: 1) the two morphotypes shared fewer haplotypes compared to the null model, and 2) average genetic distance between morphotypes was significantly greater than in the null model. Partitioning haplotype variation with AMOVA demonstrated that 35% of the variation was explained by morphotype, whereas 28% of the variation was explained by site. We consider three hypotheses for this morphological and genetic divergence in *F. fragum*: 1) intraspecific polymorphism, 2) biological species, 3) incipient species; and discuss the roles of ecological gradients and life-history traits in a divergence-with-gene flow model of speciation.

Environment-induced Skeletal Change in Transplanted Clones of *Favia speciosa* and *Diploastrea heliophora*

*Peter A TODD**, *Richard J LADLE*, *Nicholas J I LEWIN-KOH*, *Loke Ming CHOU*

School of Life Sciences, Napier University, 10 Colinton Rd, Edinburgh, EH10 5DT, UK. United Kingdom of Great Britain and Northern Ireland
p.todd@napier.ac.uk

Environment-dependent variation in the morphological, physiological, or behavioural expression of a genotype is termed phenotypic plasticity. The diverse and unpredictable reef environment makes adaptation difficult for the sessile marine organism, however, corals with plastic phenotypes may be able to adjust to different habitats within their life span. To test for small-scale morphological plasticity in the Indo-Pacific massive species *Favia speciosa* (Dana 1846) and *Diploastrea heliophora* (Lamarck 1816), fragments (clonemates) from twelve colonies of each species were reciprocally transplanted among six new habitats located within two environmental gradients: a depth cline, and a nearshore to offshore gradient in sedimentation rates and total suspended solids (TSS). After seven months, all fragments were collected, cleared of tissue, and ten morphometric characters extracted from randomly chosen corallites. Reaction norms based on character means were plotted for both species and describe environment-induced changes in corallite architecture. These changes, verified by analysis of variance, are more pronounced in the depth cline than along the sediment gradient. Responses for both species are identified by canonical discriminant analysis, although trends are much reduced for *D. heliophora*. Similarity of response is suggested by exploratory factor analysis where, for both species, size attributes dominate the first factor, antisymmetry the second, and corallite exertion the third. Highly significant genotype x environment interactions for *F. speciosa* indicate that, for this species, genotypes vary in the level of plasticity expressed. Light and TSS emerge as the primary factors influencing morphological change, although other parameters might act additively, synergistically or antagonistically with them. In shallow waters, increased corallite exertion may enhance light capture or, alternatively, protect the central (oral disc) area of each polyp from harmful UV radiation. Morphological variability, combined with environment-induced changes in pigmentation, could impede accurate identification of these taxa.

The Scleractinian Species - A Holistic ApproachVassil N ZLATARSKI*131 Fales Rd., Bristol, RI 02809 United States of America
vzlatarski@yahoo.com

What gives rise to the scleractinian species conundrum, and how might we simplify it? The widely recognized difficulty in defining the scleractinian species may be attributed to two factors: the objective nature of these elusive organisms, and the subjective impact of us as researchers. Because coral nature is, except within the narrow boundaries of certain controlled experiments, independent of our will, our only hope for developing a more objective concept lies in striving for improved researcher techniques and integration of molecular and morphological approaches. The present work identifies three areas in which our subjective impact may hinder resolution of the scleractinian species - nomenclature (N), ethics (E) and taxonomy (T) - and posits that shifts in these three paradigms will lead to more objective results. This focus on NET results requires introspection on the personal, inter-colleague and international associations levels. The International Code of Zoological Nomenclature offers a tool for regulating nomenclature procedures, but it has been troublingly ignored recently. Ethical issues require appeals to our conscience, recognition of the necessity of publishing following peer review by specialists and use of quality tests. Taxonomy can be facilitated by constantly updated species notions and a holistic approach. Present-day knowledge on extant and fossil Scleractinia suggests that eleven variables be taken into account in defining species: the three dimensions of physical space, time, variability, long generation times and propagation through fragmentation, synchronous multispecific spawning, hybridization, ocean currents, symbiosis and life in aquaria. The exceptional variability of Caribbean scleractinians, described on ten levels, is frequently neglected. Because Cuban reefs are a hotspot of biodiversity in the Atlantic, and because of the preservation in Cuba of the richest Caribbean collection, containing bimorphic colonies and morphological bridges, Cuban scleractinians play a key role in species definition. Ten suggestions for future strategies in scleractinian species taxonomy are offered.

Molecular Characterization of *Zoanthus* (Zoanthidae, Anthozoa) Morphotypes on Brazilian Coast Using 16S and COI Mitochondrial GenesLeila L LONGO*, M Cristina ARIAS, Erika SCHLENZ

Rua do Matao, 277, Cidade Universitaria, Sao Paulo, SP Federative Republic of Brazil

llongo@ib.usp.br

In the last decades molecular markers has been used on taxonomic research as a tool for detecting intra and interspecific variation. Cnidarian mitochondrial DNA presents some important peculiarities as it differs from other Metazoa on structure, genic order and contents. Zoanthids are colonial and sessile Cnidarians which have zooxanthellae symbionts. They are abundant along the Brazilian coast. This study presents the first results on genetic variability of *Zoanthus* (Zoanthidae, Anthozoa) on Brazilian coast using the 16S and COI mitochondrial genes. Samples were collected from Piaui to Rio de Janeiro States. Morphological analysis of 235 specimens has evidenced 12 morphotypes of *Zoanthus*. Samples corresponding to each morphotype were used on molecular study. DNA was extracted from the column, mesenteries, filaments and stolons using phenol/chloroform protocol. Heterologous primers were used for the amplification of mtDNA regions. The PCR products obtained were cloned and sequenced. For 16S gene we obtained a fragment of 740 bp for 9 of 12 morphotypes analysed. Comparing the sequences we observed two groups of similar morphotypes that differ from each other on four nucleotides substitutions (transitions). Only one morphotype was very divergent from both groups, showing 10 or 11 nucleotides substitutions (1 transversion and 9 or 10 transitions). This morphotype presented morphological differences contrasting the description of *Zoanthus sociatus* species, and was initially considered as intraspecific variation. Therefore, our molecular results indicated that they worth better attention as taxonomic value. For COI gene we obtained a fragment of 487 bp for two of 12 morphotypes analysed. The sequences did not differ from each other. Our results brought up new perspectives on 16S gene potential as a populational and taxonomic marker, however more investigations are needed on this approach.

Discovery, Cloning, and Analysis of Novel Fluorescent Proteins from Various Color Morphs of *Corynactis californica*Christine E SCHNITZLER*, Steven HADDOCK7700 Sandholdt Road Moss Landing, CA 95039 United States of America
christy@mbari.org

There are more than thirty characterized genes in the green fluorescent protein (GFP) family, nearly all from members of the Phylum Cnidaria, most from the Class Anthozoa, including many reef-building corals. It is not known how widespread in nature fluorescent proteins (FPs) from the GFP family are, mainly because their presence has not been examined in many organisms. It is also unclear what specific biological functions fluorescent proteins serve in nature: hypotheses range from photoprotection to advertising, but little direct experimentation has been done. Since the fluorophore of FPs forms autocatalytically, many downstream applications have been developed for these proteins as molecular probes and biomarkers. We have succeeded in cloning two novel FP genes (ccaRFP1 and ccaYFP1) from body wall tissue of one color morph of a local corallimorpharian, *Corynactis californica*. We are addressing the question of whether fluorescence emission differences between color morphs of this species are genetically determined or phenotypically plastic characters that are perhaps induced by an environmental cue. Reconstructing the evolutionary history and relationships of FP genes within the gene family is impeded by the lack of a strong phylogeny for many taxonomic groups with members that have FP genes, including the Order Corallimorpharia. Demonstrating the need for robust family and order-level phylogenies is important to help strengthen research into functional gene families such as the GFP family.

Molecular Phylogeny of the Octocorallia (Cnidaria: Anthozoa): A New Systematic Scheme for Higher Taxonomic CategoriesCarlos A SANCHEZ*, Katharina E FABRICIUS, Lesa PEPLow, Madeleine J H VAN OPPENCarretera al Sur, km 5.5., La Paz, Baja California Sur United Mexican States
csanchez@uabcs.mx

We present robust molecular phylogeny of Octocorallia at higher taxonomic levels (suborders and orders), based on mitochondrial DNA coding sequences (Cytochrome Oxidase subunit II and ATP subunits 6-8), and two intergenic regions from 95 species in 21 families. Our phylogenetic tree, based on Bayesian analyses, is incongruent with the current octocoral classification system. This phylogenetic reconstruction, complemented by results from previous molecular studies and considerations of morphological features, suggest the existence of six major Octocorallia clades, which fall into two main assemblages, namely the Alcyonacea and all non-Alcyonacean groups. The former assemblage consists of the clearly distinguished order Alcyonacea, however the relationships among its suborders remained unresolved. The latter assemblage contains the clades Pennatulacea-Ellisellidae, Calcaxonia, Helioporacea, *Paraminabea*-Paragorgiidae/Coralliidae, and Briareidae. Genetic and morphological boundaries among these five clades are not clearly defined, and we have therefore refrained from assigning a specific taxonomic category to this assemblage. Molecular similarities suggest a close affinity between Pennatulacea and Ellisellidae, which is also supported by similarities in their axial structure. For morphological reasons we maintained the present status of Helioporacea as a distinctive order. Briareidae, Paragorgiidae, and several orphan "alcyoniids" have a fundamentally similar canal system in common, which is further supported by high levels of similarity in mitochondrial genes. Our mtDNA data resolve relationships among higher categories as well as family and genus levels. However, the data are of limited value to assess relationships between species within the Octocorallia or the relationship between Octocorallia and Hexacorallia. We provide an evolutionary framework with diagnostic of genetic and morphologic features to the new systematics scheme. The importance of axis microstructure, internal canal system, and polyp dimorphism as diagnostic features needs to be re-examined. Coordinated studies of morphological and molecular octocoral systematists are indispensable for progress in understanding the diversity and the evolutionary processes in octocorals.

Incongruence between Molecular and Morphological Systematics in the Soft Coral Family Alcyoniidae

*Catherine S MCFADDEN**, *Phil ALDERSLADE*

1250 N. Dartmouth Ave., Claremont, CA 91711 United States of America
mcfadden@hmc.edu

Molecular systematic work on alcyonacean octocorals is revealing incongruence between morphological and genetic differentiation at a variety of taxonomic levels. Mitochondrial *msh1* and *ND2* gene sequences suggest that the soft coral family Alcyoniidae is polyphyletic, consisting of numerous clades that are not closely related to one another. For instance, the widespread and common tropical genera *Sarcophyton*, *Lobophytum* and *Sinularia* form a clade that is very distant genetically from other alcyoniid genera such as *Cladiella* and *Klyxum*. Within the former group, species of *Sarcophyton* and *Lobophytum* form several paraphyletic clades, suggesting that the morphological traits used to distinguish these two genera have been subject to homoplasy and do not reflect their genetic relationship. Finally, individuals identified morphologically as belonging to the geographically widespread species *Sarcophyton glaucum* often differ from one another by genetic distances that are greater than those separating most genera of octocorals. These results suggest that minor morphological differences among colonies of *S. glaucum* that have been interpreted as intraspecific variability may in fact represent species-level differences. Further molecular and morphological work is necessary at all taxonomic levels before we can begin to re-interpret the taxonomic significance of morphological variation in the Alcyoniidae and other octocoral families.

High Morphological Differentiation and Overlapping Morphotypes in a Caribbean Gorgonian Coral: Molecular Approaches and Phenotypic Plasticity

*Juan A SANCHEZ**

Private Bag 14-901, Kilbirnie, Wellington, New Zealand
j.sanchez@niwa.co.nz

It has been suggested that shallow-water coral diversity could be higher than previously thought, due to the existence of sibling species complexes with little morphological differentiation. In spite of this, apparently valid species could be part of morphological complexes that exceed the traditional ranges of variation for species distinctions. Among coral species the levels of plasticity within traits, often considered diagnostic for species identification, are poorly understood. A good example is the remarkable phenotypic plasticity found in *Pseudopterogorgia bipinnata* (Octocorallia: Cnidaria). Up to 10-fold differences were noted in branch and internode sizes (shallow/exposed to deep/protected; 1-45 m), which completely change the species appearance. To examine the genotype/environment relationship and phenotypic plasticity in *P. bipinnata*, I compared three microsatellite loci, mitochondrial (MSH1), and nuclear (ITS-1) DNA sequences of the populations present in the coral reefs of Belize (Carrie Bow Cay), Panama (Bocas del Toro) and Bahamas (as outgroup). Despite the large and discrete differentiation of morphotypes there was no greater genetic dissimilarity other than geographic divergence (e.g., Belize vs. Panama vs. Bahamas). Even more intriguing, although the change in phenotype seemed independent of genotype, the phenotypes co-occurred in overlapping zones, where two phenotypes were found side-by-side sharing the same environment. This explains why this species has been considered multiple species in the past (e.g., *P. kallos*, and *P. bipinnata*) but there is further need of investigation. There could be maternal-specific developmental "signals" determining phenotype at marginal environments or, alternatively, it could be an incipient case of genetic assimilation.

Microsatellite DNA and Clonal Structure in the Sea Whip, *Junceella juncea* (Octocorallia: Gorgonacea)

*Shang-Yin Vanson LIU**, *Chang-Feng DAI*, *Hon-Tsen YU*, *Tung-Yung FAN*

National Taiwan University P. O. Box 23-13 Taipei, Taiwan, R. O. C. Taiwan
oceandiver6426@yahoo.com.tw

The identification of different clones is fundamental to the study of population structure among asexual populations. However, due to the low genetic variation of mtDNA and the contamination of zooxanthellate DNA, very few molecular markers are available for studying the clonal structure of cnidarians. The highly variant tandem repeats (microsatellite DNA) randomly distributed among the eukaryote genomes are useful markers to study clonal structure of colonial cnidarians. In this study, we isolated 6 loci from a zooxanthellae-free octocoral *Junceella juncea* using methods of enrichment and traditional partial library screening. Among the 3856 clones screened by partial library method, only 10 positive signals were found and 3 of them could be used to design primers and be well amplified. However, all loci isolated by enrichment method showed low variations or were monomorphic among populations, it may result in in vitro hybridization during PCR amplification. Overall, 4 of 6 loci were polymorphic and the other 2 were monomorphic. We used the 4 polymorphic loci to study the clonal structure of *J. juncea* collected from 7 reefs at 3 sites, i.e. Xia-shui-jui, Nanwan in southern Taiwan, and Shi-cheng in northern Taiwan. A total of 40 multilocus genotypes were found among 152 colonies and the number of genotypes (clones) identified at 7 reefs ranged from 2 to 16. The ratio of observed to expected genotypic diversity (Go:Ge) ranged from 0.018 to 0.422 suggesting that asexual reproduction plays a major role in the maintenance of established populations. The results also indicate that the distribution of microsatellites may be rare in the genome of *Junceella juncea* and the high variation of microsatellites can be used to identify the genets and remets within populations.

Mass Spawn or Mass Delusion: Revisiting Spawning Synchrony among Scleractinian Corals

*Andrew H BAIRD**

Townsville, Qld 4811 Australia

andrew.baird@jcu.edu.au

The annual mass spawning of scleractinian corals on the Great Barrier Reef (GBR) is one of the most spectacular of natural phenomena. Similar studies in the Caribbean and the Red Sea failed to find similarly high spawning synchrony among species and the paradigm of the mass spawn being unique to the GBR became entrenched. The mass spawning paradigm consists of two propositions: firstly, that multi-specific synchronous spawning was restricted to regions characterized by large fluctuations in environmental variables such as temperature; and secondly, all mature colonies breed annually with tight synchrony in gametes release over a large scale. Subsequent work from numerous locations within the Indo-Pacific indicates that multi-specific synchronous spawning is a characteristic feature of all speciose coral communities. Similarly, the proposition that most mature colonies breed annually with tight synchrony in gametes release over a large scale on the GBR is also untenable. A high proportion of colonies in a similar reproductive condition is the exception rather than the rule because a significant proportion of individuals of sexually mature size do not breed every year, and spawning among colonies of the same species is regularly split between consecutive months. I argue that one result of the pervasiveness of the mass spawning paradigm has been to inhibit research into coral reproductive biology, particularly on the GBR. Consequently, substantial gaps in our knowledge remain and details of the life history of all but a few intensively studied species are completely unexplored. In this talk, I present data from a number of geographical locations, including Japan, to demonstrate that spawning patterns are far more detailed and varied than implied by the paradigm of the mass spawn

Spawning and Early Development of Host Sea Anemones

Anna SCOTT, Peter L HARRISON*

National Marine Science Centre, PO Box J321, Coffs Harbour Jetty, NSW Australia

ascott@nmssc.edu.au

Very little is known about the sexual reproductive biology of host sea anemones. Accordingly, this study aims to provide the first quantitative data on the sexual reproduction, larval development and metamorphosis of the host sea anemones, *Entacmaea quadricolor* and *Heteractis crispera*, found within the Solitary Islands Marine Park, Australia. Individuals of both species were collected, maintained and monitored in flow-through seawater tanks to determine spawning times. Male and female *E. quadricolor* synchronously spawned gametes into the water column for external fertilization, three and four nights after the full moon in March 2003. *H. crispera* spawned in March, April and May 2003, seven, nine, and six nights after the full moon, respectively. Spawned eggs of both species were positively buoyant, spherical, green in colour, zooxanthellate and had clumped spires of microvilli. Spermatozoa were flagellate. Embryos were collected and reared until they had developed into larvae, and then placed into settlement cages with various types of natural substrata to allow settlement and metamorphosis. Larvae rotated, swam about actively, and displayed active searching behaviour. *E. quadricolor* larvae were competent to settle five days after spawning, and *H. crispera* larvae were first competent to settle four days after spawning. Once settled on the substrata, the larvae metamorphosed into juvenile anemones, with small tentacle buds evident six and five days after spawning for *E. quadricolor* and *H. crispera*, respectively. Data from this research provides essential information for management, as the mass culture of host sea anemones has the potential to reduce collecting pressures on wild populations, and would allow the restocking of anemones on reefs denuded by human and natural disturbances.

Reproductive Pattern of Corals in Southern Taiwan: Seasonal, Lunar and Diurnal Periodicity

Tung-Yung FAN, Ke-Han LIN, Fu-Wen KUO, Lee-Shing FANG*

Pingtung, Taiwan 944, R. O. C. Taiwan

tyfan@nmmba.gov.tw

The seasonal, lunar and diurnal periodicity in reproductive timing of 79 coral species in southern Taiwan were studied by examining gonad development, field observations of spawning behavior as well as outdoor larva-collection flow-through systems. Seventy-one species are scleractinian corals and 8 are alcyonaceans with 74 are broadcasters and 5 are brooders. The spawning of broadcasting species occurred from March to October with most species spawned in April and May. The brooding species planulated throughout the year. Broadcasters spawned on a lunar cycle from 1 to 11 nights after the full moon and the spawning of the majority of broadcasters peaked around the last quarter moon phase. Brooders planulated on a lunar cycle with larval release peaked around the first quarter moon phase or throughout the month. The broadcasters released gametes in the evening between 20:00 to 22:00. However, the planulae production of brooders peaked in the morning between 4:00 to 7:00 or occurred all the day. The remarkable difference in the seasonal, lunar and diurnal patterns of reproductive timing between broadcasting and brooding corals represents the segregation of reproductive timing of these corals. The relationship between reproductive pattern and environmental (temperature, rainfall, tide) and biological (fertilization, predation, dispersal) factors are discussed.

Life History of the Temperate Soft Coral, *Dendronephthya gigantea*, from Korea

Sung-Jin HWANG, Marco INVOLTI, Jun-Im SONG*

Department of Life Sciences, Ewha Womans University Seoul 120-750, Korea

sjhwang@ewha.ac.kr

An azooxanthellate soft coral, *Dendronephthya gigantea*, is a highly abundant in Jeju Island of Korea. To investigate the life history of this species, the reproductive mode, the gametogenic cycle, the timing of reproduction and the larval development were studied. For the examination the sexual reproduction, 5cm long branches were collected monthly from 10 to 20 colonies. To determine the mode of reproduction, some of them were kept in aerated tanks containing artificial sea water for one week. Others were used to study the gametogenic cycle by histological sections. For the purpose of considering the relationship between lunar phase and timing of reproduction, their spawning and planulation were monitored in the sea and the culture room. And also, planulae were reared with filtered sea water in the growth chamber (24°C) for larval development. As a result, the species being confirmed as a gonochoric brooder continuously released planulae from July to September 2003. Mature oocytes and sperm sacs were respectively 290-500mm and 250-320mm in diameter. Within one polyp, 6 to 10 oocytes were counted. After 3 days of planulation, orange colored planulae grew up to white polyps which had mesenteries and tentacles with 3 pairs of pinnules. And then, the young polyps were getting 9 pairs of pinnules until 10 days. These results indicate that the species shows the high fecundity and the rapid metamorphosis at early stage compared with other brooders.

Reproduction Ecology of *Oulastrea crispata* (Faviidae) from Tung Ping Chau, Hong Kong

Ting Pong LIN*, Put O ANG

Shatin, N.T., Hong Kong SAR People's Republic of China
sven213@sinaman.com

Oulastrea crispata is a common species found on rock surface in shallow water region of Tung Ping Chau, Hong Kong. Five colonies (> 3 cm in diameter) were collected monthly for 31 months (Jul 00 to Jan 03) and 14 months (Jul 00 to Aug 01) in AYW and AMW respectively. The development of oocyte and spermary stages over time was examined histologically. *Oulastrea crispata* is a gonochoric broadcaster. Results indicate that the sexual reproduction pattern is complex as both oocyte and spermary developed asynchronously. The growth of gametes was different among colonies collected in the same month. Furthermore, asynchronous gamete development also took place among polyps within the same colony. Due to this asynchronous development, several spawning events likely took place annually and especially between late spring and early autumn. There were peaks of oocyte development in May and September in 2001 and 2002. However, there was less gonad development in winter when compared with that in summer. Spermary was usually absent in winter.

Sexual Reproduction of *Acropora* Reef Corals at Moorea, French Polynesia

Andrew CARROLL*, Peter HARRISON, Mehdi ADJEROUD

National Marine Science Centre, Bay Dr, PO Box J321, Coffs Harbour, NSW, 2450, Australia
carroll_andrew@yahoo.fr

Little information is available on sexual reproductive processes among reef corals in isolated Central Pacific reef areas, including French Polynesia. Moorea is part of the Society archipelago, and lies 25 kilometres to the northwest of Tahiti. Sampling of *Acropora* spp. coral colonies was completed during 2002 and 2003, at four sites on the outer reef slope and reef lagoon around Moorea, in order to determine their reproductive status. Thirteen *Acropora* spp. spawned gametes between 6 and 9 nights after the full moon (nAFM) in October 2002. In November 2002, spawning of egg and sperm bundles was observed 6 nAFM in colonies of *Acropora* cf. *austera* in aquaria, and confirmed in field colonies. In October 2003, spawning was observed in aquaria and inferred in the field for five *Acropora* spp. between 7 and 8 nAFM. During November 2003, spawning of egg and sperm bundles from 25 *Acropora* colonies was observed in aquaria between 6 and 8 nAFM, and spawning was inferred in the field in 106 tagged *Acropora* colonies between 6-9 nAFM. These are the first records of spawning by *Acropora* corals in French Polynesia. Ongoing analysis of sequential samples taken from tagged colonies will provide details of the patterns of gametogenesis and the timing of sexual reproduction for *Acropora* and several other ecologically dominant coral species. The impacts of bleaching events at Moorea in 2002 and 2003 on coral survival and fecundity are also being assessed. This information will provide important insights into the reproductive processes that affect population maintenance of reef corals in French Polynesia.

Fecundity and Periodicity of Planula Release in the Reef-building Coral *Stylophora pistillata*

David ZAKAI*, Amir AVISHAI, Tamir CARAS, Zvy DUBINSKY, Nanette CHADWICK-FURMAN

P.O. Box 667, Eilat, Israel.
dudu.zakai@nature-parks.org.il

Fecundity and periodicity of planulae release in the reef-building coral *Stylophora pistillata* were examined over 5 years at Eilat, northern Red Sea. During 1998, patterns of planulae release by 30 colonies were determined under laboratory conditions, over 134 nights during the high planulation season. Corals then were tagged and returned to the reef. In 2003, 20 of these colonies were recollected and the same parameters were re-measured over 118 nights. The number of planulae released varied widely between colonies, and did not correlate neither with coral colony volume nor its surface area. The rate of planulae release per coral volume was 6% lower in 2003 than in 1998, while coral volume increased > 5% during this period. The periodicity of planulae release did not vary significantly between the 2 years examined. In both years, colonies of *S. pistillata* released planulae on a lunar cycle, peaking between nights 1 - 10 following the full moon phase. Random collection of planulae from 15-cm-diameter colonies of *S. pistillata* in the field during both years, using plankton net traps, showed a significant correlation with the planulae release cycle under laboratory conditions. In field colonies, the number of planulae released was 2 times lower in the year 2003 than in 1998. Thus, the laboratory conditions employed here did not alter the natural cycle of planulation in *S. pistillata*. Reduced planula release between years in the field may result in part from anthropogenic impact. However, the larger reduction in planula release between years under laboratory conditions may be due to processes of coral senescence in combination with anthropogenic impacts.

Patterns of Coral Spawning on Equatorial Reefs in Mombasa, Kenya

Sangeeta MANGUBHAI*, Peter HARRISON

PO Box 10135, Bamburi, Mombasa, KENYA Australia
smangubhai@africaonline.co.ke

Few studies have been done on the spawning patterns of scleractinian corals in equatorial regions. It has been suggested that spawning may be less synchronous on equatorial reefs compared to tropical reefs, due to weaker environmental cues such as temperature and seasonality, which are thought to govern the onset and timing of coral reproduction. This paper presents the first data on the seasonality and timing of spawning events in Kenya, at a latitude of 4° S. The study began in April 2003, in the Mombasa Marine National Park and Reserve, and focuses on 5 species - *Echinopora gemmacea*, *Platygyra daedalea*, *P. sinensis*, *Acropora valida* and *A. tenuis*. Spawning was inferred from the disappearance of mature, coloured eggs and spermaries from sequential samples collected from tagged colonies. In addition, over 100 colonies of *Acropora* species were tagged and repeatedly sampled to determine the extent to which spawning is synchronized within and among species. Data on sexual patterns, mode of development, gamete size and environmental cues controlling spawning will also be presented. Studies on coral reproduction in Kenya have become increasingly important following the 1998 El Nino event in the Western Indian Ocean, which resulted in widespread bleaching and subsequent mortality of corals.

Exploring the Dynamics of Fertilization During Bouts of Broadcast Gamete Release by Tropical Green Seaweeds on Coral Reefs

Kenneth CLIFTON*

0615 SW Palatine Hill Rd, Portland, Oregon United States of America
clifton@lclark.edu

Common tropical green seaweeds such as *Halimeda*, *Caulerpa*, and *Udotea* (Bryopsidales) reproduce synchronously in a manner that shares many analogs to the mass spawning behavior of sessile marine invertebrates, including corals. Frequent and consistent bouts of gamete release on Caribbean reefs by green seaweeds thus offer an excellent opportunity to examine the dynamics of gamete release, fertilization, and dispersal for broadcast spawning organisms in general. In vitro studies of seaweed reproduction indicate that sperm concentrations between 10^7 and 10^9 gametes/ml are typically necessary to allow fertilization. Field collections during natural spawning events indicate that sperm concentrations sufficient for fertilization rarely occur more than 1 m from a gamete-releasing male, although currents and surge may permit high sperm concentrations much further from their source. Sperm limitation in these seaweeds may promote selection for copious gamete release; a single thallus may release over 100 trillion (10^{14}) gametes within a 10-minute period. The total number of gametes released is a function of both thallus size and gamete size. Natural patterns of proximity between males and females suggest that most individual seaweeds achieve only moderate to little reproductive success following gamete release, while a few achieve very high levels of fertilization because of their closeness.

Species Dependent Reproductive Responses of Eastern Pacific Reef Corals Related to the 1997-98 El Nino Event

Susan B COLLEY*, Peter W GLYNN, Anita S MAY

4600 Rickenbacker Causeway, Miami, Florida 33149 United States of America
stheodosiou@rsmas.miami.edu

The El Nino 1997-98 and post-El Nino associated reproductive activities of eight species of eastern Pacific scleractinian corals were compared with previously published long-term trends. Since reproductive activity in eastern Pacific corals is responsive to local temperature regimes, samples were collected in Panama from upwelling (Gulf of Panama, where no bleaching occurred in 1997-98) and nonupwelling sites (Gulf of Chiriqui, with two bleaching events in 1997-98). Sampling was also accomplished in the Galapagos Islands, a thermally variable environment (with one bleaching event). Long-term and El Nino 1997-98 temperature records at these locales were also compared with reproductive activity. Histologically processed samples (~600) collected from 1997-2002 included species from three families of corals (Pocilloporidae, Poritidae and Agariciidae) and were scored for the presence or absence of gametogenic development and mature gametes. Most populations remained reproductive throughout the El Nino warming period despite poor tissue integrity of many samples. Preliminary results indicate that gametogenesis in some species was detrimentally affected while in others it may have been enhanced. Also, at least one species demonstrated an enhanced effect initially during the warming episode and diminished activity later. Eastern Pacific corals normally display multiple breeding periods per year which are seasonally influenced by upwelling, the mixing of the equatorial and eastern boundary currents and the migration of the Intertropical Convergence Zone. Multiple breeding periods may result from the relatively warm and narrow SST ranges experienced in this region. Anomalously warm temperatures may, however, enhance the gametogenic development of these corals and cooler temperatures may cause a dampening effect.

Elevated Temperature Sensitivity of Fertilization and Early Development in the Mushroom Coral, *Fungia scutaria*

David A KRUPP*, Lea L HOLLINGSWORTH

45-720 Kealahala Road, Kaneohe 96744, USA
krupp@hawaii.edu

Most studies investigating the effects of elevated temperature on scleractinian coral focus on its role in bleaching, growth, and mortality. Only a handful of studies have dealt with the impact of elevated temperature on the earliest stages in the life cycle of coral: fertilization and early development. In our study, we examined the success of fertilization and early development in *Fungia scutaria*, a solitary coral exhibiting separate sexes. Spawmed gametes were collected, aliquoted to 20 mL glass vials, and incubated in water baths set at temperatures ranging from 27°C to 34°C. The vials were examined the next morning (ca. 12 h after spawning) for the presence of viable larvae. High survival occurred at incubation temperatures 27-30°C. Survival dropped off precipitously at temperatures above 31°C. These observations may have implications regarding the effects of global warming on reef corals. This work was supported by the Hawaii State Biomedical Research Infrastructure Network (HS-BRIN; NIH/NCRR grant RR-16467) and the University of Hawaii Investing in Multidisciplinary University Activities through Hawaii EPSCoR program (NSF RII grant 0237065).

Coral Gametogenesis and Broadcast Spawning Are Driven by Solar Insolation

Robert VAN WOESIK*

150 West University Blvd United States of America
rvw@fit.edu

Many corals synchronously broadcast their gametes into the water column. Coral reproductive schedules and gamete maturation have long been related to concomitant increases in regional Sea Surface Temperatures (SST). Here I question the relationship between gametogenesis and SST and show evidence that the onset of gametogenesis and the development of gametes, leading to spawning synchronicity, may be more related to solar insolation, which is the electromagnetic energy incident on the surface of the earth. Solar insolation and SSTs are not however mutually exclusive phenomena, and clearly solar insolation drives SST. Corals have been found to synchronously mass spawn in the tropics. The rise toward and fall from solar insolation maxima coincide with coral spawning events in the tropical western Pacific Ocean. Indeed, SSTs are poor predictors of coral spawning in the tropics. On a larger geographic scale, mass spawning also coincides with near-maximum solar insolation (~ 6 kWh/m²/day) events from 33°N to 30°S in the western Pacific Ocean, and differential solar insolation should be considered as one of the primary variables driving coral reproductive cycles. Two insolation maxima in the tropics, a consequence of the vernal and autumnal equinoxes, the two periods when the declination of the sun is at the equator, lead to multiple spawning events per year. Multiple, multispecific mass spawning events per year in the tropics, compared with an annual event at higher latitudes, increases the likelihood of genetic recombination that may facilitate speciation within sympatric environments, which may explain, in part, why the tropical western Pacific Ocean supports the world's highest coral diversity.

Sexual Reproduction of *Madracis mirabilis* : Further Evidence for a Pseudo-brooding Strategy

Samantha J DE PUTRON*

Ferry Reach, St Georges, GE 01 Bermuda

sputron@bbsr.edu

Colonies of the scleractinian *Madracis mirabilis* are hermaphroditic, with mature oocytes and spermaries developing over the period of maximum annual seawater temperatures during August and September in Bermuda. There was lunar periodicity to spermatogenesis, with mature spermaries present over the new moon period. Oocyte development was asynchronous, although mean oocyte diameter was also maximal over the new moon. Developing embryos were never found in the histological sections. However, early stage planulae were collected from *M. mirabilis* colonies held in aquaria and from *in situ* larval traps. The reproductive mode of *M. mirabilis* is suspected to be a “pseudo-brooding” strategy of internal fertilisation followed by a short and variable brooding period of just hours to days. The selective potential of this modified reproductive strategy is discussed, along with further evidence of its occurrence in *Madracis* and other scleractinian species.

Reproduction of Transplanted Fragments *Acropora formosa* : Effects of Fragment Size and Oocyte Developmental Stage of the Donor Colonies

Nami OKUBO*, Makoto OMORI, Tatsuo MOTOKAWA

O-okayama, Meguro-ku, Tokyo, 152-8851 Japan

namiokubo@nifty.com

In order to develop techniques for coral reef restoration, we conducted transplantation experiments of the coral *Acropora formosa* fragments. Two different size fragments were transplanted in different seasons, and monitored their reproduction. The successive observations on transplants showed the two trends in the fate of oocytes: 1) the small-sized fragments tended to resorb their oocytes, but most large-sized ones developed their oocytes and spawned; 2) fragments with oocytes at early developmental stage tended to resorb their oocytes, but those with oocytes at late developmental stage developed their oocytes and spawned. Hence, these results suggested that the fragment size and the oocyte developmental stage influence the fate of oocytes and whether the fragments spawn. In histological sections of transplants where oocytes disappeared, two morphologically distinct cells with many eosinophilic granules (spread hyaline cell and round-shaped eosinophilic cell) were detected in most of mesenterial filaments and in place where oocytes were found before. The hyaline cells were found in the donor colonies, but few of them were stained by Eosin in the donor colony at each developmental stage until the spawning. These cells may participate oocyte resorption.

Phototrophic Prokaryotes in Bora Bay, Miyako Island, Okinawa, Japan

*Beatriz E. CASARETO**, Jean BLANCHOT, Loïc CHARPY, Yoshimi SUZUKI
Meishin BLDG., Kamiikedai 1-14-1, Ota-ku, Tokyo, 145-0064 Japan
casaretobe@aol.com

High contributions of phototrophic prokaryotes were reported in different coral reef ecosystems: French Polynesia atoll lagoons, Great Astrolabe reef (Fiji), Great Barrier Reef (Australia), New Caledonia lagoon. In these oligotrophic ecosystems, contrary to the open ocean, *Synechococcus* largely dominate *Prochlorococcus*. The questions are: Are phototrophic prokaryotes everywhere dominant in coral reef ecosystems? What is the influence of coral reef environment onto prokaryotes composition and dominance? Do coral reef communities graze prokaryotes? On the bases of these questions we studied the phytoplankton composition and abundance at Bora Bay, Miyako Island, Okinawa. Indeed, this ecosystem is located in the North hemisphere and it can be considered as mesotrophic thanks to nutrient rich ground waters input in the lagoon. In addition, the lagoon area is small compared to the reef area. Methods: Field studies consisted on 1) surveys; 2) plankton incubations with ¹³C incorporation; 3) dome chamber incubation to estimate the grazing impact onto the picoplankton community. Water samples were taken using NISKIN clean bottles: DIC, DOC and POC using GF75 (0.3µm of retention capacity) were measured. Samples for Chl-a measurement were size fractionated in a serial filtration by 10µm, 3µm, 1µm and GF75 (0.3µm) filters. Picoplankton studies were done using a flow cytometer (Beckman Coulter) taking into account picocyanobacteria, picoeukaryotes and heterotrophic bacteria. Results: In Miyako, we found a phytoplankton community structure very similar to other coral reef lagoon, with 60% of cells with a size less than 3µm. Lagoonal waters were dominated by *Synechococcus* (<1µm size), meanwhile in the open ocean waters, the smallest coccoid cyanobacteria *Prochlorococcus* (± 0.6µm size), reach the same abundance as that of *Synechococcus*. A significant decrease in coccoid cyanobacteria abundance was observed close to the barrier reef. The hypothesis that coral reef communities are able to graze on picoplankton was confirmed during dome experiments.

Spatial Distribution of Phytoplankton Community Structure in Relation to Eutrophication in the SW Lagoon of New-Caledonia

*Severine JACQUET**, Bruno DELESALLE, Jean BLANCHOT, Jean P TORRETON

IRD BP A5 98848 Noumea, Nouvelle Calédonie French Southern Territories
severine.jacquet@noumea.ird.nc

As a consequence of human activities, many oligotrophic and mesotrophic coral reef lagoons are subjected to increased eutrophication. The effects of added nutrients on phytoplankton populations in these environments are still poorly known, as the phytoplankton composition was scantily taken in account in the few studies devoted to this topic in tropical coastal waters. The lagoon of New Caledonia Island is one of the largest coral lagoons in the world and, while several studies described on the physics and biology (mainly benthos) of the lagoon, very few focused on the phytoplankton communities. The SW Lagoon of New Caledonia receives minimally treated urban effluents from the city of Noumea and some agricultural and industrial wastewaters. The effects of these effluents on the phytoplankton were investigated at three levels: the total chlorophyll a concentration, the phytoplankton size distribution and the phytoplankton community composition (picoplankton and microalgae). In coral reef lagoons, inorganic nitrogen is often considered as a limiting factor for phytoplanktonic growth. Our results confirmed this statement as changes in the phytoplankton abundance and composition were obvious in spite of a relatively narrow (0.1 to 3.0 µM) range of inorganic nitrogen concentrations. Larger (>10µm) groups prevailed in areas with high nutrients concentrations. Increased nitrogen also affected the phytoplankton composition, either picoplankton or microalgae. The relative contribution of *Prochlorococcus* usually decreased with increasing nutrient concentrations while *Synechococcus* became more abundant. Similarly, regarding the microalgae, coccolithophorids and dinoflagellates dominated in the oligotrophic sites, whereas diatoms mainly developed in eutrophic bays. These results show that, in this environment, the nutrient concentrations (mainly the inorganic nitrogen) not only influenced the phytoplankton abundance but also the phytoplankton community structure.

Phytoplankton in Coastal Water off Reunion Island : Biomass and Trophic Significance for the Saint-Gilles La Saline Coral Reef

*Pascale CUET**, Jean BLANCHOT, Remi GARNIER, Jean TURQUET, Marc TOUCHARD, Clementine ESBELIN, Charles DELMAS, Jean-Pascal QUOD
15 Av. Rene Cassin BP 7151 97715 Saint-Denis Messag. Cedex 9 France
cuet@univ-reunion.fr

Although excess production of the reef flats at Saint-Gilles La Saline (Reunion island, western Indian ocean) is slightly positive in undisturbed areas, it is clearly negative in areas damaged by the combined effects of nutrient loading and undergrazing. Therefore, it was previously suggested that the carbon budget of this coral reef might be balanced by an input of exogenous organic matter. In order to assess the potential significance of oceanic inputs (coastal phytoplanktonic production), we analyzed monthly (from Sept. 2002 to Sept. 2003) water samples from coastal and reefal areas (respectively eight stations 70m deep located all around the island, and three reef flats) for Chl. a and picophytoplanktonic abundance. Surface water from the windward East coast (6 to 10m rain per year, while rain is 5 to 10 times weaker on the leeward West coast where the coral reefs lie) was affected by river runoff and groundwater discharge, and enriched with NO₃⁻ + NO₂⁻ and PO₄³⁻ compared with the other coastal areas. At 70 m deep, mean Chl. a was 0.29 ± 0.13 µg/L, with no difference between the stations. At the surface and 35m deep (pooled data), Chl. a was only slightly higher on the East coast (mean 0.28 ± 0.17 µg/L) than in the other coastal areas (0.23 ± 0.16 µg/L; p = 0.03), suggesting that phytoplanktonic abundance in the coastal area is mainly controlled by nutrient availability in oceanic water, rather than by terrigenous inputs. Chl. a was lower in reefal water (0.13 ± 0.07 µg/L) than in coastal surrounding water, and a drastic decrease in picophytoplanktonic abundance (*Prochlorococcus*, *Synechococcus* and picoeukaryotes) occurred. Those data suggest that grazing of the phytoplankton by benthic organisms may contribute significantly to the carbon budget of the reef flats at Reunion island, and increase nutrient enrichment previously attributed to groundwater discharge into the back-reef zone.

Importance of the "Micro-diet" for Scleractinian Corals

*Fanny HOULBREQUE**, Eric TAMBUTTE, Cecile RICHARD, Christine FERRIER-PAGES, Denis ALLEMAND

c/o Musee Oceanographique, Av Saint-Martin, 98000 Monaco
houlbreque@centrescientifique.mc

This study investigated the ability of three scleractinian coral species, either zooxanthellate (*Stylophora pistillata* and *Galaxea fascicularis*) or azooxanthellate (*Tubastrea aurea*) to feed on the microbial consortium. Changes in the concentrations of dissolved organic carbon (DOC), bacteria, cyanobacteria and flagellates were monitored over an incubation of a few hours. Results obtained showed that ingestion rates were directly proportional to the prey concentration in seawater. In terms of number of prey ingested per polyp, bacteria were the first group ingested, followed by cyanobacteria and heterotrophic flagellates. However, when converted into carbon and nitrogen, nanoflagellates (both auto- and heterotrophic) represented the most important contribution, 84 to 94% of the total carbon and 52 to 85% of the nitrogen ingested (per polyp or protein). The other species such as bacteria, cyanobacteria and picoflagellates represented only 1 to 7% of the ingested carbon. During the incubation, DOC concentrations increased in the chambers containing *T. aurea* and *G. fascicularis*, given production rates equal to 0.23 ± 0.17 and 0.10 ± 0.10 µmoles DOC polyp⁻¹ h⁻¹. However, in all chambers containing *S. pistillata*, DOC concentrations decreased (from 101.69 ± 13.53 to 93.59 ± 4.67 µmoles DOC l⁻¹) equal to an ingestion rate of 0.251 ± 0.217 nmoles DOC polyp⁻¹ h⁻¹, suggesting a dual process of release and uptake in these corals. In the symbiotic species, pico- and nanoplankton accounted for 6.6 to 7.8% of the carbon brought by photosynthesis but was a major supply of nitrogen. Indeed, in *S. pistillata*, the amount of nitrogen supplied by the ingestion of pico- and nanoplankton (19 ng N polyp⁻¹ h⁻¹) was ca. 5 times higher than the estimated amount brought by the uptake of dissolved nitrogen at in situ concentrations (3.8 ng N polyp⁻¹ h⁻¹). Pico- and nanoplankton may therefore constitute an important food source for these corals.

Depletion of Pico-and Nanoplankton over a Reef Dominated by Scleractinian Corals

Jean BLANCHOT*, Fanny HOULBREQUE, Bruno DELESALLE, Yves MONTEL, Christine FERRIER-PAGES

14 rue du Stade de l'EST 97490 St Clotilde Ile de la Reunion France
blanchot@univ-reunion.fr

This study investigated the in situ depletion of pico and nanoplankton concentrations over a lagoonal patch reef located in the lagoon of Mayotte Island (Indian Ocean). The reef was mainly (> 80%) dominated by scleractinian corals (*Acropora* sp, *Galaxea astreata*, *Echinopora* sp, *Fungia* sp, *Pocillopora* sp) while other benthic organisms were giant clams, sea anemones, sea urchins and some colonies of the soft coral *Sarcophyton* sp. Water samples for the determination of chlorophyll a and particulate organic carbon (POC) concentrations, and pico-and nanoplankton abundances were conducted at 7 stations along transects, 300 meters long, starting and ending in the lagoon, outside the patch reef. Since the current was less than 1 cm s⁻¹, samples were considered to be independent. Results showed that the waters above the reef were strongly depleted (33%) in total chlorophyll. The depletion mainly concerned chlorophyll < 10 µm (0.32 to 0.21 µg chl l⁻¹). In contrast, the > 10 µm chlorophyll concentrations were not significantly different between the reef and the surrounding waters, suggesting that large phytoplankton was poorly grazed by the reef communities. POC concentrations did not show any special trend, which can be due either to a large amount of detrital POC or to a significant contribution of large phytoplankton to the POC. Concentrations of picoplankton, such as cyanobacteria, *Prochlorococcus*, pico-eukaryotes and heterotrophic bacteria, also significantly (53 to 42%) decreased over the reef. These data therefore suggest that pico-and nanoplanktonic cells can be an important food source for a reef dominated by scleractinian corals.

Benthic Primary Production and N₂ Fixation in a Fringing Coral Reef at Miyako Island, Okinawa, Japan

Beatriz E CASARETO, Y SUZUKI, Y ISHIKAWA, K KUROSAWA*

Kamiikedai 1-14-1, Ota ku, Tokyo 145-0064, Japan
CASARETOBE@aol.com

Among main primary producers in coral reef ecosystems the importance of macrophytes and symbiotic zooxanthellae have been widely recognized. However the role of epiphytic and endolithic microalgae have been not well considered. The goal of this work is to evaluate the role of benthic microalgae as primary producers and N₂ fixers, using several field experiments. Different sediment types (excluding macrophytes) were incubated in core-type chambers at several station within Bora Bay in July of 1998 showing high P/R ratios of 1.02 to 2.03. These results suggest that production is the predominant metabolic process in these sediments. Net primary production of endolithic microalgae was measured by bottle incubations using ¹³C tracer technique in July of 2000 and N₂ fixation rates using ¹⁵N₂ as tracer gas in July of 2002. Net primary production of endolithic microalgae, varied from 1.9 to 2.6 g C day⁻¹ m⁻² of rubble surface, and N₂ fixation rates ranged from 0.41 to 0.48 mg N m⁻² day⁻¹ being about two times higher during day-light compared to night-time rates. The contribution of epi-phytic algae to the N₂ fixation was small and less than 20% compared to that of endolithic microalgae. Concentrations of *Chl a* of endolithic microalgae in coral rubble (13.7 µg *Chl a*/g coral rubble; SD=5.57; n=10) are of the same order of magnitude to that of living corals in association with their symbiotic zooxanthellae (31 µg *Chl a*/g coral; SD=31.8 n=34) (Sorokin, 1995; Casareto, personal com.). These observations show the important role of coarse rubble sediments for the primary production and N₂ fixation in coral reef ecosystems.

Coral Tissue Movement in Response to Light: Do Corals Move to Help their Dinoflagellates?

Angela LAWTON*, Ross J JONES, Ove HOEGH-GULDBERG

Slip Rd, University of Queensland, St Lucia QLD 4072 Australia
alawton@marine.uq.edu.au

The symbiotic dinoflagellates of corals *in symbio* experience a wide range of light intensities based simply on their location within three dimensional structure of the coral colony. For example, in the interior of openly branching colonies such as *Stylophora pistillata*, light levels on horizontal planes can be less than 10% of the ambient irradiance intensity on the outside (exterior), depending spacing of the branches. While it is known that dinoflagellates are able to acclimate to different light conditions to maximize their productivity, how this varies on a micro-spatial scale and with respect to colony morphology is unknown. Using oxygen microsensor and Pulse Amplitude Modulation (PAM) chlorophyll fluorescence techniques, the photosynthetic rates of symbiotic dinoflagellates in the relatively mobile tentacles and in the relatively fixed coenosarc tissues (connecting tissues between polyps) was measured in the exterior (sunlight exposed) and interior (self-shaded) areas of five colonies of *S. pistillata*. The coenosarc tissue showed the anticipated photoacclimatory difference between the high light and shaded areas of the colony; however, the Photosynthesis v Irradiance (PI) curves from the tentacles were nearly identical. This indicates that the dinoflagellates from the two areas grew in similar light regimes and that tissue movement (polyp expansion and contraction) could optimize the light field for the algal symbionts. The tissue expansion and retraction can be quite dramatic under rapidly changing light conditions, apparently allowing for an optimization of the light field for the algal symbionts. These patterns may constitute an additional photoprotective process for the holosymbiont in addition to those associated with the algae (i.e. dissipation of excess light as heat) and host (i.e. protection of the algae by host-derived pigments). Such expansion and contraction patterns may be important for surviving coral bleaching events.

The Effects of Coral-Algal Interactions on the Photosynthetic Ability of the Corals in Tung Ping Chau Marine Park, Hong Kong SAR

Choyce L S CHOI*, Put O ANG

Shatin, N.T. HKSAR Hong Kong
choyce@sinagirl.com

Competition of corals with fleshy macroalgae was monitored in A Ma Wan (AMW) and A Ye Wan (AYW) in Tung Ping Chau, Hong Kong, starting in spring 2001 to spring 2002. The frequent sweeping and shading of the algal thallus on coral tissues was observed to cause coral bleaching. Monitoring of the photosynthetic abilities of the corals was carried out with the use of an underwater Pulse Amplitude Modulated (PAM) fluorometer. The photosynthetic yield of the coral was significantly lower in March when the algal coverage was the highest. In shallow water in AMW, the photosynthetic yield of the corals ranged from 0.3-0.4. This gradually increased to the normal range of 0.6-0.7 in summer when the algal cover was nil. Different portions of the corals were also measured by the PAM. There were slight differences in the photosynthetic yield of different regions of the corals. The top region of the corals usually showed a comparatively lower photosynthetic yield than the bottom region of the corals. This may be explained by the photo-inhibition effect of the chlorophylls in the zooxanthellae of the upper region of the corals. This phenomenon was observed in all seasons.

Ecological Mechanisms of Coral Reef Resistance in a Tropical Upwelling System*Tyler B SMITH**

4600 Rickenbacker Causeway, Miami, Florida United States of America

tsmith@rsmas.miami.edu

Tropical upwelling regions appear unsuitable for coral reef development yet the growth of true coral reefs in these areas has been known for a number of years. Upwelling from below the thermocline causes highly variable water temperature, including temperatures near and below scleractinian coral mortality thresholds. Upwelling also raises vital plant nutrient concentrations, raising water column productivity and possibly altering competitive relationships between corals and faster growing benthic algae. This research has investigated the ecological consequences of upwelling on coral reefs in the Gulf of Panama in the Panamanian Pacific. A factorial caging study investigated the response of coral reef algal communities to the factors caging, season and nutrients. Preliminary analysis of the results suggests that elevated nutrients caused by upwelling increase coral reef algal biomass accumulation by an order of magnitude but that the extra algal production is removed by herbivory. In contrast, artificial additions of nutrients showed no propensity to increase algal production in upwelling or nonupwelling seasons. As a compliment to manipulative experiments, field surveys were conducted to explore the relationships between temperature and herbivory, measured as bites per minute, and herbivore species and herbivore biomass distributions over spatial scales corresponding to upwelling/nonupwelling areas. The results of the complete analyses of experiments and field surveys will be discussed in the light of their contribution to an understanding of reef resistance to the potential stresses of reduced herbivory, temperature and elevated nutrients present in upwelling environments.

Storm and Stress: Modelling Strategies for Recruitment and Survival of Corals in Discovery Bay, Jamaica, and in the Wakatobi Marine Park, S. E. Sulawesi, Indonesia

*Michael J C CRABBE**, *David J SMITH*

Whiteknights, Reading, Berkshire, U.K., RG6 6AJ United Kingdom of Great Britain and Northern Ireland

m.j.c.crabbe@rdg.ac.uk

We have developed and tested computer models for scleractinian coral recruitment and survival, and show that in studies of nearly 2,000 coral colonies in reefs off Discovery Bay, Jamaica, severe storm damage not only destroys branching corals, it also results in limiting non-branching coral recruitment. In contrast, estimated recruitment dates of over 1,000 coral colonies in the Wakatobi Marine National Park, S.E.Sulawesi, Indonesia, showed the importance of sedimentation, bomb fishing and coral mining in limiting massive coral recruitment and survival. Studies on corallite dimensions - width, height, densities, and inter-corallite distances - of individual coral colonies of *Galaxea fascicularis* showed that under light-limiting conditions, *Galaxea fascicularis* has developed strategies to optimise energy utilization from heterotrophic feeding and photosynthesis, and these different strategies can be implemented within a single colony. Under low light conditions, distribution and size of corallites is such as to optimise heterotrophic nutrition, while in conditions where light is not limiting, distribution and size of corallites is optimal for photosynthesis. In areas where bomb fishing is a major problem, monitoring of bleaching in *Porites* colonies induced by blasting could be a useful way of monitoring blast fishing practices in susceptible areas.

Tropical Cyclone Impacts on Coral Reef Communities: Modelling the Disturbance Regime in the Great Barrier Reef Region, 1969-2003

*Marij L PUOTINEN**

Townsville, QLD 4811 Australia

gempl@jcu.edu.au

Tropical cyclones periodically cross the Great Barrier Reef (GBR), generating large waves that cause structural damage to reefs, ranging from broken corals to removal of entire sections of substrate. Over time, repeated impacts can significantly alter coral reef community structure. Thus, effective management of the GBR requires an understanding of the cyclone disturbance regime (which reefs are likely to be affected and how often). However, the spatial distribution of cyclone damage over time across even single reefs for most of the GBR is poorly known. Though cyclone disturbance patterns operate over century time scales and 100s of km space scales, most studies have examined single storm events across a few reefs or many storm events for a single reef. Further, detailed observations of cyclone damage to reefs in the GBR are rare. Examining the impacts of cyclones over time thus required reconstructing a likely disturbance history from what information was available. Meteorological models were used to hindcast the likely magnitude and distribution of cyclone energy from the meteorological record. This hindcast energy, along with measures of the spatial patterning of reefs, was linked statistically to field observations of reef damage to predict the distribution of cyclone disturbance of areas not surveyed. Implementing the requisite meteorological and ecological models within a GIS made it feasible to apply these techniques over a longer time period (~3 decades) and across a larger area (the entire GBR) than has been done before. The resultant cyclone history can be used to examine the degree to which cyclone disturbance controls broad measures of reef community structure (coral coverage). Four types of damage were successfully modeled: coral breakage, dislodgement of massives, exfoliation and severe damage of any type. The timing of predicted damage of these types suggests that cyclone disturbance of the GBR is intermediate in nature.

Spatial Dynamics of River Plumes in the Great Barrier Reef

*Lioudmila AMETISTOVA**, *Ian S F JONES*, *Shigeru TABETA*

Ocean Technology Group J05, University of Sydney, Sydney 2006, Australia

lametist@yahoo.com

Protecting water quality in the Great Barrier Reef World Heritage Area is recognized as one of the major challenges facing management of the area. One of the most important processes directly impacting the Great Barrier Reef (GBR) is the input of terrestrially derived nutrients and sediments to nearshore regions. This mainly occurs via river run-off, especially during periods of intense rainfall typically associated with tropical cyclones. An empirical-analytical bio-optical model for a coastal region in the vicinity of the Herbert River (Central GBR) was developed, which relates satellite-derived (SeaWiFS) optical properties to physical and biological parameters of the surface waters of the region. The model was verified using sea-truth data collected during field studies in 2002-2003 and applied to a flood event in 1999. The dynamics of Herbert River plumes observed from the space helped in understanding whether sediments and pollutants coming from the river reach coral reef ecosystems during high intensity low frequency events. Numerical modelling is essential in order to understand transport processes of river-origin matters or to predict environmental change in the future. A 3-D hydrodynamic model of the Herbert River estuary and the nearby offshore region was constructed as the joint project between Tokyo and Sydney universities. It takes as input the tide, the alongshore coastal current at the GBR boundaries and the freshwater inflow from the Herbert River. Including suspended sediments component in the major module further expanded the model. The results are then compared to the concentrations of relevant parameters observed by satellites. The combined remote sensing and modelling approach enabled to monitor discharge properties, composition and spatial dynamics of river plumes entering the GBR.

How Can Floods Drive Diversity in a Non-reefal Coral Community?

*Juan C ORTIZ**, *Diego ROJAS*

Centre for Marine Studies, The University of Queensland, St. Lucia QLD 4072, Australia

jortiz@marine.uq.edu.au

The non reefal coral community found in Chichiriviche de la Costa cove (Central Venezuela) was affected by intense rains (10 times higher than average) in December 1999. This event led to flooding of the Chichiriviche River and landslides that covered part of the coral community. This community was originally characterized in March 1999 and characterized again in May 2000. It showed relatively high richness (24 species) and low live coral cover (6.6%) before the disturbance compared with other non reefal coral communities of the Caribbean. After the disturbance 5 species present in the original characterization were not found. These were species with cover lower than 0.5% before the disturbance. A reduction of 42.4% in the total live coral cover was also observed. In both characterizations the community appeared divided in three sectors, each one presenting different ecological characteristics. The analysis of the disturbance of 1999 and measurement of salinity, radiation and turbidity among the community done in 2002 showed that each of the zones presented different environmental conditions. The most disturbed area presented the highest environmental heterogeneity; lowest live coral cover, lowest richness, highest evenness and highest structuration in relation to the depth gradient. The less disturbed area showed an opposite pattern for all those variables. The loss of rare species in the most disturbed area produced an increase in the evenness, while in the less disturbed area few rare species were lost maintaining the evenness low. If we consider the flood of December 1999 a magnification of the seasonal freshwater and sediment discharge into the cove, it is possible to explain the high richness found in this community as a consequence of an extinction-colonization dynamic equilibrium. This mechanism would drive the community to a relatively constant number of species, but with periodical variations in the evenness through time.

Impact of Storm Waves and Storm Floods on Hawaiian Reefs*Paul L JOKIEL**P.O. Box 1346, Kaneohe, Hawaii United States of America
jokiel@hawaii.edu

Major storms are infrequent events of high intensity and short duration that can exert a profound influence the structure of Hawaiian reefs. Extreme wave energy directly damages corals and retards coral community development. A paradox is that storm surf also represents a positive factor that maintains vitality of many communities through the mobilization and removal of terrigenous, calcareous and organic sediments that otherwise will smother a reef system. Flood events erode the land and deposit sediments on the reefs that can kill corals and block recruitment of new coral colonies. Fresh water delivered by storms also can lower local salinity to levels that are lethal to corals and reef organisms. Nutrients and pollutants associated with fresh water runoff are transported onto coral reefs during such storms. The impact of these events is poorly understood for several reasons. These events are very transient in nature and seldom are observed directly on reefs due to difficulties in making observations during conditions of extreme wave motion or turbidity. The duration of most coral reef investigations is too short to allow evaluation of the major storm events that occur with a frequency of decades to hundreds of years. The pattern of impact for a major storm is highly complex, and influenced by local bathymetry, shoreline topography and directionality of the storm event. Nevertheless, sufficient data are available to provide a general spatial and temporal description of the relative importance of major storm waves and storm floods on reefs throughout the main Hawaiian Islands.

Fate of Flood Sediment on a Fringing Coral Reef, Molokai Hawaii*Michael FIELD**, *Michael BOTHNER*, *Pat CHAVEZ*, *Susan COCHRAN-MARQUEZ*, *Paul JOKIEL*, *Andrea OGSTON*, *Curt STORLAZZI*400 Natural Bridges Drive, Santa Cruz, California United States of America
mfield@usgs.gov

Major low-pressure systems converged on the island of Molokai in late November 2001 and late January 2002, generating heavy rainfall and coastal flooding. Rainfalls caused heavy run-off of soil and boulders, causing road closures and forming coastal deltas and turbid sediment plumes. Aerial photographs showed discrete sediment plumes whose locations were related more to soil availability in the adjacent watersheds than to rainfall intensity. We monitored the effects of floods on the reef with current meters, wave gauges, turbidity sensors, bottom cameras and sediment traps on the shallow reef flat and the adjacent fore reef.

Transport of the sediment in plumes along the reef flat was sporadic, and the highest turbidity levels at the instrument site occurred several days to weeks after the storm. Turbid water flowed across the reef flat as well as alongshore, and was deflected onto the fore reef by a large, impervious wharf. The flow of turbid water onto the fore reef was documented by photographs obtained every 6 hours at a depth of 11 m. An array of time-series sediment traps at 10 m water depth recorded maximum sediment collection rates in the days immediately following the flood event. Sediment collection rates were also influenced by resuspension caused by wave generated bottom stress.

The reef flat at Molokai is an important storage site for terrigenous sediment transported to the coast, both in large flood events, and in small seasonal stream flow. Sediment is repeatedly re-suspended and advected along the reef flat, with large amounts being transported onto the fore reef in the weeks following a flood, followed by decreasing amounts through time. Because sediment introduced from flood events is re-suspended many times before ultimately being transported off the reef, the potential impact to the coral reef community from terrestrial run-off is large.

Natural Stress on Coral Reefs in Hawaii: A Multi-decade Study of Storm Wave Impact and Recovery*Steven DOLLAR**1000 Pope Rd. Honolulu HI 96822 United States of America
sdollar@flex.com

Physical stress from storm waves is the dominant force shaping the structure, composition and succession of open coastal reefs in Hawaii. While storm-induced impacts to reefs are instantaneous, and thus easily measured, the recovery cycle has been difficult to quantify because the successional process takes place on a timescale of decades. Damage caused by catastrophic storm waves and subsequent recovery was investigated with a series of line transects on a reef off the west coast of Hawaii over a 30-yr period (1973-2002). At the initiation of the study in 1973, three discrete zones existed across the reef, each defined by a different dominant coral and structural composition. In 1980 a Kona storm generated the largest storm surf on record for the area which destroyed the coral zonation pattern almost entirely. Recovery of the reef measured in 2002 varied significantly between zones. The shallowest region, dominated by the pioneering species *Pocillopora meandrina*, completely recovered to pre-storm conditions. Coral cover in the mid-depth zone increased significantly but with different species assemblages, while the deep slope zone was reduced to a bed of rubble fragments which showed very little recovery over the 22-yr period. These results provide a good illustration of the intermediate disturbance model, and provide insight into the processes that control the constructional composition of Hawaiian reefs. Because responses of reef ecosystems to human-induced stress are superimposed on natural cycles of impact and recovery, a good understanding of the response of reef systems to natural stresses is an important aspect in evaluating the effects of human activities.

The Influence of Waves on Reef Morphology and Coral Distribution: Molokai, Hawaii*Joshua B LOGAN*, *Curt D. STORLAZZI**, *Michael E FIELD*, *Eric K BROWN*, *Paul L JOKIEL*USGS Pacific Science Center, 400 Natural Bridges Drive, Santa Cruz, California, 95060 United States of America
cstorlazzi@usgs.gov

The fringing reef off southern Molokai, Hawaii is currently being studied by the U.S. Geological Survey and the University of Hawaii. In one component of this study, remote sensing, modeling and field observations were utilized to understand the physical controls on reef morphology and the distribution of different coral species. An extensive fringing coral reef stretches along the central two-thirds (40 km) of Molokais south shore; along the east and west ends there is only a thin veneer of living coral with no modern reef complex. Two major morphological features of the fringing reef are strongly correlated with wave energy. First, reef flat width was found to decrease exponentially with increasing wave energy. Second, mean spur-and-groove (SAG) height and wavelength were shown to be inversely proportional to wave energy. In high-energy environments, SAG morphology remains relatively constant across all water depths. In low-energy environments, however, SAG structures display much greater variation, being relatively small and narrow in shallow depths and developing into much larger and broader features in deeper water. A model was developed that calculates wave-induced hydrodynamic forces on corals of a specific form and mechanical strength. From these calculations, the wave conditions under which specific species of corals would either remain intact or break due to the imposed wave-induced forces were determined. By combining this hydrodynamic force-balance model with various wave model output for different oceanographic conditions, we were able to map the locations where specific coral species should be stable (not subject to frequent breakage). The combined model output was then shown to correlate with data on coral species distribution and coral cover at 12 sites along Molokais south shore. Our study quantitatively documents the hypothesis that waves exert control on the morphology of the reef tract and are important in defining coral community structure.

Variability of Hawaiian Reef Accretion and El Nino over the Holocene Epoch

*John J ROONEY**, Charles H FLETCHER, Mary S ENGELS, Eric E GROSSMAN, Michael E FIELD

Kewalo Research Facility, 1125B Ala Moana Blvd., Honolulu, HI 96814, USA
United States of America

John.Rooney@NOAA.gov

Modern reef accretion in the main Hawaiian Islands is generally restricted to areas that are sheltered to some degree from large wave events. Core and hand samples of fossil reef from a number of localities in the islands show evidence of accretion during the early to mid-Holocene epoch in areas where continued accretion is now precluded by high wave energy. In most cases the change in patterns of accretion can be attributed to variations in sea level, or to reef growth decelerating as the reef "catches up" to sea level. However, samples from selected sites on Kauai, Oahu, and Molokai show evidence of rapid accretion that abruptly decreased or terminated approximately 5,000 years ago. This decline in reef accumulation occurred prior to the best estimates for the decrease in relative sea level rise (ca. 3,000 years ago) during the mid-Holocene high stand of sea level in the main Hawaiian Islands. Despite the availability of hard substrate at a range of depths suitable for reef organism recruitment and growth, accretion has not resumed at these locations, offering further evidence that factors other than sea level may be responsible. The primary limiting factor today appears to be wave energy associated with large North Pacific swell events and hurricanes, both of which have a tendency to deliver more energy to Hawaiian waters during El Nino years. Several studies have shown that El Nino/Southern Oscillation (ENSO) events were both fewer in number and smaller in magnitude prior to approximately 5,000 years ago. We hypothesize that reduced ENSO activity resulted in fewer and smaller severe wave events in Hawaii during early-mid Holocene times, enabling reef accretion in areas where it is precluded by large North Pacific swell and hurricane-generated wa

Corals and Coral Reefs as Recorders of Decadal-scale Holocene Storm Frequency: An Example from the Dominican Republic

*Lisa GREER**, Peter K SWART, H Allen CURRAN, Gala GUERARD

Geology Department, Lexington, VA 24450 United States of America

greerl@wlu.edu

The Holocene Enriquillo Valley fringing reef (Dominican Republic) offers a unique and robust record of storm activity from ~7 to 5 ka. Changes in reef facies, microfaunal assemblages, and the geochemistry of corals and other carbonates within reef framework may reflect profound salinity changes associated with passing storms during the mid to late Holocene. While it is impossible to quantify paleo-hurricane statistics (e.g. amount of rainfall, wind speed, or speed of passage), changes in Enriquillo reef morphology and species composition attest to the impact that tropical storms and hurricanes may have had on the overall architecture of this reef during the mid Holocene. Several key facies changes within the reef may even have originated in response to particularly intense storms. Lateral persistence of unconformities, the variable thickness of storm sediment layers, or grain size of sediments deposited within reef framework may even lend clues to the intensity of individual storms. These data suggest that tropical storm activity was integral to the formation and demise of the Enriquillo reef. Analyses of microfossil assemblages and isotopic compositions associated with storm and calm-water conditions suggest that passing storms resulted in dramatic changes in salinity of the paleo-Enriquillo embayment. The most promising evidence for storm generated salinity changes is recorded in the high-resolution stable carbon and oxygen isotopic variability of massive Enriquillo coral skeletons. Dramatic shifts of up 2-3 per mil (oxygen) in the span of a few years may be attributed to rapid fresh-water flooding of the semi-restricted embayment. These shifts occur with an approximate cyclicity that may reflect decadal scale changes in tropical Atlantic sea surface temperatures that mediate tropical storm generation at present. Comparison of these data with historical records indicate a modest increase in frequency of tropical storms in the region since ~5 ka.

Pre- and Post-disturbance Differences in the Growth and Survival of Coral Transplants in Single- and Mixed-species Plots

Romeo M DIZON*, Helen T YAP

Diliman, Quezon City Republic of the Philippines

dizonr@upmsi.ph

The relationship between biodiversity and ecosystem function is currently a hot topic in ecology. Unfortunately, very few marine studies have been done to explore the issue. In this paper, the responses of coral assemblages to nutrient enrichment were assessed in the field using monospecific (*Porites cylindrica*) and multispecific plots (*Porites cylindrica*, *Porites rus* and *Pavona frondifera*) from September 1999 to October 2002. Fertilizer was applied to half of the plots (both mixed- and single-species plots) using flowerpot diffusers in September 2000. Buoyant weight measurements (all species) and branch tip counts (*P. cylindrica*) were periodically done on the corals. Results show that prior to nutrient enrichment, *P. cylindrica* transplants in the mixed-species plots had higher growth rates (ANOVAR, $P=0.018$) than those in the single-species plots. However, upon the introduction of the perturbation, succeeding comparisons show a higher survival experience in the single-species transplants than the *P. cylindrica* in the mixed-species plots (Logrank test, $P<0.05$). Growth rates were also significantly lower in the enriched plots than those in the control plots (ANOVAR, $P=0.001$). *Pavona frondifera* grew the fastest, followed by *P. rus*. Results indicate that (1) diversity enhances community processes in unperturbed systems but is overridden by the adverse effects of chronic disturbances, (2) less diverse communities exhibit a greater resistance to perturbations, and (3) corals show differential sensitivities or tolerance thresholds to environmental stresses. These results demonstrate that the positive effects of diversity on ecosystem processes and its negative effects on ecosystem stability are not necessarily mutually exclusive. Reef communities tend to optimize their functions within the limits set by prevailing environmental conditions, resulting in a continuing trade-off between productivity and persistence.

Coral Behaviour Generates Reef Morphology

David BLAKEWAY*

Crawley, WA 6907, Australia Australia

d.blakeway@graduate.uwa.edu.au

The morphology of coral reefs is generally attributed to environmental influences, including the topography of the reef's substrate and the effects of waves and currents. Little is known about natural reef growth forms in the absence of these influences. Here I use computer simulations to show that characteristic large-scale reef morphology can arise as an emergent property of local-scale coral behaviour, and that specific reef patterns are diagnostic of specific coral types.

The Effect of Morphology, Polyp Size and Depth on Feeding in Three Species of Panamanian Corals

James E PALARDY*, Andrea G GROTTOLO, Kathryn MATTHEWS

240 South 33rd Street, Philadelphia, PA 19104 United States of America

jpaldary@sas.upenn.edu

Although it is known that corals obtain fixed carbon as a result of both photosynthesis and heterotrophy, the proportionate contribution of each source remains unclear. Feeding rates and the species composition of zooplankton captured by three coral species were directly observed in situ at two depths on a shallow patch reef at Isla Contadora, Gulf of Panama, in February 2003. *Pocillopora damicornis* (branching, small polyps), *Pavona clavus* (mounding, small polyps) and *Pavona gigantea* (mounding, large polyps) were placed inside feeding chambers on the reef and exposed to high concentrations of natural zooplankton. After one hour of feeding, the corals were collected, and the number and type of zooplankton within 100 polyps of each fragment counted. The quantity of zooplankton captured increased with depth, increased with polyp size at both depths, and was significantly higher in corals with mounding morphology than in corals with branching morphology. Although these results seem to confirm Porters (1976) model for resource partitioning, increased prey capture was not due to an ability of large-polyped corals to capture bigger or more diverse prey. Species composition of captured zooplankton was not correlated with polyp size, morphology, or depth, suggesting that higher feeding rates in large-polyped corals may be due to increased feeding area and/or greater feeding efficiency.

Algal Blooms on the Reefs of West Maui: Linking Nutrient Dynamics to Large-scale Patterns in Algal Abundance

Jennifer SMITH*, Celia SMITH, Heather SPALDING

3190 Maile Way, Honolulu, Hawaii 96822 United States of America

jesmith@hawaii.edu

Large-scale algal blooms have been occurring on the reefs of west Maui for the last decade. Until recently very little research had been conducted that directly or indirectly linked nutrient input to algal abundance. The goals of this study were to sample several different physical and biological variables along a depth and distance from shore gradient to determine if relationships were present among the measured variables. Samples were collected every other month for 6 months. Ambient water column nutrient concentrations were generally low or undetectable while sediment pore water samples were significantly enriched in ammonium, phosphate and silicate concentrations with simultaneous low salinity, indicating ground water intrusion. Algal tissue nutrients in terms of percent tissue nitrogen and delta 15N all showed a near shore enrichment source which generally corresponded to pore water nutrient concentrations. These results suggest that large-scale algal blooms occurring on the reefs of west Maui may be enhanced by anthropogenic nutrient enrichment.

Reticulate Evolution: A Look at Coral Population Structure across Multiple Spatial Scales

*Mark J A VERMEIJ**, *Stuart A SANDIN*

Southeast Fisheries Science Center, 75 Virginia Beach Drive, FL33149 Miami United States of America
mark.vermeij@noaa.gov

We investigate the occurrence of two morphotypes in a coral population in response to environmental variability at three spatial scales: within-reef scale (reef complexity at a 10cm scale), island scale (across sites on one island), and the basin scale (across islands within the Caribbean). New genetic and morphological data demonstrate that the two principal morphotypes of the *Madracis pharensis/decaetis* complex show low genetic diversification, suggesting that hybridization (or interbreeding) is common. Complementary data relating the frequencies of habitat types with relative frequencies of the two morphotypes at the within-reef and island scales support this model of interbreeding within the complex. However, at the largest scale, we find that these smaller-scale patterns are not consistent. Among-island variability of habitat conditions and patterns of dispersal are likely to be driving these spatial population patterns at the largest scale. By relating environmental heterogeneity to the population composition in a coral morphospecies complex, we have a novel opportunity to test patterns and processes of coral (reticulate) evolution in the field.

Multi-scale Relationships between Abundances of Coral Reef Herbivores and Availability of their Resources

*Richard M WILDER**

University of California, Santa Barbara, CA 93106-6150 United States of America
wilder@lifesci.ucsb.edu

Using field surveys, I determined the relationships between abundances of herbivorous fish and sea urchins and the availability of food and shelter in lagoons surrounding Moorea, French Polynesia at two spatial scales: one larger than the daily ranges of both fish and urchins (2-4 km between sites), and one within the daily range of fish but larger than the range of urchins (75-200 m between sites). At the larger scale, abundances of both fish and urchins were related positively to the amount of shelter at a site, but were not related to food availability. At the smaller scale, the abundance of fish was not related to either resource, whereas the abundance of urchins was related positively to food availability but not shelter availability. The lack of resource association with fish abundance at the small scale was likely a result of the high mobility of fish, which homogenized patterns in their abundance at the smaller scale and obscured any small scale associations with their resources. However, variation in food availability among small scale sites elicited a behavioral response by fish, in which foraging rates of fish were faster in areas of greater food availability. The switch between spatial scales in resource association with urchin abundance was likely caused by the presence of deep water barriers among large scale sites, which prohibited movement among sites. As a consequence, large scale urchin abundance patterns were likely a result of settlement and/or predation patterns whereas small scale patterns were likely a result of movement among sites. These results indicate that (1) relationships between abundances of organisms and their resources change with the temporal and spatial scale of analysis, and (2) resources influence different demographic processes at different scales, ultimately influencing abundance patterns of organisms.

Latitudinal Patterns of Marine Herbivorous Fishes in the Western Atlantic

*Sergio R FLOETER**, *Carlos E L FERREIRA*, *Michelle J PADDACK*

735 State St., Suite 300, Santa Barbara, CA 93101, USA
floeter@nceas.ucsb.edu

Herbivorous fishes are important components of trophic relationships in reef systems and are known to have a profound impact on the distribution, abundance and evolution of algae. The relative diversity of herbivorous fishes is known to decrease towards higher latitudes, but actual abundance and biomass patterns remain unclear due to a lack of studies covering wide latitudinal ranges with standardized sampling. Standardized underwater visual censuses (UVC) in 10 sheltered and shallow (<10m) localities throughout the western Atlantic provided comparable data on densities and biomass of the four main herbivorous fish families (Acanthuridae, Kyphosidae, Pomacentridae, Scaridae) along an extensive latitudinal gradient (9 to 28° lat.). These families are easily estimated by UVC, and comprise the bulk of herbivore biomass. Feeding rate (measured as bites per 5min) of the ocean surgeonfish *Acanthurus bahianus* were estimated at three locations (Arraial do Cabo, SE Brazil; Florida Keys; Bocas del Toro, Panama). Despite different histories and habitat characteristics (i.e. Brazil and Caribbean), simple linear regressions produced significant negative relationships between latitude and (1) total density, (2) biomass, (3) species richness and (4) relative proportion of herbivorous fishes in Atlantic reef systems. The trends are driven by different components in the different hemispheres (i.e. scarids in the Caribbean and acanthurids in Brazil). The dominance of scarids in the Caribbean may reflect the greater degree of reef development. Feeding rate of *Acanthurus bahianus* is significantly higher at higher temperatures (i.e. Panama > Florida > SE Brazil). At 18° C, near the thermal limit of distribution of the species, feeding rate is proportionally lower than expected given the metabolic rate of teleost fishes compared to warmer temperatures, suggesting a temperature-related physiological constraint.

Reconciling the Relationship between Pelagic Larval Duration and Range Size in Reef Fishes: The Importance of Dispersal Barriers

*Benjamin I RUTTENBERG**, *Sarah E LESTER*

Dept of EEMB, University of California, Santa Barbara, California 93106 United States of America
ruttenbe@lifesci.ucsb.edu

Dispersal ability is often invoked as an explanatory factor in range size variation. Marine fishes are ideal for testing this theory because they include species with contrasting dispersal abilities and range sizes. Pelagic larval duration (PLD) is often used as a proxy for dispersal ability because while PLD may not be a perfect descriptor of average dispersal distance, time spent in the plankton should be correlated with dispersal potential. There is a wealth of PLD data, estimated from otolith increments, available for tropical reef fishes. Previous research examining the relationship between PLD and range size in reef fishes has found equivocal results, but all of these studies were limited either in taxonomic breadth and/or geographic coverage. We have assembled a database that includes all published tropical reef fish PLD data, covering over 350 species from 28 families in all tropical oceans. We also use a fully quantitative measure of range size, defined as the maximum linear distance between the furthest two points in the range of a species. Using these data, we examine the relationship between PLD and range size across multiple scales, ocean basins, and taxonomic levels. Our comprehensive analyses resolve contradictory prior results; we found that PLD is positively correlated with range size only in the Indo-Pacific, and only when including species whose ranges span formidable dispersal barriers, such as those between the Central Pacific and Hawaii or the Eastern Pacific. This relationship not only holds at the generic and family levels but PLD explains more of the variance in range size at higher taxonomic levels. Our results have implications for our understanding of both the processes that determine range size and speciation in reef fishes.

Analysis of Caribbean-Wide Reef Fish Data Using Multiple Community Assembly Rule Models

*Brice X SEMMENS**, Peter J AUSTER

Box 351800, Seattle, Washington 98195-1800 United States of America
semmens@u.washington.edu

Patterns in reef fish assembly have the potential to confound conservation efforts made without knowledge of such patterns. While many studies have demonstrated the importance of species interactions on coral reefs using experimental approaches, few have looked for emergent patterns in geographically broad community data sets. We used the Atlantic and Gulf Rapid Reef Assessment (AGRRA) dataset to test the following assembly rule models: Diamond's Assembly Rules, Guild Proportionality, Nestedness, and Size Structure. The AGRRA dataset contains community data from 20 reef areas of the greater Caribbean. AGRRA reef fish surveys include all members of Acanthuridae, Chaetodontidae, Haemulidae, Lutjanidae, Pomacanthidae, Scaridae and certain members of Serranidae and Balistidae. We tested the assembly rule models using EcoSim software, Nestedness Calculator software, and custom Matlab programs. Our results suggest that Caribbean reef fish assemblages are both nested and structured by interspecific competition. While it is more common for nestedness to occur in systems structured by extinction, we believe that the observed nestedness in Caribbean reef fish assemblages results primarily from colonization. Habitat heterogeneity and species-specific habitat affinities can cause the same type of species-by-site 'checkerboarding' that results from inter-specific competition. We therefore re-evaluated the data using an analysis method that accounted for species' habitat preferences, and again found evidence of inter-specific competition. However, there were no consistently strong pairwise species interactions across reef sites.

Do Food Availability and Population Density Determine Fecundity in a Coral Reef Fish? Evidence from an Experiment and an Observational Study of Natural Populations

*Jameal F SAMHOURI**

621 Charles E. Young Drive South, P.O. Box 951606, Los Angeles, CA, 90095-1606 United States of America
samhour@ucla.edu

Many studies of fish population dynamics focus on abiotic factors that lead to variable replenishment of populations, and top-down processes, i.e. predation, that result in removal of individuals from populations. Fewer studies find evidence for the importance of bottom-up effects, i.e. competition due to resource limitation, in producing changes in demographic rates. I combined an experiment with observations of natural populations to evaluate the importance of resource (food) limitation and density-dependence in driving egg production in a planktivorous Caribbean damselfish, *Stegastes partitus*. In the experiment, I manipulated food availability and conspecific density of adult *S. partitus* on a patch reef array near Lee Stocking Island, Bahamas, to address two main questions: (1) Is per-capita fecundity density-dependent?, and (2) Does food limitation constrain fecundity? Increased conspecific density caused a decrease in the magnitude and frequency of egg production, while food limitation decreased only the frequency of egg production. Results from the small-scale experiment thus suggested that fecundity should be density-dependent and food availability should constrain fecundity in natural populations of *S. partitus*. To examine these ideas, I monitored egg production in two populations occurring on natural reefs near the experimental reef array but separated from each other by 10 km. The lower-density population at Goby Spot Reef showed an increased frequency of egg production relative to the higher-density population at Tug & Barge Reef. I also related natural food availability to egg production at these two sites. I conclude that demographic processes operating on local scales are reflected to some degree in larger-scale spatial patterns of *S. partitus* population dynamics.

Island-scale Differences in Density-dependent Mortality of Juvenile Bluehead Wrasse, *Thalassoma bifasciatum* (Labridae), on Continuous Caribbean Reefs

*J Wilson WHITE**

Dept. of EEMB, University of California, Santa Barbara, CA 93106-9610
 United States of America
w_white@lifesci.ucsb.edu

The focus of reef fish ecology research is shifting towards scaling-up of local reef-based processes to explain metapopulation-wide patterns. Unfortunately, the success of these efforts may be limited if local processes vary over large spatial scales. In particular, it is unclear to what extent density-dependent processes are consistent within a species and across space and time. Do cohorts settling at different times or places experience density-dependence of the same strength and at the same time in their life-history? For example, research on populations of bluehead wrasse at St. Croix, USVI, has revealed spatially variable patterns of both recruitment and juvenile mortality. Recruitment is consistently high at a leeward site (Butler Bay) but relatively low and variable at a windward site (Jacks Bay). However, both sites have adult bluehead populations of consistently similar size. In order to investigate natural patterns of recruit mortality, I batch-tagged recruiting fish in small plots on continuous reefs at both sites and monitored their survival for approximately 1 wk (after which juvenile fish become less site-attached). Mortality was density-independent at both sites in months with low recruitment; during a large recruitment pulse mortality became density-dependent at Butler Bay but remained density-independent at Jacks Bay. This pattern may be explained by data revealing both higher predator densities at Butler Bay and greater habitat complexity at Jacks Bay. Alternatively, density-dependent mortality may occur at a different spatial scale or life history stage at Jacks Bay. In either case, these results demonstrate that local populations may experience density-dependence of varying strengths and at different spatial scales, thus affecting our ability to scale-up experimental results to explain large-scale population dynamics. However, preliminary modeling efforts using the St. Croix data suggest that m-scale processes may explain island-wide population patterns provided information on predator density and habitat quality is incorporated.

The Effect of Predation Risk and Group Size on Fitness of a Common Prey Fish on Coral Reefs

*Ameer A ABDULLA**

Townsville, Queensland 4811 Australia
Ameer.Abdulla@jcu.edu.au

Little emphasis has been placed on non-lethal (risk) effects of predators that may influence prey behaviour in marine environments. This study investigated such non-fatal interactions, which have the potential to affect the fitness of coral reef fish. We present a foraging model that predicts predators will significantly reduce the growth of a prey individual at low prey group size, but will have a smaller effect at higher prey group sizes due to a reduction in per capita vigilance. We tested these predictions in the field using experimental manipulations of group sizes of *Pomacentrus moluccensis*, a tropical reef damselfish, and a system of artificial coral reefs and cages at Lizard Island on the Great Barrier Reef. Results indicate that the risk of predation affects the behaviour and reduces the growth rate of the prey. At high group sizes these effects were diminished. The data suggest that suppression of growth due to predation risk may affect population dynamics of adult coral reef fish by regulating the rate of individuals reaching reproductive maturity and/or by increasing the probability of size-selective mortality on juveniles. Observational data collected from Lizard Island reefs suggest that a reduction in per capita vigilance with increase in group size may explain the diminished individual costs of predation risk recorded in large groups. Social groups in coral reef fish systems may have evolved, in part, to optimise the trade-offs between survival and reduced growth.

Using Local Knowledge in Coral Reef Resource Management

*Kenneth RUDDLE**

Katsuragi 2-24-20, Kita-ku, Kobe-shi, Hyogo-ken 651-1223 Japan
i3k-rddl@asahi-net.or.jp

The basic characteristics and components together with the potential practical usefulness of local coastal-marine knowledge systems are now familiar. But most research remains academic and is little used by managers and policy makers. In this presentation I summarize the main findings of the field, and describe an on-going project to systematize and use local knowledge in fisheries management planning and policy design. Some areas in which modern coral reef resource management could be deficient and where fishers could contribute complementary local knowledge to policy-makers and planners are (1) Routine Fishing Behavior, (2) Local Management Methods, (3) Conservation, (4) Stock Assessments, (5) Environmental Impact Assessment, (6) Local Hydrography, (7) Mapping, (8) Fishing Methods and Technologies, and (9) Fish Systematics and Biology, among probably many others. Although local knowledge is a crucial source of information for fishery development, its generally unsystematic presentation and nebulous content makes use by policy makers or managers difficult. Using field data obtained through Participatory Rural Appraisal (PRA) local knowledge can be effectively systematized, analyzed and displayed visually using a Geographical Information System (GIS) for use in fisheries management. In this way local fisheries knowledge can be converted into geo-spatial data form via GIS, and the succinct results used easily to guide fishery management and planning, especially by offering directions for rights-based fisheries and co-management. Local knowledge is rarely used in coastal-marine development projects or management systems. Although widely attributed to disparagement and interrelated ideological and institutional factors, academic researchers, who have largely failed to organize and present their information in a way usable by planners and policy makers, must share the blame. The on-going research described here shows a way to overcome this.

Reef Fisheries Co-management in Okinawa

*Shinichiro KAKUMA**

1 Asahimachi Naha Okinawa Japan
kakuma@subtropics.or.jp

Reef fisheries resources in Okinawa have decreased recently. Typical conditions for sub-tropic fisheries management are many species, many remote islands, few researchers, many recreational fisheries, and a strong sense of community. Considering these conditions, efficient compliance and enforcement, the resources should be managed primarily through partnership between the government and the communities (co-management). Among management tools (e.g. seasonal closures, size limits, gear restrictions, catch quotas, licenses, etc.), Marine Protected Area (MPA) seems most effective. Alternative income for the local fishermen is essential because usually, in the co-management, initial reduction of the harvest is required. Except for aquaculture, Fish Aggregating Devices (FADs) may play an important role as alternatives because the fishing pressure is diverted to offshore from coastal areas that easily receive the influence of over-fishing. The fisheries around FADs in Okinawa are characterized by not being managed by the government, but by fisheries cooperatives and fishers. The biggest problem of FAD fisheries is loss of FADs by typhoons, however such accidents are decreasing as there are more sub-surface FADs these days. The Onna-son fisheries cooperative drew up a community-based management plan of sedentary resources as part of the fishery extension project in 1982. The establishment of MPAs was a pillar of the management tools. The support from the government included dispatch of extension officers, provision of hatchery-produced juvenile giant clams, and guidance of re-stocking techniques. Another comprehensive fisheries co-management project was implemented intended for an emperor fish in Yaeyama area in 1995. Okinawa Prefectural Fisheries Experiment Station conducted various researches for the resource management. MPAs were set in four main spawning grounds with a closed season in a main spawning season of April and May, and all fishing methods and all fish species are prohibited. Both cases of co-management have seemed successful to date.

Conflicts and Co-management in Reef Fisheries of Ryukyu Archipelago, Southwestern Japan

*Tomoya AKIMICHI, Jun AKAMINE, Sinichiro KAKUMA, Daisuke TAKEKAWA, Maki KAWABATA, Shigeru YANAKA, Soyo TAKAHASSHI, Fujio UEDA, Naoki NAITOH, Taku IIDAI**

Takashima-cho 335, Kawaramachi, marutamachi, Kamigyo-ku, Kyoto 602-0878 Japan
akimichi@chikyu.ac.jp

The Ryukyu archipelago in southwestern Japan is known as having one of the richest coral reef habitats in the western Pacific. In a long chain of these islands, extending along the northeast to southwest axis, a variety of small-scale fisheries have persisted at least over one hundred years or so. Despite small-scale and geographical delimits, indigenous knowledge and practices employed in reef fisheries have born unique and adaptive values in a local setting. However, these fisheries have recently faced with serious difficulties in sustaining cultural and economic achievements in harmony with the surrounding coral reef environments. External socio-economic changes as well as environmental deterioration process of the coral reefs are major causes of this change. In Okinawa, which administratively covers most of the Ryukyu's island groups, impacts of land-based development since the political return to Japan from the U.S. administration in 1972 have been revealed as serious threats for both small-scale fisheries and the marine environments. Indeed, degradation of coral reefs and failure in coastal management, as well as expanding demand for marine tourists and sea products, and due to land-based anthropogenic activities such as agricultural and industrial pollution, have given negative effects and stresses upon maritime regimes. Based on anthropological field studies, this symposium discusses several distinct instances regarding (1) transformation of indigenous knowledge and practices retained by reef fishermen induced by external impacts and its significances, (2) conflicts over the territorial use of the sea, due to technological and socio-economic changes, and then explore (3) co-management model in nearshore and off-shore fisheries in Ryukyu archipelago. From these instances, further integrative aspects for future management initiatives will be explored in a broad geographical regime of the coral reefs of the world.

Rights to the Environment Based on Practical Knowledge : The Discord between Fishermen Divers and Tourist Divers in Miyako-Jima Island and their Views of Nature

*Daisuke TAKEKAWA**

4-2-1 Kitagata Kokura-minami Kitakyushu, 802-8577 Japan
daisuke@apa-apa.net

In August 1996, "The Miyako-jima Island Diving Dispute", a disagreement over the use of the sea that broke out between those in the diving industry and fishermen, was broadcast nationwide. At the start, both parties tried to resolve the dispute through damage payments, but they were unable to reach an agreement. Gradually they began to realize that the root of the problem was a fundamental difference in how they viewed the sea and marine resources. With respect to the question, "Whose Sea is it?", traditional fishing rights guarantee fishermen certain rights, but they are not necessarily adequate for legally maintaining the coexistence of fishing and tourism. I examine the grounds upon which the rights traditionally brought up by those using the sea as a commons are based. I have come to think that fishermen's sense of ownership with respect to the sea is not based upon any legal right to enclose and monopolize sea territory, but rather that it is based upon practical knowledge of individual fisherman. Put more simply, they consider that the right to use the sea is based on the idea that, "Those who know the sea can use the sea." It is an "open" system whereby the knowledge of each individual user is an asset, and based upon that knowledge, users mutually guarantee each other's rights. This concept of rights is very different from that of farmers, who believe that the land is the basis of all production; it is instead similar to hunters' traditional attitude toward the environment, which is now coming to be understood by ecological anthropologists. In short, it is only through a common recognition of each other's views of nature brought about through dialogue that the fishermen and the tourist divers will be able to resolve their problems and create new rights.

Effect of Squid Black-Ink Soup Intake on Blood Flow through a Parallel Array of Microchannels

*Eiko UEZU**, Keiko KOJA, Michiko SAKIHAMA, Eiko KADEKARU, Kazuo NASHIRO, Midori KUNIYOSHI, Kayoko UEZU, Yuji KIKUCHI

1 Senbaru, Nishihara-cho, Okinawa Japan
u1199949@edu.u-ryukyu.ac.jp

Okinawa is well known as a prefecture for longevity even in Japan. There have been many studies conducted trying to identify what factors which contribute to long lifespan. Food has been gaining attention with its role in longevity. In this study, we have tested the effect of Squid Black-ink soup, a traditional Okinawan cuisine, on blood fluidity. **Materials and Method:** For Squid Black Ink soup, 75g of Aoriika (a kind of squid), 45g of pork (loin), 20g of Hosobawadan (*Crepidastarm lanceolatum* N.), 15g of shaved dry tuna for soup stock, 230 ml of water, and 3g of Aoriika black-ink were used per person. To determine the blood fluidity, blood was drawn using venipuncture with a sterile partially vacuumed syringe coated with 5% heparin, from the middle vein at the inside of the elbow of the lower arm of each subject sitting upright quietly. Blood samples were drawn before the experimental Squid Black-ink soup meal intake along with 150g of white rice, as a control. Additional blood collections were done twice after the meal: post-1-hour and post-2-hour meal. The blood samples were analyzed immediately after the collection according to the method by Kikuchi et. al. with a micro channel array (Bloody 6-7; Hitachi Haramachi Electric Industry). The time it took for 100 µl of blood to flow through the channel was measured. **Results:** By consuming Squid black Ink soup, the time for the 100 µl of blood to flow through the micro array channel was reduced by 11-13 % compared to the pre-meal sample, and thus an improvement of the blood fluidity was observed.

The Humphead Wrasse, *Cheilinus undulatus* : A Threatened Reef Fish of Commercial Importance

*Yvonne SADOVY**

Pok Fu Lam Road, Hong Kong
yvsadovy@hkucc.hku.hk

The humphead wrasse, *Cheilinus undulatus*, is a large (reaching 2m), long-lived reef fish, that has a high value in the international live reef food fish trade, and is also sought for chilled fish domestic markets in SE Asia and the western Pacific. The species fetches high prices alive, and is increasingly being targeted for international trade and tourist markets. It is unable to withstand heavy fishing pressure and, wherever moderately to heavily fished, populations quickly decline; in a few cases the species appears to have been extirpated. As numbers of preferred market-sized fish decline, juveniles are increasingly taken from the wild for grow-out; this is a form of mariculture whereby wild fish are grown to market size, further exacerbating the problem of overfishing. The species cannot be hatchery-raised at present. The combined capture of adults of this naturally uncommon species, high demand and price paid for its flesh, and the practice of juvenile capture is driving populations to very low levels in many areas. Despite protection in several countries, considerable illegal, unregulated and undocumented trade persists, and there is a need for stronger management to be effected. This is a clear example of a reef fish species threatened by commercial exploitation because of a combination of vulnerable life history, high value and uncontrolled fishery and trade. Because of weak or absent national or international controls on this species, creative approaches are needed for major exporting and importing countries to cooperate to assist implementation of domestic laws, improve the compilation of trade data, and ensure sustainable commerce.

Who Is to Be Blamed?: Socio-Cultural Notes on the Blasting Fishing for Livelihoods in the Spratly Islands

*Jun AKAMINE**

Yamanohata 1, Mizuho-cho, Mizuho-ku, Nagoya, Aichi Japan
akamine@hum.nagoya-cu.ac.jp

The dynamite fishing or explosive fishing is one of the popular fishing methods in the Spratly islands, southern portion of the South China Sea. Being destructive not only to coral substrate but also juveniles of different species, it has been prohibited by the Philippine law such as PD704 in 1975 and Republic Act 8550 in 1998. However, the dynamite fishing is still rampant in the Spratly islands. Fishery fleets from the southwestern Philippines frequents the area. Some 18 to 20 fishermen engage in 2-month fishing expedition. Each trip costs at least five thousand dollars. The whole operation is funded by fish traders in the western Mindanao. Catch is often limited to *Caesio* spp or what is locally called sulig or sulid. The catch is processed into salt-preserved dried fish. The dried product is shipped and traded at Mindanao where the inland farmers produce dollar-earning crops. The fishermen are the refugees from the conflicts in the 1970s between the Muslim rebellions against the central government. The paper pays attention to the historical and marketing characteristics of the dried fish industry in the southern Philippines and points out some structural problems on the dynamite fishing in the Spratly Islands. Also, the paper discusses socio-cultural aspects on the resource exploitation among the fisheries communities in the Philippines, which support the destructive fisheries.

Role of Fisherwomen in Coral Conservation and Management: A Report from the Reef Dependent Fishing Village (Tharuvaikulam) of Gulf of Mannar, Southeast Coast of India

*Jamila PATTERSON**, Deepak V SAMUEL, Dan WILHELMSSON

44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India
jamilapat@hotmail.com

Tharuvaikulam fishing village is located along the southern part of Gulf of Mannar, Southeast coast of India. Fisherwomen make up about 55% (5524) of the total population of 10,085. The fisher folk of this village involve in reef related fishing activities near the two islands namely Vaan and Koswari. Earlier, women did not participate in any fishing related activities, but carried out routine household work. In the late 80s, they started to move out of the village for higher education and at present, 76% of the women are literate (at least up to secondary level) and nearly 16% of the fisherwomen are working in government offices in the neighboring towns. Some fisherwomen engage in mending new or old nets, running small shops or selling essential garments within the village. Introduction of self-help groups (SHGs) has aided them in small savings that can be taken as a loan to help the males in their households to purchase fishing accessories. The families were basically dependent on the reef for coral quarrying and fishing activities. In eighties, some women were also involved in the transport of mined corals from the landing sites to the transporting vehicles for daily wages of Rs.50/ day (US\$ 1.09). Nowadays, constant environmental education and awareness efforts among fisherwomen have helped also in disseminating the conservation strategies to their family members, especially the male households. The alternative livelihood options, importantly crabs and lobster fattening, fish and prawn pickle production and small savings have accelerated their self-dependency and confidence. The fisherwomen along with the SHGs have now voiced against coral mining and destructive fishing. Their role in conservation has come into limelight and the improvement in their lives has led a revival among the women fisher folk.

Community Based Artificial Reef Development in North Sulawesi- Lesson Learned from Pilot Project InteCoReef -

Akinori SATO, Akiko OKITSU, Janny D KUSEN, Dennie MAMONTO*

7-5, Sekido 1-chome, Tama-shi, Tokyo Japan

akinoris@ca2.so-net.ne.jp

North Sulawesi Province has vast length of coastal area, which is characterized by highly diverse and complex physical conditions, and is rich in coastal resources. However, coastal resources have been exploited by people and are facing serious depletion problems. For managing the vast coastal area, the most effective and indispensable way is the so-called Community Based Coastal Management (CBCM) which is one of important management strategies. The idea is to let the users manage their area and resources since they are the ones who know the situation the most and can get benefits by managing the area. It is recognized that community empowerment is very important in order to function CBCM. The idea of CBCM is very sound; however, the theoretical model sometimes would not work in the reality due to many hidden conditions of the local situations. The JICA Study, the Study on the Integrated Coral Reef Management Plan in North Sulawesi (InteCoReef), therefore, decided to implement the Pilot Project of CBCM in four communities in North Sulawesi from October 2000 to February 2002 as an operational research in the Study area to find the most appropriate implementation mechanisms, and reflected the result of the Pilot Project to the master plan. One of activities in Pilot Project, artificial reef was made and installed by the community people. Before installing artificial reef, community people formulated rules for use of artificial reef. Artificial Reef trial is encouraging people to make their efforts on the coastal management. It is learned that the sense of incentives for the management is the important factor to maintain the enthusiasm of communities to keep their efforts on coastal management. We conclude that artificial reef can be used as trigger for introduction of CBCM.

Coastal Habitat Linkages: Key to Coastal Stability But at Great Risk in the Tropics

*Miguel D FORTES**

University of the Philippines, Diliman, QC 1101, Republic of the Philippines
mdfortes138@yahoo.com

Coral reefs, seagrass beds and mangroves require different conditions for optimal growth. Seagrass beds thrive best where conditions are intermediate between the other two. They often form the ecotone between the two divergent ecosystems. Reefs, seagrasses, and mangroves are closely linked by four fundamental processes: nutrient, physical, animal migration and human impact. They point to the potential of these virtually unknown relationships as foundation for the sustainability of reef resources and livelihood base of coastal inhabitants in the tropics. These relationships are the basis of the 'ecosystem approach' as the framework for action in biodiversity conservation.

Seagrass bed, as an ecotone, is an area of tension between coral reefs and mangroves. They control the material, water, and energy flows between the habitats. More importantly, seagrass meadows support a rich diversity of species from adjacent systems. As such, seagrasses are sensitive to fluctuations because species coming from their neighboring systems encounter "marginal conditions" and are at the extremes of their tolerance levels to environmental alterations. This sensitivity makes seagrasses useful indicators of changes not easily observable in either coral reef or mangrove forest.

The coastal zone, however, is a region of strong gradients and major human impacts. The processes that link the habitats are at risk due to: more than 50% of the world's population live along the shores; more than 70% of the largest cities (>1.6 million) are coastal; 90% of global fisheries which feed 1 billion people; 25% of the global primary (biological) carbon is produced here. In addition there is: strong gradients and variability in coastal zones; it is a major sediment and nutrient sink; intense biogeochemical processing; and intensified agriculture and animal production and associated nutrient runoff.

Coral reef, seagrass bed and mangrove interfaces require intense management, research and monitoring efforts focused on environmental problem solving.

Fish Movements and Habitat Connectivity within Coral Reef Ecosystems: Variations in Process and Function at Two Spatio-Temporal Scales

*Richard S APPELDOORN**, *Randy CLARK*, *Ronald L HILL*, *Conrad W RECKSIEK*, *Bryant ROQUE*

Mayaguez, PR 00681-9013 Puerto Rico

r_appeldoorn@rumac.uprm.edu

Many fishes move across habitats (e.g., coral, seagrass, mangrove) within the coral reef seascape. These movements typically occur at two different spatio-temporal scales: long-term ontogenetic migrations and daily feeding movements. Ontogenetic habitat shifts are common in many coral reef fishes and may involve fundamental changes in behavior, feeding, and the use of structure. In some species, ontogenetic migrations occur over relatively large spatial scales spanning the range from coastal mangrove and seagrass habitats to shelf-edge reefs. Mangroves and seagrass beds are key settlement/nursery areas, and some species appear to be dependent upon these habitats. Evidence suggests that either restricted habitat distribution or large ontogenetic migration distances may limit the abundance of some species. At this scale, nutrient transfer represents the net living biomass of migrating fish and occurs primarily in an offshore and on-reef direction. In contrast, daily feeding movements typically occur over much shorter spatial scales, with the difference in location between feeding and excretion acting as an additional mechanism for transporting nutrients and organic matter across habitats. Analysis of gut contents from fishes caught crossing habitat boundaries shows the greatest amount of transport across the seagrass-reef boundary followed by the mangrove-sand boundary. Directional differences in transport were only observed at the seagrass-reef and seagrass-sand boundaries, with the greatest movement being from reef to seagrass. Such data, however, do not indicate the total spatial extent of transport or the final destination habitat.

Relative Importance of Interlinked Mangroves and Seagrass Beds as Feeding Habitats for Juvenile Coral Reef Fish on a Caribbean Island

*Ivan NAGELKERKEN**, *Gerard VAN DER VELDE*

University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, Kingdom of the Netherlands

i.nagelkerken@sci.kun.nl

Juvenile reef fishes shelter in mangroves and seagrass beds, but little is known about the relative importance of these habitats as feeding grounds. In the present study, we determined the degree to which fishes from mangroves and seagrass beds feed in these habitats. Stable carbon isotope analysis was used as a technique to distinguish between food consumption from the two habitats. Individuals of four nocturnally active Caribbean fish species caught in mangroves during daytime showed a carbon signature indicative of food consumption from mangroves as well as seagrass beds. Individuals of the same species sheltering on adjacent (< 50 m distance) seagrass beds during daytime, however, showed a carbon signature indicative of exclusive feeding on seagrass beds irrespective of the size of adjacent mangrove forests. This indicates that two ecologically different populations exist for the four species studied: a population of fishes sheltering in mangroves during daytime and feeding in mangroves and seagrass beds at night, and a population of fishes sheltering in seagrass beds during daytime and also feeding in seagrass beds at night. In addition, stable isotope analysis was performed on the 23 most common fish species on seagrass beds adjacent to mangroves. One herbivore and one zoobenthivore species appeared to feed predominantly in the mangrove habitat, whereas two zoobenthivore species showed a stable carbon signature suggestive of food intake from the mangrove as well as the seagrass habitat. For the other 19 seagrass fish species, which contributed 90% to the total seagrass fish density, the mangroves did not appear to play a significant role as a feeding ground. The low importance of the mangroves as a feeding habitat for these fish species is most likely explained by both the absence of large tidal differences and the higher food abundance in seagrass beds than in mangroves.

Utilization of Various Coastal Habitats by Juvenile Fishes in Bermuda

*Joanna M PITT**

17 Biological Station Lane, St. George's GE01, Bermuda

jpitt@bbsr.edu

Seagrass beds and mangroves have long been known to support the juveniles of many species of fishes that later migrate to coral reefs. There has so far been a paucity of data available on these life-cycle migrations in Bermuda however. Temporal and spatial distribution patterns of juvenile and subadult fishes will be presented for mangrove, seagrass bed and coral reef locations that have varying degrees of association with other biotopes. All locations were surveyed using the same form of underwater visual census. The juveniles of most species are usually associated with a specific biotope and even when individuals are found in all three biotopes during the juvenile phase, a preference is generally discernible. Temporal patterns in the utilization of the three biotopes by different size classes of some species, notably the grunts (Haemulidae), are apparent. These patterns vary with the availability and proximity of the various biotopes. In addition, the juveniles of certain economically important species have been found to utilize mangrove and/or seagrass biotopes almost exclusively. The implications of these data for the transfer of energy will be discussed, along with the need for integrated management of these biotopes and the restoration of anthropogenically reduced coastal habitats.

A Comparison of Fish Communities of Subtidal Seagrass Beds and Sandy Seabeds in 13 Marine Embayments of a Caribbean Island, Based on Species, Families, Size Distribution and Functional Groups

Ivan NAGELKERKEN, Gerard VAN DER VELDE*

Toernooiveld 1, 6525 ED Nijmegen Kingdom of the Netherlands
i.nagelkerken@sci.kun.nl

Differences in fish community structure between different estuaries and bays can be large, and generalisations are complicated by the use of a wide variety of sampling methods. In this study, fish communities of subtidal seagrass beds and sandy seabeds in 13 marine embayments of a Caribbean island were sampled using a uniform method. The objective of the study was to determine whether the seagrass and sandy seabed habitats of various embayments are characterised by typical fish assemblages which differ in terms of taxa (species, families), size classes (life stages) and functional groups (ecological species groups, feeding time and diet). This was linked to the hypothesis that differences in fish assemblages between habitats in different embayments are larger at taxonomic levels than at the level of functional groups. A second objective was to determine the most useful discriminating features between the two habitat types. The hypothesis was rejected, since differences in fish assemblages from different seagrass and sandy seabed sites did not increase from functional to taxonomic level, but from size class to diet/species to family/feeding time to ecological species group. However, the seagrass and sandy seabed habitats could each be characterised by typical fish assemblages which differed in taxonomical and functional group composition, irrespective of differences in environmental and biotic variables between the embayments in which these habitats were situated. The two habitat types could be best characterised on basis of fish family, ecological species group, feeding time and size distribution. Seagrass beds mainly harboured nocturnally active nursery species (Haemulidae, Lutjanidae), whose relative abundance was related to vegetation cover. Sandy seabeds mainly harboured diurnally active bay species (Gerreidae) whose relative abundance was related to cover of bare sand. Similarities in taxonomical and functional traits of fish species predicted whether they occurred more abundantly in seagrass beds or sandy seabeds.

Inter-ecosystem Interactions between Land and Coastal Ecosystems: A Case Study in Hokkaido

Hiroshi MUKAI*, Y TANAKA

Akkeshi, Hokkaido 088-1113 Japan
mukaih@fsc.hokudai.ac.jp

Coastal ecosystem is maintained by allochthonous inputs from land ecosystems. The processes and patterns of the subsidy affect on coastal food webs, trophic cascades and production processes in coastal ecosystems. The processes and patterns of the subsidy, for example, nitrogen input from terrestrial ecosystems, vary with area of catchment, land use, vegetation, precipitation, etc. In Akkeshi water-system, Hokkaido, Japan, the processes and patterns of the subsidy to coastal ecosystem were studied. In particular, the difference of response in the subsidy between regular runoff and irregular events, flood or heavy rains, was focused in Bekaubeushi watershed of eastern Hokkaido. Regular observations once a week and intensive observations during several days after rain on volume of water-flow and nitrogen (DIN and PON) of the small rivers with different land use were taken place and compared each other. From these observations, it was hypothesized that basic food web in the Akkeshi-ko estuary is supported by nutrient supply of regular runoff and a huge amount of nutrient input with sporadic runoff cannot be taken in the food web. Nutrient process through high seagrass production is another possible pass of nutrient recycling. To examine this hypothesis, food analysis of clams and oysters, simulation model analysis of water flow in regular and irregular events, sediment analysis and so on are conducted. These investigations have lead to the understandings of different responses by the coastal ecosystem at regular and at irregular events.

Downstream Consequences of Increased Run-off and Mangrove Dieback: A Case Study from the Pioneer Estuary (Queensland, Australia)

Stacy D JUPITER*, Stuart R PHINN, Norman C DUKE, Balz S KAMBER, Donald C POTTS, Guy MARION

1156 High Street, Santa Cruz, CA 95064 United States of America
jupiter@biology.ucsc.edu

Mangroves play an important role in preserving nearshore water quality by trapping suspended particles and pollutants in estuarine sediments. The mangroves of the Pioneer estuary (Queensland, Australia) have undergone a net loss of 30% (250 ha) over the last half century due to clearing, development, hydrological manipulations, and climate variability. Additionally, over the past decade, a severe species-specific dieback has impacted 50% of mangrove cover within the system. We predict that rapid mangrove loss has resulted in increased erosion of estuarine sediments and pollutants which may manifest as: increased incorporation of trace elements into coral skeletons through time; increased partial mortality of massive coral colonies; and increased algal cover at nearshore sites. We have three principle aims in this study: (1) to determine the extent of correlation between changes in the Pioneer estuary mangroves and nearshore water quality; (2) to establish the spatial extent of potential run-off impact to nearshore reefs adjacent to the Pioneer River mouth; and (3) to quantify differences in benthic composition and condition between reef sites at varying distances from the mouth. To assess the strength of connection between mangroves and nearshore water quality, we compare temporal changes in mangrove distribution, mapped from aerial photography at 5-10 year intervals from the 1940s-present, with historical records of proxies for suspended sediment concentration (i.e. barium, rare earth elements, high-field-strength elements) measured from 0.5m coral cores. We address the spatial extent of run-off impact through analysis of cores from massive *Porites* colonies obtained at varying distances from the river mouth. Lastly, we quantify run-off impact through assessment of benthic cover and partial mortality of massive colonies along replicate transects near each coring site. The complete set of results will provide a basis for management of coastal mangrove ecosystems as a control of nearshore water quality within a barrier reef.

Biomarkers of Chief Primary Producers in Coral Reef, Seagrass Bed, and Mangrove Forest Ecosystems

Masumi YAMAMURO*, Izumi NARUSHIMA, Susumu SAKATA

Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki Japan
m-yamamuro@aist.go.jp

Coral reef, seagrass bed, and mangrove forest are characteristic ecosystems in tropical and subtropical coast, and they are often situated close to one another. Among them, coral reef is highly vulnerable to eutrophication, while seagrass bed may act as sink for nutrient and terrestrial organic matter as is often described for temperate beds. Mangrove forest may also act as sink for terrestrial organic matter and protect seagrass bed from excess accumulation of organic matter. To examine the contribution of autochthonous and allochthonous organic matter in coral reef, seagrass bed, and mangrove forest ecosystems, we analyzed several biomarkers of chief primary producers and organic matter of the sediment in each ecosystem. The samples were freeze-dried, pulverized, and saponified with 0.5M KOH in 20:1 methanol/water solution under reflux. Neutral lipids were collected first from the residue, then from the solution by extraction three times with hexane/ethyl acetate (9:1). The extracts were combined and divided into four fractions of different polarity, i.e. saturated hydrocarbons, aromatized/polyunsaturated hydrocarbons, ketones, and alcohols by column chromatography on silica gel. The alcohol fraction was subjected to trimethylsilylation using BSTFA. Subsequent GC-MS/FID analysis employed a Hewlett-Packard 6890-5972 system with on-column injector, a CP-SIL 5CB-MS capillary column, and helium carrier gas. Compounds were identified by comparison of their retention times and mass spectra with published data. Chief primary producers in each ecosystems showed characteristic biomarkers. Mangrove leaves collected at the upstream of the forest were predominated by long-chain n-alkanes, typically C29 and C31, and by diterpenes of phyllocladene and kaur-16-ene. Dominant n-alkanes of seagrasses were C21, C23, and C25 for *Halophila ovalis*, and C21 for *Enhalus acoroides*. There were no appreciable hydrocarbons in both the flesh and the skeleton of corals. These findings may be applicable to identify the major source of organic matter in the sediment of each ecosystem.

Comprehensive Assessment of the Hydrodynamic Features and Material Transport Characteristics across Coastal Ecosystem Habitats of Fukido Area, Ishigaki Island

*Hitoshi TAMURA**, Kazuo NADAOKA, Enrico C PARINGIT, Jun MITSUI, Yoichi SUZUKI, Wataru KUMAGAI, Atsushi WATANABE, Hajime KAYANNE
2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552 Japan
tamura@wv.mei.titech.ac.jp

To investigate the hydrodynamic feature and associated heat and material transport of a fringing coral reef where some coastal habitats (coral, seagrass and mangrove) are coexist, we conducted field survey at Fukido reef and mangrove area on Ishigaki Island, Okinawa, Japan. More than 15 moored buoys, on which various sensors for continuous measurements of current, water temperature, salinity and turbidity concentration were installed and several wave gauges were also deployed at the bottom. We carried out 3 times field survey for 2 seasons (summer: 2002/8-9/29, 2003/8/6-8/18, winter: 2003/1/15-2/9). At the same time we have applied numerical computation for investigating the detailed characteristics of the currents and associated temperature, salinity and sediment transport. We used a quasi-3D shallow water turbulence model (SDS-Q3D model) improved for specific application to fringing-type coral reef. For numerical computation two important points were considered carefully, bathymetry and canopy effect of benthic habitats. Previously there exists no available bathymetry data for the reef area due to its shallowness and Fukido reef area constitutes very complicated morphology. We used the bathymetry of the study area estimate by remote sensing data analysis method developed by Paringit and Nadaoka (2002). To evaluate the seagrass and coral canopy effect to current field, we tried to develop the coral and seagrass canopy model that can be applied to shallow water turbulence model.

Okinawa Jangusa Watch - Citizens' Initiative for Seagrass Monitoring

*Masahito YOSHIDA**, Naoko KOUCHI, Masahiro NAKAOKA
Yamaji-Sanbancho Bldg.3F, 5-24 Sanbancho, Chiyoda-ku, Tokyo 102-0075 Japan
myoshida@nacsj.or.jp

In Okinawa, seagrass on which dugongs feed is called Jangusa-literally means dugong-grass, and seagrass beds that nurtures dugongs and sea turtles are called Jangusa-numi (sea of Jangusa). But unfortunately, Okinawa's seagrass beds are currently facing the greatest threats by the proposed construction of U.S. military airport and/or reclamation. The Nature Conservation Society of Japan has therefore decided to launch a community-based Seagrass-Watch monitoring program by conducting Okinawa Jangusa-Watch in 2002. Before the first Jangusa-Watch, distributions of seagrass beds and coral reefs in the region between Teniya Cape, Nago-city to Kin Cape, Kin-town were interpreted from aerial photos and then mapped on a 1/25,000 topographical map. The result obtained from the aerial photographs showed that the largest seagrass bed was located along the coast of Henoko to Toyohara/Kushi in Nago-city, and relatively unfragmented seagrass beds were found around Kayo and Abu in Nago-city as well as Matsuda and Kanna, and an area between the mouth of Oku-kubi River to Kin Cape. Following the training, volunteers conducted seagrass survey by estimating cover of seagrass at Kayo and Henoko, Nago City. Using snorkeling technique, (1) time, (2) depth of water, (3) sediment, (4) percentage seagrass cover, (5) percentage cover of each species, and (6) comments such as the presence of dugong feeding trails and disturbance by red soil erosion were recorded, followed by the post-survey calibration of the observer estimates. Seven seagrass species that grow in this region were observed in seagrass beds in Kayo, Henoko, and Toyohara. Feeding trails of the dugong and sea turtle were found in Kayo and Toyohara, respectively. On aerial photographs, the seagrass bed seemed to reach only 500m from shore; however, ground survey revealed that it actually went out up to 1000m from shore.

Ecosystem Inputs to the Integrated Coastal Zone Management Plan in Subic Bay (Northwestern Philippines) and the Northern Sierra Madre Natural Park (Northeastern Philippines)

*Ma Gregoria Joanne P TIQUIO**
Velasquez St., University of the Philippines-Diliman, Quezon City 1101 Republic of the Philippines
jtiquio@yahoo.com

Seagrasses are often considered less important as coral reefs or mangroves such that protection of the structural and functional integrity of these habitats is often undermined. Appreciation of seagrass beds is largely in the context of the fishery resources derived from it and the benefits the latter earns for the economy. There is very little knowledge on the seagrass-coral reefs-mangroves linked by high-order interactive processes that maintain their stability and structural integrity. There are several strategies currently used to manage marine resources in the country, foremost of which is the establishment of marine protected areas. As worldwide deterioration of seagrasses habitats has been documented there is an urgent need to include seagrass habitats in the establishment of marine protected areas, especially when seagrasses, mangroves and coral reefs are present in the same area. This study highlights the importance of integrating the major marine ecosystems (mangroves, seagrasses and coral reefs) in the establishment of marine protected areas. Assessments of the mangrove, seagrass and coral reef resource were conducted at two sites in the Philippines namely, Subic Bay and the Northern Sierra Madre Natural Park (NSMNP), by using standard survey techniques. The main objective of the study was to identify specific areas at which the existing protected areas could be extended to include important marine components. For Subic Bay, the extension site situated at the eastern portion of the bay was chosen based on the following criteria: a) presence of ecological marine components that need protection; and b) accessibility of this area to the Subic Bay Management Authority for the implementation of protective measures. For the NSMNP, the mangrove-seagrass-coral reef complex in Dibakung was recommended for protection.

Acknowledging the Habitat Requirements of Juvenile Coral Reef Fishes: The Tiger-tailed Seahorse *Hippocampus comes* as a Case Study

*Sian K MORGAN**, Amanda C J VINCENT
Project Seahorse, Fisheries Centre, 2204 Main Mall, UBC, Vancouver, British Columbia Canada
s.morgan@fisheries.ubc.ca

Investigating habitat-use by juvenile coral reef fish is necessary to show whether Marine Protected Areas, often only encompassing coral reefs, afford protection at all stages of species life histories. Mangroves and seagrass are frequently assumed to function as nurseries, but the habitat requirements of many reef fish recruits remains unknown. The goal of this research was to assess habitat use by newly settled tiger-tailed seahorses (*Hippocampus comes*) in the central Philippines. These data have implications for management as seahorses are heavily exploited in the Philippines for use in traditional medicine and for aquarium display. Specifically this work asked; a) at what size newly settled seahorses were found on the benthos, b) whether newly settled seahorses used different habitat from coral-associated adults, and c) whether macroalgae, as opposed to seagrass, was important habitat for juvenile seahorses. Habitat and seahorse size/abundance were surveyed in four habitats: coral reef crest, seagrass, wild macroalgal beds (*Sargassum* spp.) and farmed macroalgal beds (*Eucheuma* spp.) Benthic cover was quantified during the day by standard line intercept method along randomly placed transects. Seahorse fishers then searched for seahorses at night. Benthic cover and seahorses were quantified in each habitat on three occasions at four sites. Results showed that newly settled seahorses (>25mm standard length) inhabited wild *Sargassum* beds, while adults were most commonly found on reef crests in coral and sponge-dominated habitat. Findings suggest that juvenile settlement coincides with the reproductive season of *Sargassum* spp. when large algal reproductive structures are available as holdfasts. This work implies that in the Danajon Bank, wild *Sargassum* beds should be included in Marine Protected Areas to assure protection for all phases of the seahorse life history. Macroalgal beds may also deserve further investigation as nursery grounds for coral reef fishes.

A Paradigm for Monitoring and Conservation of Large-scale and Multi-Jurisdictional Reefal Areas

Ameer A ABDULLA, *Kristina GJERDE**

Parque Tecnológico de Andalucía, Calle Marie Curie, 35 - Edif. Sede Social, 29590 Campanillas, Málaga Kingdom of Spain

Ameer.Abdulla@jcu.edu.au

Ecosystems such as tropical and cold water coral reefs may extend over vast areas, sometimes straddling the boundaries of one or more nations, or the high seas. This can create challenges to management and conservation. At present, large-scale coral reefs suffer reduced monitoring effort due to the large area being managed, while multi-jurisdictional areas lack a unified infringement detection and enforcement response. Such areas have traditionally relied on “passive” management for compliance through regional and international agreements. We propose a novel framework for the conservation of such remote or disconnected ecosystems utilising innovative technology and emerging practice based on the enforcement of fisheries regulations, including on the high seas. Recent advances in satellite remote sensing and GPS coupled with a heightened naval involvement and the development of legal and financial mechanisms may provide key advances. We present case studies from Australia, the US, and the Mediterranean to illustrate fundamental points and discuss the potential strengths and weaknesses of the proposed paradigm.

Building Consensus Towards a Global System of Marine and Coastal Protected Areas

*Marjo K VIERROS**

UNEP/SCBD, 393 St-Jacques, Suite 300, Montreal, QC, H2Y 1N9, Canada

marjo.vierros@biodiv.org

The Convention on Biological Diversity provides a broad framework for action for the conservation and sustainable use of biodiversity. Some recent advances within the work of the Convention relate specifically to marine and coastal protected areas, and include the adoption of an ambitious target for increasing the area covered by, and the representativeness of, the current global system of MPAs. The target also highlights the importance of protecting coral reef ecosystems, which continue to be a priority for the work of the Convention. A detailed strategy for reaching this target, including technical guidance aimed at countries, was also developed and adopted. These advances underscore the increasing political acceptance of MPAs as effective tools for sustainable management of marine resources, and the need to manage such resources in an ecosystem context. Acceptance of the utility of no-take MPAs is also increasing, though the issue remains somewhat controversial. These advances are consistent with, but more specific than those outlined in the Plan of Implementation of the World Summit on Sustainable Development, and provide an example of global level consensus building that will hopefully provide a precursor for practical ground-level action.

Developing Social Science Research Priorities for US Coral Reef MPAs

*Sarah C LYONS**, *Charles M WAHLE*

99 Pacific St., Suite 100F, Monterey, CA 93940 United States of America

sarah.lyons@noaa.gov

The human dimension plays a large role in the effectiveness of coral reef marine protected areas (MPAs). However, the social sciences are often overlooked in the planning, management and evaluation of these MPAs. There is a need for understanding the social, cultural, and economic contexts in which policy maker’s conservation decisions will be applied. Based on the National MPA Social Science Research Strategy, the United States’ National Marine Protected Area Center Science Institute has commenced a series of workshops designed to prioritize social science information needs at the regional and local levels, where specific MPA issues play out. These workshops build the framework for regional research programs and also stimulate and encourage collaboration and coordination within the region among agencies, social scientists and stakeholders. The intended audience of the regional research plans includes MPA managers, agency decision-makers, researchers, funders, and affected stakeholder groups. This oral presentation will focus on the priority research needs identified in the two workshops covering US coral reef waters: a.) South Florida and the U.S. Caribbean and b.) the U.S. Pacific Islands, as well as the key issues regarding the development and enhancement of the regional capacity in these two areas.

31,500 Public Submissions, Countless Databases, Years of Experience! How Were they Used to Rezone the Great Barrier Reef?

*Leanne THOMPSON**, *Belinda JAGO*, *James INNES*, *James HALL*, *Deb SLATER*, *James AUMEND*, *James CORBETT*, *Leanne FERNANDES*, *Jon DAY*, *Bruce KINGSTON*, *Phil CADWALLADER*, *Chris THOMAS*, *Peter MCGINNITY*, *John TANZER*

2-68 Flinders Street, PO Box 1379, Townsville, QLD, Australia, 4810 Australia
leannef@gbrrmpa.gov.au

Protecting the biodiversity of the Great Barrier Reef ecosystem was the clear aim of the biggest planning exercise ever undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA). The rezoning the Great Barrier Reef Marine Park (Marine Park) generated a huge amount of interest from not only communities adjacent to the Marine Park, but from all over Australia and the world. Information came in many forms, not only through written submissions but through databases, maps, field notes and the experience and knowledge of the GBRMPA staff who provided a link to the community.

The GBRMPA received over 31,500 submissions, the largest for any environmental planning process in Australia, and had over 500 meetings in at least 90 locations. More than 40 layers of data were used, compiled from years of research about the biological, physical and economic values of the Marine Park. Turning this and other data plus GBRMPA staff’s knowledge and experience into a useful and useable form to develop a Marine Park Plan was the challenge.

The GBRMPA developed a Draft Zoning Plan using submissions received from the first community consultation phase, reserve design systems such as Marxan, a Geographic Information System and internal expertise. This Draft was released for further public comment, after which it was further field reviewed and critically analysed, before passing onto the political process. These steps are illustrated using the Townsville region as a case study.

The rezoning of the Great Barrier Reef Marine Park is an example of successful planning: turning gathered raw data into useable information to decide which parts of the Great Barrier Reef ecosystem to protect in no-take areas.

Building Networks of Marine Protected Areas: Lessons from Five Large-scale Marine Conservation Efforts in Tropical Coral Reef Systems

*Ghislaine LLEWELLYN**, *Evangeline MICLAT*, *Lisette WILSON*, *Ken KASSEM*, *Melanie MCFIELD*, *Irene KAMU*

Ecosafe Consultants, 3 Pickering Street, #03-06 Nankin Row, China Square Central, Singapore 048660 Republic of Singapore
gllewellyn@tingey.com.sg

New approaches piloted over the last four years in the Western Indian Ocean, Caribbean and Western Pacific have led to measurable progress in marine conservation and provide lessons on the success factors and challenges in scaling-up to build MPA networks. Results from work in large scale ecological units including Eastern Africa, Mesoamerican reef, Sulu Sulawesi Seas, Solomon Bismarck Seas, and the territorial waters of Fiji, illustrate success factors that cut across a range of social, political, cultural and ecological systems, including multi-country situations that share migratory marine species and important trans-boundary sites. Early lessons are that implementation is accelerated if a range of relevant stakeholders are involved in the decision making process, and that planning for trans-boundary systems should be done collectively. Protected area network planning should be integrated within a larger framework of coastal and marine resource management, and should include dialogue with representatives of key sectors, especially those with fisheries interests. Protected areas should be recognized for the range of functions they can perform, such as fisheries benefits and species conservation, but biodiversity conservation and maintaining the integrity and productivity of the system should be retained as a fundamental goal. Using biodiversity principles of representation, maintenance of ecological processes, maintenance of viable populations and resilient areas, and preservation of special elements and values, priority biodiversity areas can be identified and clear targets and goals set. Applying such a framework has contributed to a doubling of the area under protection in Eastern Africa, including filling critical gaps and protecting key trans-border sites. In Fiji, the results are being considered by the Great Council of Chiefs, and in the Sulu Sulawesi Seas, a memorandum of understanding has been signed at the highest political level, paving the way for implementation across three countries.

Weaving an Ideal Design of MPAs into the Real World: The Great Barrier Reef Case Study

*Leanne FERNANDES**, *Jon DAY*, *Belinda JAGO*, *James HALL*, *Kirsti SAMPSON*, *Darren CAMERON*, *James INNES*, *John TANZER*, *Adam LEWIS*, *Dave LOWE*, *Kerrie GORMAN*, *Bruce KINGSTON*

2-68 Flinders Street, PO Box 1379, Townsville, QLD, Australia, 4810 Australia
leannef@gbmpa.gov.au

Well-designed biophysical principles that operationalise a system-wide approach were an essential foundation for building a network of no-take areas within the Great Barrier Reef Marine Park. But they were not sufficient. People's uses, knowledge and value systems needed to be explicitly and demonstrably integrated into the planning process for many reasons: to ensure all available information was considered; to avoid, as far as possible, negative social, economic or cultural impacts and to generate the maximum possible level of ownership of the outcomes. Bringing these uses and values into planning was extremely resource intensive, difficult and imperfect but, for the Great Barrier Reef, there was no other option. A high degree of community engagement was achieved through:

- social, economic and cultural operational principles that coupled with the biophysical principles;
 - public distribution and invitations for comment on both sets of principles;
 - invitations for input as to where new no-take areas should and should not be located to help develop a draft zoning plan; and
 - a second round of discussions and feedback to revise the draft plan.
- Distribution of information occurred through a variety of means: meetings, letters, web, CDs, email, advertisements in newspapers, media releases, community information sessions, community access points and a freecall number. A high level of engagement was also sought with key political players. All bases for zoning decisions were documented to reflect what was known about all the biological and human values that were relevant to the area being zoned.

Effective Marine Protected Area Management Requires an Ecosystem-based Approach with Innovative Tools Instead of Managing Islands in the Stream

*Billy D CAUSEY**

P.O. Box 500368, Marathon, Florida 33050 United States of America
Billy.Causey@noaa.gov

Marine protected areas (MPAs) have been designated for decades, based on political, conservation and socioeconomic interests. Seldom have these factors been applied in combination with biological, ecological, and oceanographic features while considering their broader ecosystem functions and contributions. The location and resultant boundaries, as well as the spatial extent of earlier MPA designations, were too often based on political trade-offs, rather than the application of natural and socioeconomic sciences. Rarely were conservation goals and objectives the primary criteria used to select and determine MPA boundaries. More often, the geographical extent and boundaries of an MPA were based on what could be agreed to by groups with opposing viewpoints, rather than scientific criteria. This has led to the designation of MPAs that when standing alone were not as effective in attaining resource conservation goals as they would have been if they had been established as part of a network or as a larger, more holistic MPA. This paper uses lessons-learned in the Florida Keys where coral reef managers have transitioned from managing small MPAs that were like islands in the stream, being affected by impacts from around their boundaries, to a large ecosystem-based MPA whose success is far greater due to the biological and ecological linkages achieved in conjunction with the oceanographic connectivity of the MPA with other coral reef systems in the region. Today coral reef managers have far more tools available to them that can be used to select the boundaries and designate effective MPAs with a greater level of consensus among stakeholders. It is important to the future use of MPAs as conservation and protection measures that they are no longer simple paper parks, but rather effective and functional areas, based on the application of the most modern natural and socioeconomic scientific tools..

Status of Community Based Marine Protected Areas in the Philippines: Successes, Emerging Issues and Future Directions

*Margarita N LAVIDES**, *Jose Ma Antonio BRINGAS*, *Don Geoff TABARANZA*, *Chona CUNANAN*

4F Fil-Garcia Tower Kalayaan cor. Mayaman Sts. Diliman, Quezon City, Philippines
lavides@yahoo.com

Currently, Haribon studies show that there are already close to 600 marine protected areas established in the Philippines. A number of events have heightened the popularity and acceptability of establishing MPA as a coastal management strategy — notable of which are the legal and jurisdictional shift brought about by the Local Government Code of 1991 and the Philippine Fisheries Code of 1998. A number of marine conservation and coastal management projects central to which is the establishment of MPAs also fueled a nationwide interest on MPAs. Though very few have empirical evidence to prove impacts a large body of anecdotes would prove successes. Haribon gathered both empirical proofs and anecdotes and some successes would point out to the following: 1) an average 4-year old marine sanctuary increases the fish catch of local fishers by an average of 50%; 2) a 50-95% decrease in illegal fishing surrounding the marine sanctuary; 3) improved habitats, varying increases in coral cover and fish density and improvements in fish biodiversity; 4) improved competence and accountability in government and the community; 5) lead to open communication between the local government units and the community; 6) development of collectivism; 7) built commitment to protect and manage the resources; and 8) encouraged other communities to set up a sanctuary. Though a number of successes are notable, only 18-20% of the total established MPAs in the country are functional. Most of these functional MPAs are community-led or community based. Oftentimes sustainability of MPA management and enforcement is hindered by conflicting socio-economic and politico-cultural forces which lead to a number of challenges and emerging issues. On the other hand, these lead to some future directions towards a more sustainable management of community based MPAs in the Philippines.

A Network of Locally Managed Marine Areas (LMMAs) as a Strategy to Address Coastal Conservation through Socio-Political Connectivity

*Pamela SEETO**, *Michael GUILBEAUX*

PO Box 5911 Boroko, NCD, Papua New Guinea

pseeto@packard.org

Well-designed networks of marine protected areas (MPA) are essential for coral reef conservation in many places, yet it is often challenging for practitioners and scientists to establish networks of MPAs that adequately fulfill the biodiversity conservation needs, as well as the social needs at a particular site. The Locally Managed Marine Areas (LMMA) Network is comprised of networks of LMMAs in 7 countries in the Pacific, and is based on the requirements of project commitment and participation. This is an example of a unique and practical approach that has emerged to address some of the social and political obstacles to successful MPA network initiatives. This participatory approach to networking facilitates the establishment of networks of community based MPA's that are monitoring and adaptively managing their respective projects, as well as contributing to an overall evaluation of their success. In contrast to many conventional networks of MPAs, LMMAs are driven more by local community criteria and needs, rather than scientific and biodiversity criteria per se. Some LMMAs that have been designed and implemented by local communities have been critiqued as being insufficient in their ability to maintain ecological functions or conserve biodiversity over the large scale. However, these LMMA approaches not only provide useful contrasts to other more biologically driven networks, but may also play a complimentary and critical role in their success and long-term sustainability. The challenge now in many areas, is to integrate the two approaches, and several case studies will be presented that outline how some LMMA projects are trying to achieve this convergence when progressing from sites to systems. As biologically driven approaches seek greater local stakeholder support for their networks, participatory LMMA approaches seek greater biological functionality through adaptive management and learning. Socio-political factors influencing the success of these LMMA networks will also be highlighted.

Managing Better Together: Creating a Network to Encourage Community Involvement in Coral Reef Conservation in Hawaii:

*Scott ATKINSON**, *Eric CO*

212 Merchant Street Suite 200 Honolulu, HI 96813 United States of America

scott@conservationpractice.org

The coral reef ecosystems of the Hawaiian Islands have been severely degraded through a combination of threats including alien species, overfishing, coastal development, and pollution. Throughout the Hawaiian Islands, numerous coastal communities are working to encourage better management of coral reef ecosystems and fisheries in the areas where they live and fish. A wide range of approaches are being used ranging from the collection and application of elder knowledge (Kupuna) in the daily management of fishing behavior to direct partnership with the State government to encourage the formal creation and enforcement of marine protected areas. The majority of coastal communities are facing similar challenges and have a similar goal: to ensure that future generations inherit healthy coral reef ecosystems for their own use and enjoyment and for the benefit of the ecosystem overall. Building on successes in networking Locally Managed Marine Areas (LMMAs) in other parts of the Pacific including Fiji, a group of dedicated local communities and marine managers have come together to form a network of LMMAs in Hawaii. The theory behind the network is that we can manage better together than alone. The process of establishing this network with test this hypothesis over the next two to four years. Activities of the network will include: skills building through development of modular trainings in key coral reef management actions such as: strategic management planning, biological assessment and monitoring, community-based enforcement, developing co-management and/or partnership arrangements with the State agencies that are mandated with marine management, and assessing and adapting project progress. This paper summarizes the successes of similar networks in the Pacific and provides details of the process of establishing the Managing Better Together network in the Hawaiian Islands.

Initiatives Towards Networking of Marine Protected Areas in the East Asian Seas

*Annadel S CABANBAN**, *Ridzwan A RAHMAN*, *Evangeline B MICALAT*

Sepangar Bay, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia

annadelc@ums.edu.my

The scientific consensus on marine reserves is that a network of such areas has more ecological benefits for the conservation of species and for fisheries enhancement. Two initiatives in the East Asian Seas are being developed towards achieving these benefits for the region. In October 2001, under the auspices of the United Nations Environment Programme, representatives of the countries in the East Asian Seas met at the Universiti Malaysia Sabah, Kota Kinabalu at the Workshop to Establish a Regional Network for Marine Protected Areas in the East Asian Seas. The Workshop has identified areas of coral reefs to be part of a network, proposed a regional mechanism to administer this network, and recommended initial actions to refine the selection of coral reefs areas. Funds are necessary to make these recommendations operational. During 31 May to 2 April 2003, stakeholders of Indonesia, Malaysia, and Philippines met under the Sulu-Sulawesi Marine Ecoregion Programme in Kota Kinabalu at the Workshop towards the Formulation of Network of Marine Protected Areas in the Sulu-Sulawesi Marine Ecoregion. The framework is now being finalized for adoption by the countries.

Managing Highly Diverse Coral Reefs in North Coast Papua New Guinea through Locally Managed Networks: Socio-Cultural Context and Trends in Changing Biodiversity

*Aaron P JENKINS**

P.O. Box S6, Superfresh, Tamavua, Suva, Fiji

apjenkins@connect.com.fj

The archipelagos of Melanesia contain among the highest and most intact tracts of marine biodiversity on the planet. In the context of most Melanesian countries with traditional resource ownership, community-based, locally managed, marine protected areas (LMMAs) are the primary form of marine resource protection. Wetlands International- Oceania has, over six years, facilitated the establishment and management of an operational network of LMMAs on the north coast of Papua New Guinea, particularly within the Madang province. The local network is receiving positive endorsement at local, provincial and national levels within the country, is contributing to local fish stock enhancement, increasing local income from dive tourism and contributing to global learning on marine protected areas as part of the Asia-Pacific wide LMMA Network. In this paper firstly we present a brief history of the development of the Madang LMMA network with particular emphasis on the changes in socio-cultural context and how these influence the success of local marine conservation efforts. Secondly we present changes in density and biodiversity of fishes and benthic cover over six years within the longest established areas within the network in comparison to unmanaged control areas. We present clear evidence that these local conservation efforts have resulted in significant numerical fish stock enhancement in some well - managed sites. We discuss these results in the context of changing coral reef fish community structure and declining live coral reef habitat. We discuss some of the reasons for conservation success and failure in these areas and also the increasing need to address catchment level issues if nearshore MPAs are to achieve a measure of long term success.



Oral Session
July 2 (Fri)



Predicting and Mapping Metrics of Fish Community Structure over Large-scales Assists Managers in Enacting Spatially Explicit Management Decisions

*Chris CALDOW**, John CHRISTENSEN, Chris JEFFREY, Matt KENDALL, Mark MONACO

1305 East-West Hwy. (SSMC4, N/SCI-1), Silver Spring, Maryland 20910
United States of America

chris.caldow@noaa.gov

Managers of tropical marine ecosystems must frequently enact spatially explicit management decisions at scales larger than that at which research is typically conducted. To address this issue, NOAA's Caribbean reef fish monitoring program, lead by the Biogeography Team, has utilized its partnerships with the National Park Service, University of Puerto Rico, and the Virgin Islands Government to develop predictive, large-scale, spatial models of fish community metrics to be used in affecting these decisions. The foundation for this effort is the nearshore benthic habitat maps developed by the Biogeography Team and coastal bathymetric information. Using a random stratified sampling approach, over 1400 surveys have been conducted in the last three years around the nearshore waters of Puerto Rico and the US Virgin Islands. Utilizing canonical correlation analysis to examine the relationship between metrics of fish community structure and physiographic characteristics (bathymetry, bathymetric variation, habitat type, and proximity to other habitat types) provides a mapable surface of community metrics within a Geographic Information System (GIS). This talk will discuss how spatial models created to predict basic metrics in fish community structure in one location can be invoked in other areas and to discuss the success to which that has been done. The ability to invoke these models over large areas (the scale of a Caribbean island) provides reason for optimism at predicting regions that should be thought of as candidates for Marine Protected Area selection or in assisting managers with other spatially explicit management decisions. Further exploration of the patterns found in the model, necessarily provides a more intimate comprehension of how these species are influenced by their surrounding environment and these models can then be deconstructed to assess the primary factors influencing these communities.

A GIS-based Dynamic Decision Support System for Florida's Coral Reefs

*Johnathan T KOOL**, Felimon C GAYANILO, John W MCMANUS

4600 Rickenbacker Causeway, Miami, Florida United States of America

jkool@rsmas.miami.edu

Spatial Information is playing an increasingly important role in the analysis and management of coral reef systems, however frequently data are dispersed across the large number of agencies and organizations that maintain them. We, at the National Center for Caribbean Coral Reef Research (NCORE) have assembled a number of spatially referenced data sets pertaining to coral reefs of the Florida Keys, and have developed an Internet-based Dynamic Decision Support System (DDSS) to assist coral reef managers and scientists in identifying and accessing spatial data sets of interest to them. The relevant data sets identified using the DDSS are assembled together as a map collection, and are queryable and customizable through an ArcIMS-based web interface. The data layers have associated metadata which users can access through the web interface, in addition to a 'data bibliography'; which concisely summarizes the data sources, authors, and how the data may be obtained. We also hope that any interested researchers will submit additional information for incorporation into the DDSS. This will greatly facilitate data sharing and co-ordination of coral reef research in the Caribbean.

The Nature Conservancy's Approach to Delineation of the Area Harboring the Richest Reefs on Earth, the Coral Triangle

*Rili DJOHANI**, Peter J MOUS, Alison GREEN

Jl. Pengembak 2, Sanur, Bali, INDONESIA Republic of Indonesia

eprawitasari@tnc.org

The world's center of marine biodiversity is known to zoogeographers as the Coral Triangle. This area includes a major part of Southeast Asia's most pristine coral reefs, which are severely threatened by over-fishing, destructive fishing practices, coastal development, pollution and mass bleaching events. Conservation of marine biodiversity in the Coral Triangle's geographic sub-units necessitates a comprehensive approach to site selection, resulting in resilient networks of Marine Protected Areas. The Conservancy's framework for priority setting is Ecoregional Conservation Assessment. This methodology aims to capture all nature values within an ecoregion by selecting a portfolio of sites for conservation action. To use the Coral Triangle as a unit for ecoregional conservation assessment its boundaries must be delineated. For this purpose, The Nature Conservancy's South East Asia Center for Marine Protected Areas (SEACMPA) convened a group of experts at its office in Bali Indonesia over the period April 30 - May 2, 2003. The experts were asked to apply best available science to get to a degree of consensus on the boundaries of the Coral Triangle and its sub-units (ecoregions and functional seascapes). The boundaries of the Coral Triangle, ecoregions and functional seascapes identified in this process were not intended to provide new biogeographic insights. Rather, these units were designed specifically for conservation planning. This paper presents the findings of this experts workshop, and explains The Nature Conservancy's approach to designing networks of Marine Protected Areas.

Ecological Economic Modeling and Valuation Meta-analysis for Coral Reefs as Tools for Marine Protected Area Management

*Herman S J CESAR**, Pieter Van BEUKERING

IVM-VU (A-670), De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

herman.cesar@ivm.vu.nl

This paper presents two recent developments in decision making on coral reef management. First is a new ecological-economic coral reef model aimed to assist scientists and managers in evaluating ecological and economic impacts effectively. The model is applied to case studies on tourist overuse, algae blooms and MPA management in Hawaii and on climate change impacts on selected reefs in the Caribbean. The integrated model, referred to as SCREEM (Simple Coral Reef Ecological Economic Model), links ecology and economy in a dynamic manner. SCREEM incorporates the relevant ecological-economic relations by following pathways, linking the coral reef ecosystem and its uses and location with the physical goods and services provided by this reef type and the economic value of these values. The results show that coral reef management, though sometimes costly, tends to be justified in economic terms based on the large economic benefits provided by coral reef ecosystems.

The second supplementary development is a meta-analysis for coral reef valuation. This overview study is based on over 100 coral reef valuation studies from around the globe. Using regression analysis to synthesize the results, the methods enables the estimation of the economic value of a coral reef area based on limited local information on the ecological and economic situation in an area. This method is groundtruthed with results from the Hon Mun Marine Protected Area in Vietnam. By comparing the results of the primary valuation of Vietnam's coral reefs with the values estimated using a value transfer function derived through the existing meta-analysis, the so-called 'transfer error' was measured and explained. This technique facilitates valuation studies and cost benefit analyses of marine protected areas and coral reef threats in areas with limited data availability and financial resources.

Three-dimensional Model of Atoll Lagoon Circulation

*Eric PETERSON**, *Maria BEGER*, *Silvia PINCA*

79 Thomas Street, Sherwood 4075 Australia

e.peterson@uq.edu.au

The hydrodynamic processes in a Pacific Atoll are important in determining sediment transport larval dispersion patterns. The movement of a body of water in an atoll is of three-dimensional nature and its representation by maps or surface currents is inadequate. The surface water flow is generally driven by the prevailing wind, while upwelling on the lee of reefs must entrain replacement flows from depth. These entrained flows maybe counter- or cross-flow with respect to the surface flow. Superimposed on these patterns is the bottlenecked flow of tides through ocean passes, and wash over reef flats. Asymmetries from a perfectly circular atoll bathymetry and the Coriolis Effect contribute to horizontal rotation of the lagoon water mass, which consequently causes divergence cells at places on the surface and corresponding convergence cells at the bottom. The present paper presents a computational fluid dynamic (CFD) model development at Rongelap Atoll, in the Republic of the Marshall Islands. Bathymetric mapping and hydrographic surveying determined that the lagoon bottom was relatively flat and featureless plain at 50 m depth, punctuated by isolated pinnacles which rise to heights comparable to that of the enclosing ring of reef flats. Sand appeared to fill the bottom of the lagoon and cascade out of ocean passes. Consequently the lagoon boundaries were derived from aerial photographic images, as either areas of reef-flat, deep lagoon, and sloping transition zones. The methodology of CFD modeling lagoon circulation used parametric input/output to develop vector arrows of surface flow and benthic shear stress. Benthic shear stress controls the direction of sediment transport and deep larval transport, while the magnitude may determine if conditions are suitable for the settlement of biota.

Modeling Connectivity across the South Pacific: Applying Graph Theory to Coral Reef Conservation and Management

*Eric A TREML**, *Patrick N HALPIN*

5901 Wilkins Drive, Lot TA, Durham, NC, 27705 United States of America

eat4@duke.edu

Larval exchange between reef populations is of fundamental importance to their metapopulation dynamics and population persistence. Understanding the potential flow of individuals between distant reefs and/or reserves is key to their effective conservation and management. For many marine species, the larval dispersal stage is the only means through which populations are connected. This population connectivity is determined, in large part, by ocean currents transporting individuals between distant reefs. As marine conservationists, it is necessary to understand the patterns and variability in ocean current dynamics and how they may influence the dispersal potential of reef species. Recent work has focused on larval dispersal of marine species and its importance to marine reserves, although few studies have focused on spatially and temporally explicit patterns in this potential dispersal. Here, we use sea surface current vectors and an advection-diffusion approach to model the potential dispersal between coral reefs of the South Pacific. Our series of dispersal simulations compare seasonal and year-to-year variability in connectedness across this region. This time series of probabilistic dispersal paths between reefs are analyzed using graph theory. A graph theoretic approach is effective at exploring patterns in spatial connections, as well as performing site and pathway importance scenarios. Spatial analysis reveals striking differences in both the distance and the direction of potential larval dispersal throughout the region. Temporal comparisons between seasons and among years highlight the great variability at these time-scales. In particular, a three-year contrast between a normal year, a strong El Nino episode, and a strong La Nina episode, gives insight into the possible impacts of this cycle on the connectivity between reef populations. These seasonal and year-to-year patterns in connectivity between reef populations need to be considered in the development of conservation plans and the implementation of marine protected areas.

Using Genetic Programming to Modeling Spatial Distribution of Corals and the Impacts of Climatic Changes: A Case Study from Taiwan

*Wan-Hsu TSAI**, *Chang-Feng DAI*, *Yi-Chen YANG*, *Ching-Pin TUNG*

Institute of Oceanography, 424R, POBox 23-13, National Taiwan University, Taipei, Taiwan 106, R.O.C Taiwan

b86605119@ntu.edu.tw

Spatial relationships are the core of many ecological studies. A number of methods for learning spatial relationships have been proposed and Genetic Programming (GP) is one of the more successful approaches. Here we applied GP to model the spatial relationship of corals and used it to predict the influences of climate change on coral communities in Taiwan. The reef areas were divided into 58 grids (each 12.5 km × 12.5 km) which provide the basic scheme for modeling. Coral distribution data on each grid were summarized from previous surveys conducted from 1986 to 2003. SST data based on CTD surveys from 1981 to 2003 were extracted from the Ocean Data Bank of NCOR and the averages of four seasons were used as variables for modeling. Logistic regression was applied in the process of GP modeling and convert the value to 1 (presence) or 0 (absence). For model evaluations, the 58 grids were randomly divided into two groups: a training data set for creating the model and a test data set for evaluating data quality. One-tailed χ^2 statistics was employed to determine whether test points fall into regions of predicted presence more often than expected by chance. A total of 325 coral species were modeled and 139 models were formulated. We then applied the predicted SST values from CGCM2 to our models to simulate the impacts of climatic change on coral distributions. The results show that, in the 25-year scenario, the spatial distribution of corals is likely to expand and the species richness in most areas increases. While, in the 55- and 85-year scenarios, the spatial distribution of corals reduces and the species richness in most areas decreases dramatically. Unbalanced changes of coral communities can also be envisaged from the model predictions.

Object-oriented Simulation of Coral Reef Ecosystem: Effects of Physical Disturbance and Predation on Coral Community Structure

*Tze-Wai TAM**, *Put O ANG*

Shatin, N.T., Hong Kong

pyiptwt@netvigator.com

A 3-dimensional individual-based model, the ReefModel, was developed to simulate the dynamical structure of coral reef community by using object-oriented technique. Interactions among six functional groups of reef organisms: branching and tabular form coral, foliaceous form coral, massive form coral, macroalgae, corallivorous gastropod and herbivorous fish, were allowed in the model. The behaviours of organisms are described with simple mechanistic rules that are derived from their general behaviours (e.g. growing habits, competitive mechanisms, response to physical disturbance) observed in natural coral reef community. All organisms are allowed to freely move or grow (for adult sessile organisms only) in a 3-dimensional spatial environment. The model has been implemented to explore the competitive mechanism governing the coral community structure, and the effects of physical disturbance and gastropod predation on the dynamical structure of the coral community. Simulation results suggest that (i) fast-growing habit with overtopping competitive mechanism is probably the most effective strategy for corals to gain spatial dominance in a coral community under stable environmental condition; (ii) both physical disturbance and sensitivity towards it are important in governing the coral community structure under frequently disturbed condition; (iii) selective predation effort provides mediation effect on interspecific coral competition; and (iv) multiple stable states can occur in a coral reef community under a single environmental regime.

An Agent-based Approach to Modeling the Spread and Distribution of Coral Disease in the Florida Keys

*Marilyn E BRANDT**

4600 Rickenbacker Cswy, Miami, FL 33149 United States of America
mbrandt@rsmas.miami.edu

The lack of epizootiological studies has currently been listed as an impediment to field research priorities for the study of coral diseases in the Caribbean. Black-band and White Plague (Type II) diseases are two of the most important causes of coral mortality in the Florida Keys and the Caribbean at large; however, we still know very little about what influences them and what their long term effect could be. Modeling has become a standard means of generating hypotheses concerning the spread and risk of disease in both human epidemiology and epizootiology. It has also been implicated as the next critical step in the investigation of coral disease. Specifically, agent-based models (i.e. models that consist of individual agents interacting based on rules encapsulated in the agent) are widely used to investigate the nature of disease. A recent and prominent example of agent-based modeling in epidemiology is the assessment of the effectiveness of containment strategies in bio-terrorist smallpox outbreaks. I have developed a prototype agent-based, epizootiological computer model of coral disease in the Florida Keys that allows me to investigate the dynamics important to the causation and distribution of Black-band and White Plague diseases. Each coral colony is an agent and its subsequent life history "rules" include probabilities of infection and mortality that are based on its specific state variables. State variables describe the species, size, and location of the agent among others. The model provides the opportunity to vary the significance of environmental parameters (e.g. temperature, salinity, distance from shore, etc.) between model runs. Model outputs of disease distribution are then compared to observed disease distributions in the field. Parameters of greatest epizootiological importance are considered to be those whose increased significance results in a disease distribution similar to that seen in reality.

Modeling the Growth Form of Macroalgae: A Prototype

*Aletta YNIGUEZ**

4600 Rickenbacker Causeway, Key Biscayne, FL 33149 United States of America
ayniguez@rsmas.miami.edu

Currently there is concern about the increasing abundance of fleshy macroalgae on coral reefs, leading to "phase-shifts" from coral to algal dominance. In order to better understand this process, we must look at the ecology of these macroalgae particularly their population and community dynamics. I will be presenting a prototype of a spatially-explicit, agent-based model of dominant macroalgae in the Florida Keys. This modeling approach helps to synthesize knowledge and can be used as a tool to understand the mechanisms involved in the dynamics of macroalgal growth and spread. The model is founded on the modularity of macroalgae. Their growth and development are influenced by ontogenetic rules and phenotypic plasticity. The latter trait enables them to have variety and adaptability in their growth form as the modules interact with their environment at each growth step. The model is built around an algal module with intrinsic genetic rules and interacting with external stimuli. The iteration of these modules makes up the growth form of the actual macroalgae and dictates how it utilizes space vertically and horizontally. This prototype is as flexible as possible to allow addition and/or substitution of parameters for other algal species.

Developing a Multilevel Model for the Chinchorro Bank Reserve Biosphere: A Study Case for Coral Reef Ecosystem Management

Jesus E ARIAS-GONZALEZ, Jose M CASTRO-PEREZ, Gilberto ACOSTA-GONZALEZ, Nestor MEMBRILLO-VENEGAS, Gerardo GARCIA, Rodrigo J GARZA-PEREZ, Serge ANDRÉFOUËT*

Carr. Ant. Progreso km 6 Cordemex, Merida, Yucaten, Mexico C.P. 97210. United Mexican States
earias@mda.cinvestav.mx

We present an example of a multilevel model for Chinchorro Bank Biosphere Reserve, one of the best developed atoll type reef in the Caribbean. This reserve is part of the Mesoamerican Barrier Reef System and it is one of the most important ecological sites of the Mexican Caribbean coast. This system includes coral reef, seagrass beds, a small coastal lagoon, mangroves and endangered species as sharks, fish, turtles and crocodiles. Stress on the diversity of the biota and on these resources come primarily from fishing. We have performed an analysis of habitat and fish communities characteristics, as well as spatial prediction models using GIS and generalized regression spatial analysis. We modeled the spatial distribution of coral and reef fish communities, and fishing. We obtained results in the form of predictive maps of cover percentage of the reef components (corals, algae, sponges, sea-grass and geomorphologic features), fish (dominant species), fish trophic categories (carnivorous, piscivorous, etc) and fishing (commercial fish species). Eleven habitats were defined (using multivariate classification procedures) and mapped for the whole reef (using a LANDSAT 7 ETM+ as base image). Associated fish species/assemblages predictions were generated in terms of biomass for each mapped habitat. This baseline GIS will be used to construct mass balance models to assess the impact of fisheries on the ecosystem both temporal and spatially. The multilevel modeling approach illustrated here is expected give a valuable tool for coral reef ecosystem management.

The Modelling of Biodiversity and Species Habitat Association Applied to Marine Reserve Network Design

Maria BEGER, Geoffrey P JONES, Hugh P POSSINGHAM*

St Lucia, QLD 4072 Australia
mbeger@zen.uq.edu.au

Marine reserve networks aiming to conserve coral reef biodiversity are most efficient in achieving their goal when they are chosen and configured using a systematic conservation planning process. One of the major information gaps in our capacity to develop such networks is the lack of species-level coral reef biodiversity data. For southeast Asian and west Pacific coral reef ecosystems, currently available data are patchy and of varying quality. There is little biological information about un-surveyed reefs, leading to a bias in reserve planning towards often arbitrarily chosen surveyed sites or habitats. Based on existing biodiversity data on surveyed reefs (sites), we compared two modelling approaches predicting the probability of species occurrences based on non-biological reef characteristics. We conducted this analysis using a suitable subset of reef fishes at Kimbe Bay, Papua New Guinea. The predictive power of reef characteristics such as exposure, depth, distance from shore, topography and coral cover were investigated for a logistic regression model and a Bayesian belief network modelling approach. We predicted probabilities of species occurrences on reefs not surveyed, and tested the results with data collected from these reefs. The probabilities of occurrence for the suite of fishes were then utilised to develop a marine reserve network in Kimbe Bay. This approach improved the flexibility of the network and conservation options, had a broader spatial coverage and representativeness over the use of only surveyed sites. This method improves our capability to systematically design marine reserves even when little data is available, as it helps focus survey efforts to a smaller number of reefs and increases flexibility of solutions, facilitating better accommodation of stakeholder preferences.

A Model for the Integration of Biophysical and Socio-Economic Considerations in the Design and Deployment of Marine Protected Areas

*R Y LICUANAN**, Gem CASTILLO, Wilfredo CAMPOS, Porfirio ALINO, Marie Antonette JUINIO-MENEZ

2401 Taft Avenue Manila 1004 Republic of the Philippines
licuananw@dlsu.edu.ph

Marine protected areas have become the de facto tool for management of coastal fisheries because of its relative ease of implementation and presumed long-term benefits to both fisheries and conservation. However, such benefits may be negated, if not reversed, if other interventions and restrictions are not applied, MPA size and design are inadequate, social and economic costs of establishment and maintenance are not considered, and sustainable financing is not ensured. Although the art and science of MPA use has progressed significantly over the last few years, there is still a need for a conceptual framework to integrate the various considerations and allow for scenario-building in support of management decisions. To help promote best practices given the state of the MPA science, a simple-to-use graphical model for determining MPA size is presented, using data from Tabina, Zamboanga del Sur, Philippines as a case study. Aside from determining minimum MPA size for supporting fisheries, the model can be used to help determine sustainable levels of effort, minimum distance from shore that commercial fleets can be allowed to operate, and even consequences of assigning parts of coastal waters to other uses (e.g., recreation, aquaculture, etc). An added feature is its ability to consider number and costs of people displaced by MPAs, establishment and maintenance costs vis-a-vis MPA benefits to fisheries to allow managers and local officials to appreciate the other aspects of MPA deployment beyond the biophysical considerations. Although model outputs improve with input data quality and experience of the users, the model can at least help structure thinking of scientists and managers when considering practical applications given the dynamic nature of ecosystem management.

Agent-based Simulation of Human-Environment Interactions on Coral Reefs: A Prototype of a 3D Approach

*John W MCMANUS**, Felimon C GAYANILO JR.

4600 Rickenbacker Causeway, Miami, Florida United States of America
jmcmamus@rsmas.miami.edu

Improving the success of coral reef management interventions requires enhancing our understanding of the interactions between coral reef resources and their users. Coral reefs are complex, nonlinear systems in which spatial heterogeneity and stochastic events interplay with environmental factors to result in highly variable patterns of resource availability and use. Because it is difficult to capture this interplay in differential equation models of environmental or fishery dynamics, it is reasonable to apply approaches developed specifically for studies of complex systems, such as agent-based models. We have developed a prototype of an agent-based model incorporating key elements of such a system, including depth, distance from shore, bottom cover, herbivory, planktivory, piscivory and fishing pressure. The model is built on the Java-based RePast modeling framework. With this, we explore common-property use and Gordon-Schaeffer bioeconomic resource-use dynamics under varying environmental conditions. This prototype model is a step toward developing Dynamic Decision Support Systems (DDSS) for coral reef management by incorporating scenario-testing agent-based models into Geographic Information Systems (GIS) interface, in connection with the CARRUS Alliance (Comparative Analysis of Reef Resilience Under Stress).

Genetic Structures of Commercially Important Demersal Fishes (*Lethrinus atkinsoni* and *Lethrinus nebulosus*) Around the Ryukyu Islands, Japan

Masaya KATO^{H*}, Atsuro OKUNO, Katsuhiko KISO, Hideaki YAMADA

148-446 Fukai-Ohta, Ishigaki, Okinawa 907-0451 Japan

mkatoh@fra.affrc.go.jp

The family of Lethrinidae includes many important food fishes, and about 900 tons (including some lutjanid species) are harvested annually in the vicinity of the Ryukyu Islands. Two of the most abundant species (*Lethrinus atkinsoni* and *Lethrinus nebulosus*) made up more than half of the total catch. *L. atkinsoni* and other species are known to aggregate for spawning. This behavior makes them a good target for fishing. The annual catch of Lethrinidae has decreased recently. Knowledge of the population structure of commercially important fish is necessary for effective resource management. There have been few studies that focus on the population structures of coral reef fishes in the vicinity of the Ryukyu Islands. We investigated genetic structure of two commercially important fish species (*L. atkinsoni* and *L. nebulosus*). We compared allele frequencies of six polymorphic allozyme loci among three insular populations of the emperor *Lethrinus atkinsoni* (Okinawa, Miyako and Ishigaki islands), which are 150 to 400 km apart, and of four polymorphic loci between two insular populations of *L. nebulosus* (Okinawa and Ishigaki islands). A significant frequency difference was observed at one allozyme locus (glucose-6-phosphate isomerase: *GPI*) between the Ishigaki population and the other two populations of *L. atkinsoni*. However, no significant difference was observed between the two populations of *L. nebulosus*. The genetic difference in *L. atkinsoni* may indicate limited gene flow between the populations. Selection on *GPI* alone can also create the variation in *L. atkinsoni*. The genetic similarity in *L. nebulosus* may indicate higher gene flow. Other genetic markers such as mitochondrial DNA variation may reveal different picture. DNA sequences of the control region of mtDNA will be investigated. Until we know that the insular populations of the *Lethrinus* species are surely connected, they should be considered as different resource management units.

Patterns of Population Genetic Structuring of Rabbitfishes *Siganus argenteus* (Quoy & Gaimard, 1825) and *Siganus fuscescens* (Houttuyn, 1782) along the Eastern Philippine Coast

Richard M MAGSINO*, Marie Antonette J MENEZ

UP Campus, Diliman, Quezon City, Philippines Republic of the Philippines

rickym@upmsi.ph

Siganus argenteus (pelagic egg dispersers) and *Siganus fuscescens* (demersal egg layers) are two rabbitfish species displaying different life history patterns. These two species commonly occur among eastern Philippine reefs where the North Equatorial Current (NEC) bifurcates into two, north (Kuroshio) and south (Mindanao Current) directions. Allozyme variability was used to determine and compare the temporal (effect of life history) and spatial (effect of NEC bifurcation) genetic structure of both species. A total of 19 allozyme loci of which 13 to 14 were polymorphic (at 0.99 level) were surveyed for both species. Fish samples were collected during the years 2001 to 2003 from a total of 25 reefs representing populations from the north and south bifurcations of the NEC. Genetic variability of populations indicates that both species were heterozygous. *S. fuscescens* populations (Hobs= 0.085) showed higher levels of heterozygosity than *S. argenteus* populations (Hobs= 0.053). Samples of *S. fuscescens* collected in 2003 (Hobs= 0.091; % polymorphism= 28.6%) likewise were more genetically variable than samples collected in 2002 (Hobs= 0.082; % polymorphism= 26.3%), while the inverse was found for *S. argenteus* collected from both years. Mean estimates of genetic distance (Nei D) were low for both species: *S. argenteus* = 0.002; *S. fuscescens* = 0.004. Genetic variance over all populations measured by *Fst* showed greater genetic structure for *S. fuscescens* (*Fst*=0.0458) than *S. argenteus* (*Fst*=0.0279). Consequently, rates of gene flow among populations of *S. fuscescens* (*Nm*= 3 to 10 individuals) were lower than among populations of *S. argenteus* (*Nm*= 5 to 32 individuals). Cluster analyses for both species showed grouping of populations based on spatial (Kuroshio vs. Mindanao Current) and temporal (2001 and 2003 collections) genetic considerations with some exceptions.

Connectivity in Reef Corals: An Assessment of Small-scale Patterns of Larval Dispersal Using Microsatellite Markers

Karen J MILLER*, David J AYRE

Northfields Ave, Wollongong, NSW 2522 Australia

karen.miller@utas.edu.au

Most studies on larval dispersal in reef systems have focussed on large scales such as between reefs and regions. While this is likely to be important in an evolutionary context, increasing information about the realised dispersal, especially of coral larvae, suggests the majority of larvae will settle locally. However, within the framework under which most management decisions are made, an understanding of processes that influence larval dispersal on smaller, ecological scales is required. Genetic markers are undoubtedly one of the best tools for elucidating realised levels of gene flow and larval dispersal in marine species such as corals that have microscopic, planktonic larvae, and especially at small scales. However to confidently infer the source of individual larvae it is critical to use selectively neutral, hypervariable markers that accurately reflect relationships within and among populations. We have developed state-of-the-art microsatellite markers for two species of scleractinian coral with contrasting larval dispersal ability; *Platygyra daedalea* (a typical broadcast spawner) and *Goniastrea favulus* (which has negatively buoyant eggs). Importantly, the microsatellites have proven to be at least twice as variable as allozyme markers, providing increased resolution to detect patterns of genetic structure in these corals. We have used the microsatellites to characterise population structure and infer larval dispersal across three scales (tens of metres, 100s of metres and kilometres) at One Tree Reef on the southern Great Barrier Reef. We established four reef flat sites that were approximately 150m² in area and sampled all *P. daedalea* (n=293) and all *G. favulus* (n=364) colonies within each site. Colonies were genotyped at 5 (*P. daedalea*) and 4 (*G. favulus*) polymorphic loci. The results from tests for population structuring and the implications of these results for gene flow and larval dispersal in corals at small spatial scales will be discussed.

Limited Population Connectivity and Varying Clonal Structure of *Acropora palmata* in the Caribbean

Iliana B BAUMS*, Margaret W MILLER, Michael E HELLBERG

4600 Rickenbacker Causeway, Miami FL 33149 United States of America

ibaums@rsmas.miami.edu

Declining Acroporid populations in the Caribbean are currently the subjects of conservation efforts. Conservation strategies for these populations will depend in part on both the degree of genotypic diversity within populations and the amount of larval exchange between populations. *Acropora palmata* reproduces sexually through broadcast spawning and asexually through fragmentation. Thus, estimates of population size as well as population connectivity rely on the identification of genets. We employ five highly polymorphic, Mendelian microsatellite loci to (1) describe clonal structure and (2) to estimate population connectivity. Clonal structure varies within and between regions: in Key Largo, FL, two populations are dominated by one genet each whereas a third population shows 10 different genets on the same spatial scale. In contrast, only sexual recruits (i.e., single-colony genets) were found in three populations sampled at Navassa, St. John, US Virgin Islands, showed predominantly clonal population structure while Curacao and Bonaire had much higher levels of clonal diversity. Genetic subdivision within the Caribbean basin was small, but significant ($F_{ST} = 0.045 \pm 0.018$ SE). Geographic regions with limited larval exchange between them could be identified. The highly asexual nature of some populations in concert with limited larval exchange between regions indicates that recovery of declining *Acropora palmata* populations could be slow.

Connectivity and Genetic Diversity of *Montastraea faveolata* across the Florida Keys National Marine Sanctuary: A Microsatellite Analysis

*Chad A MCNUTT**

4800 Calhoun, 369 Science and Research 2, Houston, Texas 77204-5001 USA
cmcnutt@uh.edu

Many coral reef species have the potential to disperse larvae over large distances. Recently, though, the distance that these species actually disperse has come into question. Because of the potential for low dispersal, several authors have pointed out that reefs may be more dependent on local production and recruitment of larvae, which may be significant in light of the whole-scale reef degradation that has been observed over the past four decades. The Florida Keys National Marine Sanctuary (FKNMS) served as a model to understand gene flow and genetic diversity at relatively small scales using a coral species with pelagic larvae. Allelic differences of *Montastraea faveolata* were assessed between six populations from seven microsatellite loci. Gene flow and connectivity were assessed in the context of geographic distance between populations, environmental conditions and local ocean circulation patterns. Genetic diversity was estimated from observed heterozygosity and allelic diversity. To evaluate whether genetic diversity has declined over time, effective population size (N_e) was estimated based on allele frequency shifts from several colony age classes. Estimating N_e is important to assess the rate at which genetic diversity is eroded by genetic drift. Several factors can reduce N_e , such as low population size, low immigration and increased age-specific fecundity. Due to the severe decrease in the abundance of corals within the FKNMS, it is likely that genetic variability is low due to inbreeding as a result of low N_e and immigration. Genetic variability is necessary for both adaptation to changing environments and long-term species survival. If population dynamics have changed little over time, then the historical N_e should be approximately equivalent to the current N_e . However, it is possible that several demographic factors have significantly changed due to anthropogenic influences, environmental degradation, and/or increased mortality of reef-building corals.

Population Genetics of the *Gorgonia ventalina*/*Aspergillus sydowii* Pathosystem

Jason ANDRAS, Krystal RYPIEN, Drew HARVELL*

Corson Hall, Cornell University, Ithaca, NY, 14853 United States of America
jpa24@cornell.edu

The frequency and severity of disease outbreaks have increased recently for many tropical marine invertebrate communities. Disease-related mortality within affected populations is often differential, reflecting heterogeneous distribution of susceptible individuals. Such culling by disease is capable of imposing strong directional selection and has the potential to significantly affect both the ecological and evolutionary trajectories of a population. Most studies of marine disease have focused on interactions between disease and host community numerical dynamics but have not considered the importance of genetic variation. Consequently, the roles of host and pathogen genetic structure in governing patterns of disease occurrence and prevalence are poorly understood for most marine systems. The Caribbean sea fan *Gorgonia ventalina* and its associated fungal pathogen *Aspergillus sydowii* have been closely monitored at sites throughout the Caribbean, and compose a tractable model pathosystem for investigations of marine disease. Previous work has demonstrated that virulence of *A. sydowii* and resistance of *G. ventalina* are genetically variable, suggesting that the genotypes of both host and pathogen may be involved in determining patterns of disease. To investigate this, disease surveys were conducted and samples of both healthy and infected sea fans were collected along the entire Mesoamerican barrier reef according to a geographically hierarchical strategy. Population structure and connectivity of host and pathogen populations were quantified using autosomal microsatellite markers, and interactions between spatial genetic structure and disease prevalence were examined. Data will be presented and results discussed in the context of community genetics and marine disease dynamics.

Geographic Expansion of Corals in the Gulf of Mexico via Offshore Platforms: Community Characteristics, Recruitment, and Genetic Affinities

Paul W SAMMARCO, Amy D ATCHISON, Daniel A BRAZEAU, Gregory S BOLAND*

8124 Hwy. 56, Chauvin, LA 70344 United States of America
psammarco@lumcon.edu

In the northern Gulf of Mexico, the Flower Garden Banks (FGB) are hundreds/thousands of kms from neighboring reef systems, and have been for tens/thousands of years. The continental shelf there now possesses 4,000 oil/gas platforms. The questions arise: Are corals expanding their geographic range through the Gulf via the platforms, to what degree, and what are their genetic affinities to neighboring systems. Thirteen platforms were surveyed, and coral settlement racks were deployed to determine levels of coral recruitment. Tissue samples of dominant corals were collected for genetic analysis. Adult *Agaricia agaricites* tissue was also sampled from the Bahamas, Florida Keys, FGB; and from spat on settlement plates placed on the FGB. Tissue was analyzed via AFLP to examine genetic distances between locations, and between adults and spat. Eleven coral species were found on the platforms. Eight were hermatypic; the most abundant were *Madracis decactis* and *Diploria strigosa*. Most species were characteristic of later seral communities. *Porites* and *Agaricia* spp. were absent or rare. There was no relationship between coral abundance and distance from the FGB. Abundance and species diversity was strongly correlated with platform age. Coral recruitment on the platforms was rare; recruitment density on the FGB was high. Only two species of spat were found on the platforms: *Tubastrea coccinea* and *Madracis decactis*. The presence of corals on the platforms indicates a geographic expansion in this region. Adult corals in the three reef-system locations were found to be genetically distinct. Spat from the FGB were homogeneous with the FGB adults, but were significantly different from adults in other locations. Larval dispersal in *A. agaricites* between reef systems appears to be highly limited in ecological time between these locations. The use of DNA fingerprinting via AFLP is a valuable and appropriate tool for conducting population genetic studies on corals.

High Levels of Gene Flow in Commensal, Brooding Marine Amphipods: Mitochondrial DNA Variation in Florida Populations of the *Leucothoe spinacarpa* Species Complex

Vincent P RICHARDS, James D THOMAS, Michael J STANHOPE, Mahmood S SHIVJI*

8000 North Ocean Drive, Dania Beach, Florida 33004 United States of America
ardsrich@nova.edu

In response to the global decline of coral reefs, conservation efforts have focused on the establishment of MPAs. Crucial to effective MPA design, is an understanding of the extent of genetic connectivity among reefs for the entire spectrum of its diverse inhabitants. Connectivity dynamics of cryptic reef organisms, especially those with direct development, is largely unexplored. We report here on an assessment of gene flow in the common, reef amphipod species complex *Leucothoe spinacarpa*, which exhibits direct development and is delineated into four morphotypes. Our initial focus was on exploring connectivity among geographic isolates of morphotype four, a commensal species inside the branching vase sponge *Callyspongia vaginalis*. We used variation in a 422 bp segment of the mitochondrial cytochrome oxidase subunit I (COI) gene to infer patterns of gene flow among six geographic locations along approximately 400 km of the southeast coast of Florida. A total of 42 haplotypes were identified from the 171 animals sampled. Contrary to predictions of highly restricted dispersal based on a commensal lifestyle and direct development of young, AMOVA analysis revealed high levels of gene flow throughout the region, with less than 17% of the variation occurring among geographic locations. These results show that assumptions regarding dispersal capability based on life history characteristics need to be empirically tested, and highlight the need for a more comprehensive understanding of coral reef connectivity across a broad range of taxa. To this end, we will also report on ongoing studies of comparative gene flow in a second amphipod species (morphotype three) that is commensal in the same sponge.

Using Otolith Microchemistry to Gauge Dispersal Scales and Connectivity among Marine Populations

*Robert R WARNER**, Michael SHEEHY, Jennifer E CASELLE, Benjamin RUTTENBERG

Dept. EEMB, University of California, Santa Barbara, CA 93106 USA
warner@lifesci.ucsb.edu

We lack knowledge of the mechanisms by which marine populations are replenished and sustained. This knowledge is essential in developing a scientific basis for marine resource management, including the placement and expected function of marine reserves. We are using microchemistry to explore the extent of self-seeding of local marine populations, the degree of connectivity among coastal communities, and the dispersal scale of several marine species. Natal trace-element signatures in the core of growth-recording hard parts (otoliths and statoliths) can be compared with field samples of settled juveniles in fish and invertebrates. In our temperate zone samples, otoliths and statoliths of larvae captured prior to leaving their birthplace show clearly distinct natal signatures over surprisingly short distances, and we are now characterizing the spatial and temporal scale of variation in natal signatures for open-coast species. Through analysis of otolith cores, newly recruited fishes can be assigned to birthplace on large geographic scales, and sites appear to differ in the degree to which recruits are the result of retention, of dispersal from a limited array of sources, or of more general mixing and accumulation. Pre-pelagic larval otoliths from tropical reef fishes show less distinct geographic patterns of natal signatures compared to temperate fishes, and assignment of natal origin for tropical recruits may need to be on larger scales.

Using Otolith Chemistry to Measure Connectivity among Fish Populations: Difficulties Addressed in an Experiment Using Bicolor Damselfish, *Stegastes partitus*

*Paul M CHITTARO**, Camilo MORA, Usseglio PAOLO, Hogan DEREK, Brian J FRYER, Ernesto ARIAS, Peter F SALE

401Sunset Blvd., Windsor, Ontario Canada
chittal@uwindsor.ca

Knowing the connectivity among local populations should be an important early step if management using no-take reserves is to be undertaken. To quantify larval fish dispersal and the relative connectivity of populations, several studies have used otolith microchemistry. Such studies have used collections of water chemistry and/or otolith edge chemistry from several locations as site-specific chemical signatures, which are then compared to otolith core chemistries to determine larval origination. Although advances have been made in understanding the mechanisms that influence sequestering of elements into the otoliths, there remain gaps in our knowledge; especially regarding the effect ontogeny may have on elemental concentrations. Here, we experimentally examined the extent to which larval otolith microchemistry reflects that of both water and adults, thus testing whether concentrations determined from adult fish and water samples can accurately identify larval origination.

Using ICP-MS Analysis of Coral Reef Fish Otoliths to Examine Connectivity between Islands of French Polynesia

*Alain LO-YAT**, Mark G MEEKAN, Niels C MUNKSGAARD, David L PARRY, Serge PLANES

Charles Darwin University, Science building n42, Darwin 0909, Northern Territory, Australia
a.loyat@aims.gov.au

An estimate of connectivity within metapopulations of marine fish is essential information for anyone intending to design and implement effective marine protected areas. Our work in French Polynesia examines the degree to which populations of a territorial damselfish, *Stegastes nigricans*, are open or closed at the scale of whole islands by Inductively Coupled Plasma Mass Spectrometer (ICP-MS) analysis of otoliths. Using this technique, we compare the composition and concentration of elements in the otoliths of adult, juvenile and newly recruited fish collected in polluted harbours and in several other non-polluted sites around the islands of Tahiti and Moorea. This comparison will allow us to determine the importance and the scale of self-recruitment to these islands.

Labelling of Embryonic Otoliths via Maternal Contribution of Enriched Isotopes: A New Technique for Estimating Connectivity in Reef Fish Populations

*Simon R THORROLD**, Geoffrey P JONES, Serge PLANES, Jonathan A HARE

MS 35, Woods Hole, MA 02453 United States of America

sthorrold@whoi.edu

Quantifying population connectivity through larval dispersal remains a significant hurdle in the design of marine protected areas, and more generally in the application of spatial management options in coral reef ecosystems. Identifying natal origins of fish is, however, challenging because of difficulties in conducting mark-recapture studies in marine systems. To circumvent some of these difficulties, we are developing techniques that use stable isotope and trace element signatures in fish otoliths as tags of natal origins. We are investigating dispersal pathways of gray snapper (*Lutjanus griseus*) along the SE coast of the U.S. by constructing high resolution elemental profiles across the otoliths of recently settled juveniles. Interpretation of these data remains difficult, however, due to subtle gradients in water mass properties and physiological regulation of otolith chemistry at the level of individual larvae. We have, therefore, developed artificial marking techniques that will allow large numbers of embryos to be indelibly tagged in situ by introducing unique isotopic combinations of naturally occurring elements into the otolith core via maternal contribution. The technique promises empirical estimates of larval connectivity in benthic and pelagic spawning reef fishes with a precision that has yet to be realized for any marine species with a pelagic larval phase. This will, in turn, allow for direct verification of coupled biophysical models of larval dispersal that are likely to remain the primary tool by which connectivity in coral reef systems is measured.

Spatial Epidemiology of Yellow band Syndrome in *Montastraea* spp. Coral in the Eastern Yucatan Caribbean, Mexico

Janet FOLEY, Susanne SOKOLOW*, Evan GIRVETZ, Patrick FOLEY
CVEC, Old Davis Road, Davis, CA 95616 United States of America
shsokolow@ucdavis.edu

The reefs of the eastern Yucatan peninsula, Mexico, constitute the northern tip of the second largest barrier reef ecosystem in the world. This area is experiencing a high incidence of coral disease, marked reef degradation, and algal overgrowth. The objectives of this study were to use geographical information systems (GIS) and spatial statistics to understand the distribution of a coral disease, Yellow Band Syndrome (YBS), in Akumal Bay, Mexico, and to use epidemiological techniques to determine key host and environmental risk factors for YBS. YBS was present in approximately 28.5% (CI= 18.2-41.5%) of *Montastraea* spp. coral colonies throughout Akumal Bay in 2002. Analysis for spatial clustering documented that *Montastraea* spp. colonies were highly spatially clustered at all distances, compared to expected complete spatial randomness, however, colonies with YBS tended to be overdispersed within the overall clustered spatial distribution of *Montastraea* spp. colonies. This pattern implies that the risk of disease is lessened by close proximity to a YBS affected colony, possibly due to the induction of defenses in neighboring colonies. Ammonia level was weakly negatively associated with disease severity ($R^2=0.1$, $p=0.049$). Furthermore, depth ($p=0.001$), temperature ($p=0.048$), colony height ($p=0.01$) and colony diameter ($p=0.02$) were significantly associated with disease severity. No significant associations were found between disease severity and pH, salinity, or other nitrogenous wastes. Diseases in coral likely emerge due to the synergistic interactions of pathogen, host, and environmental factors, and understanding environmental and host factors in disease may be key to understanding coral disease and decline. Although the etiology and pathogenesis of YBS are not presently known, this study demonstrates that risk factors such as ammonia, depth, and colony size may be associated with increased disease severity. Furthermore, because YBS severity is associated with environmental and host factors, studying the spatial components of host-disease interactions are critical.

The Impact of Yellow-Blotch Disease (YBD) on the Remote Reefs of Mona Island, Puerto Rico

Andrew W BRUCKNER*, Robin J BRUCKNER
1315 East West Highway, Silver Spring, Maryland United States of America
andy.bruckner@noaa.gov

An outbreak of yellow-blotch disease (YBD) among *Montastraea annularis* (species complex) was observed on reefs surrounding Mona Island, Puerto Rico in 1999. Up to 50% of all *M. annularis* colonies within permanent 314 m² radial sites were affected, including many of the largest (2-3 m diameter and height) and presumably oldest colonies. The highest prevalence of disease was recorded in shallow depths (3-10 m) off the protected west coast. While fewer colonies were affected in deeper water (15-25 m) off the south coast, colonies newly infected with YBD were identified during every survey. Measured rates of disease spread and tissue mortality has been slow (5-15 cm/year) compared to other diseases, although spatial, seasonal and annual differences were observed. Colonies first identified with a single YBD lesion have exhibited multiple centers of infection over time, compounding mortality rates. In addition, most corals identified with YBD in 1999 were still affected in 2003, with colonies losing 50-100% of their tissue over this period. The deteriorating health of *M. annularis* (species complex) is of particular concern, as these corals are the dominant reef-building species on these reefs. Mortality from YBD is being aggravated by other syndromes, especially black-band disease and white plague, which sometimes occur simultaneously on a colony. Sexual recruitment of *M. annularis* has not occurred over the study period, and bioeroding sponges, macroalgae, cyanobacteria and other competitors have colonized tissue-denuded skeleton, minimizing the likelihood of future coral recruitment or coral tissue resheeting. This study demonstrates that coral diseases are causing extensive mortality in remote locations where anthropogenic stressors are minimal. Additional research is necessary to better understand YBD and to develop strategies to mitigate disease impacts, or *M. annularis* (species complex) may suffer a fate similar to that of the Atlantic acroporids

Impact of a White Plague-II Outbreak in Deep Reef Habitats off the South-West Coast of Puerto Rico

Ernesto WEIL*
PO BOX 908, Lajas PR 00667. United States of America
eweil@caribe.net

In recent years, white plague-II (WP-II) outbreaks have been reported from many localities in the Caribbean. This disease has been observed at intermediate-to-deep areas in many reefs off the south west coast of Puerto Rico. Prevalence levels, however, were low in most surveyed localities. In early August of 2003, few colonies of *Montastraea franksi* and other coral species showed the typical signs of WP-II in one of our deep sampling sites. Then, in late August and September of 2003, when warm waters (29.5 °C) were prevalent even at 20 m deep, an epizootic event developed affecting as many as 22 coral species and a common crustose algae, mostly at deep reef (>18 m) sites of the insular shelf-edge. Two reefs were quantitatively surveyed during September using sixteen 20 m² band-transects (10 × 2 m) randomly distributed in each site. All corals were identified to species, counted and checked for presence of disease signs. Several affected colonies of the main coral species and a crustose algae were tagged and nails placed at the tissue edge and followed through time. Results indicate that WP-II prevalence at the community level was significantly higher ($7.30\% \pm 0.65$), than in previous surveys. WP-II prevalence at the species level was high and variable, with the main reef building species being the most affected: *M. faveolata* (20.7 ± 2.8), *M. franksi* (11.8 ± 1.24), *M. cavernosa* (3.6 ± 1.25), *Diploria strigosa* (13.1 ± 11.8), *D. labyrinthiformis* (16.7 ± 5.1), and *Colpophyllia natans* (45.59 ± 9.7). Rates of tissue mortality varied across species and were as high as 3.1 cm/day, killing small colonies in less than a week and many large colonies over the two months the event lasted. After water temperatures went down in November, most surviving disease colonies showed no signs of active WP-II, and no tissue mortality.

Monitoring the Coral Disease Plague Type II, on Two Coral Reefs in Virgin Islands National Park, St. John, US Virgin Islands

Jeff MILLER*, Rob WAARA, Caroline ROGERS
1300 Cruz Bay Creek, St. John VI 00830 Virgin Islands of the United States
william_j_miller@nps.gov

The coral disease plague type II, is being monitored at Tektite and Haulover Reefs, both located in Virgin Islands National Park. The study area at Tektite Reef is a nearly monospecific stand of *Montastraea annularis* with percent cover by hard coral of >50%. Monthly surveys at Tektite Reef from December 1997 through December 2003 documented new incidence of disease (bare white patches of skeleton) every month with associated loss of living coral. Increases in disease occurrences did not correlate to temperature stress. Coral cover at the study transects decreased from 65.3% (± 7.41 SD) to 43.4% (± 5.08 SD). The frequency of disease within transects ranged from 3 to 58%, and the area of disease patches ranged from 0.25 to 9000 cm². The average percent cover by the disease ranged from 0.01% (± 0.04 SD) to 1.74% (± 9.08 SD). Photo-monitoring of 28 diseased corals of 9 species (begun in September 1997) at Haulover Reef (hard coral cover 21.1% (± 12.1 SD)) revealed no recovery of diseased portions with all necrotic tissue being overgrown rapidly, usually within less than one month, by turf algae. Most coral colonies suffered partial mortality yet some colonies greater than 1.5 m in diameter were completely consumed in less than six months. Some limited recruitment (e.g., *Porites* spp., *Agaricia* spp., *Favia* spp. and sponges) has been noted on the diseased areas.

Prioritizing Research to Manage Mass Coral Bleaching: A Gap Analysis*Heidi SCHUTTENBERG**8037 Eastern Ave, #201, Silver Spring, MD, 20910 United States of America
heidi.schuttenberg@noaa.gov

In response to major coral bleaching events over the last five years, government and non-governmental organizations are developing initiatives to manage climate change impacts on reefs. The U.S. Coral Reef Task Force has passed a series of resolutions on coral bleaching since 1998, and hosted a workshop in 2003 aiming to identify science-based management responses to mass bleaching. Concurrently, the U.S. Climate Change Science Program, the largest initiative of its kind, is considering reefs as one element of climate change impacts on ecosystems. The Great Barrier Reef Marine Park Authority is actively developing a Climate Change Program, including a strategic research agenda, communication strategy, and development of management options. Internationally, the Convention on Biodiversity continues to highlight the impacts of mass coral bleaching. Several major non-governmental organizations are focusing significant resources on managing and building resilience toward mass bleaching, including The Nature Conservancy, World Wildlife Fund, and The World Bank among others. The development of these initiatives has generated a series of management-oriented research priorities that have received varying levels of official endorsement. This presentation provides a gap analysis of research relevant to the policy and management of coral reefs for climate change. It compares a synthesis of on-going research against research agendas that have been endorsed by various government and non-government organizations. The resulting analysis highlights similarities and differences between the priorities of the research and management communities for information related to mass coral bleaching.

From Scepticism to Action: Responding to Climate Change Threats to Coral Reefs*Paul MARSHALL**PO Box 1279, Townsville, Queensland, 4810, Australia
p.marshall@gbmpa.gov.au

In 2002 the Great Barrier Reef suffered its second major coral bleaching event in five years. This event triggered the most comprehensive coral bleaching response program yet conducted, enabling development and testing of new approaches and systems for understanding and responding to these ecosystem-scale disturbances. Reef management in the face of this global phenomenon appears to be a daunting challenge, yet there is an urgent need to develop and implement strategies that can mitigate damage to ecological, economic and social systems that are dependent on healthy coral reefs. While global efforts to minimize the rate and extent of future climate change are imperative, it is now clear that there is also much that can be done at the local level. Emerging research shows alarming synergies between climate and other stresses that provide impetus for local management aimed at supporting reef resilience. Tools to assist reef managers to meaningfully respond to the threats of climate change are currently being developed through international partnerships that include GBRMPA, NOAA and other government and non-government organisations. There is an ongoing need for increased knowledge and capacity relating to climate change impacts on reefs, and opportunities for more active collaborations between NGOs and Government agencies. This presentation will provide an overview of current and emerging knowledge about coral bleaching and the strategies that might be implemented to increase the chance of coral reefs surviving future warming.

Corals and Climate - Natural Variability or Alarm?*Alan E STRONG*, William S SKIRVING, Gang LIU*5200 Auth Road - Rm 601, Camp Springs, MD 20746 United States of America
Alan.E.Strong@noaa.gov

Coral reefs ecosystems are rapidly becoming ecosystem sentinels for our changing climate. Coral reefs are second only to rainforests in species diversity, and they are dying off at an alarming rate. Not only does the loss of reefs represent a tragedy of epic proportions in itself, it may be a warning sign of dangerous trends to come. Using satellite sensors at NOAA, we are currently tracking ongoing basin-wide, as well as regional and local trends, Pacific Decadal Oscillations (PDO), and El Nino Southern Oscillation (ENSO) occurrences and linking them to responses in coral ecosystems. The Coral Reef Watch (CRW) Program, led by NOAA's Satellite and Information Service, and consisting of components from NOAA Research and NOAA Fisheries Service, continuously monitors coral reef areas world-wide for changes in sea surface temperature, as well as other key parameters linked to the onset of bleaching events. These environmental products are posted on the internet in near-real-time. They are geared towards managers and stakeholders of coral reef areas and include tools to help determine what areas are more susceptible to coral bleaching enabling management efforts to be focused more efficiently. http://orbit-net.nesdis.noaa.gov/orad/coral_bleaching_index.ht

NOAA's Coral Reef Watch Hotspot and DHW Products: Trends in the Extent of Mass Bleaching*William J SKIRVING*, Alan E STRONG, Gang LIU, Chunying LIU, Jamie OLIVER*SSMC1, #5306, 1335 East-West Highway, Silver Spring, MD 20910-3226, USA United States of America
william.skirving@noaa.gov

NOAAs Coral Reef Watch (CRW) Program develops satellite based products which are designed to monitor thermal stress that leads to coral bleaching. The HotSpot product (first developed in 1997) is a measure of the intensity of the thermal stress, but do not measure the cumulative effects of that thermal stress on a biological system such as coral reefs. In order to monitor this cumulative effect, a thermal stress index, called a Degree Heating Week (DHW), was developed in 2000 and became operational in 2001. DHW represents the accumulation of HotSpots for a given location, over a rolling 12-week time period. Preliminary indications show that a HotSpot value of less than one degree is insufficient to cause visible stress on corals. Consequently, only HotSpot values >1°C are accumulated. Field observations (most of which are subjective measurements presented as informal reports) with coincident satellite data are only available for a limited number of years; these observations indicate that there is a correlation with bleached corals when DHW values of four have been reached. By the time DHW values reach eight, widespread bleaching is likely and some mortality can be expected. CRW has applied these DHW values since 2001 when generating satellite bleaching warnings and alerts. To date, over 100 warnings have been issued. Of these warnings, 45 coincident field reports have been sent in by observers and all have confirmed bleaching. This paper will present the methodologies for the HotSpot and DHW satellite products. An inter-comparison with the ReefBase coral bleaching field report data base will then be presented. Lastly, the DHW product will be used to examine the thermal stress over time.

Projecting the Frequency of Coral Bleaching Events due to Possible Changes in Climate

*Simon DONNER**, *Michael OPPENHEIMER*, *William SKIRVING*, *Alan STRONG*

402 Robertson Hall, Princeton, New Jersey, 08544 United States of America
sddonner@princeton.edu

Future changes in climate may lead to increasing frequency and severity of coral reef bleaching, a threat to the viability of reefs worldwide. This concern has arisen from observation of regional-scale bleaching events due to anomalously high sea surface temperatures, as occurred during the 1998 ENSO event. While corals have shown the ability to survive bleaching episodes relatively intact, frequent and severe thermal stress can lead to extensive coral mortality and long-term reduction in coral cover. In this study, we estimate the possible frequency of large-scale coral bleaching events worldwide in $2\times\text{CO}_2$ climate, using the results of "business as usual" climate scenarios from four global climate models (GCM) and the degree-heating-week (DHW) methodology developed by the NOAA Coral Reef Watch Program. The DHW methodology is adapted to determine the likelihood of thermal-stress related bleaching events (no bleaching, moderate bleaching or extensive bleaching) using the GCM-simulated sea surface temperature anomalies ($2\times\text{CO}_2$ climate minus 1985-2000 climate) and the NOAA 1985-2000 satellite-derived SST climatology. The resulting maps depicting the simulated frequency of moderate or extensive bleaching worldwide suggest the coral ecosystems most at risk in a $2\times\text{CO}_2$ climate, provide insight on the rates of adaptation necessary to forestall widespread coral mortality, and serve as a possible foundation for long-term climate policy.

The Hydrodynamics of a Coral Bleaching Event

*Craig R STEINBERG**, *William J SKIRVING*, *Scott F HERON*

PMB#3 Townsville MC, Queensland Australia
c.steinberg@aims.gov.au

Coral Bleaching events are weather events. Mass bleaching occurs when there is an extended summer period of calm, sunny conditions that coincide with small tides. In such a scenario over 98% of solar radiation energy is absorbed in the top 4 metres of the water column. This heat will build up unless there is a physical mechanism to mix it with the cooler water below. Hydrodynamic models provide us with a tool for predicting SST patterns during future severe mass coral bleaching events. The models are used to map mixing regions from the current fields. From this a surface temperature map can be derived. This allows for it to be independently validated against NOAA AVHRR satellite SST imagery. A case study for the Great Barrier Reef during the 1998 & 2002 events is presented. The approach is being adapted for use in other regions and a comprehensive hydrodynamic modeling effort for Palau is currently underway and will be described.

Modeling Sub-reef Scale Thermodynamics at Scott Reef, Western Australia to Predict Coral Bleaching

*James C BIRD**, *Craig R STEINBERG*, *Thomas A HARDY*, *Lou B MASON*,
Richard M BRINKMAN, *Lance BODE*

James Cook University, Townsville, Queensland, Australia
j.bird@aims.gov.au

The present method used to predict where and when coral bleaching will occur relies on Sea Surface Temperature (SST) from NOAA AVHRR satellite imagery. While highly successful for large-scale predictions, satellite derived products are too coarse (~50km) to discern sub-reef scale temperatures. They are also restricted to sensing only the surface skin layer instead of the preferred bulk water temperature and are subject to error due to atmospheric effects. The aim of this study is to find an alternative approach to determining the extent to which hydrodynamic models can predict sub-reef scale coral bleaching. In March 1998 a major coral bleaching event occurred at Scott Reef, a 40 km-wide lagoon 300 km off the northwest coast of Australia. Meteorological and coral cover observations were collected before, during, and after the event. In this study, two hydrodynamic models are applied to Scott Reef and validated against extensive oceanographic data collected between March and June 2003. The models are then used to hindcast the reef hydrodynamics leading up to the bleaching event. Results show a positive correlation between poorly mixed regions and bleaching severity. Knowledge gained from this work can be used to distinguish regions within individual reefs that are more susceptible to coral bleaching. A clearer understanding of the physical mechanisms that control bleaching will enable better planning for establishing Marine Protected Areas.

Modelling Future Reefscapes on the Great Barrier Reef Resulting from Global Climate Change and Coral Bleaching

*Scott WOOLDRIDGE**, *Terry DONE*, *Ray BERKELMANS*, *Roger JONES*

PMB #3, Townsville MC, QLD, 4810 Australia
s.wooldridge@aims.gov.au

Mortality induced by major disturbances, along with the subsequent competition for the newly created space have long been considered major structuring forces within coral reef communities. In this paper we utilise a probabilistic disturbance-recovery model to investigate the potential implications on community structure for projected increases in the frequency (recurrence interval) and intensity (days above threshold curves) of coral bleaching events on the Great Barrier Reef (GBR) in Australia. Initially, we track the trajectories (out to 2050) of three simplified coral-algae communities located in contrasting environmental settings. We investigate the sensitivity of the community trajectories to different levels of thermal adaptation and algal herbivory. To account for differences in bleaching susceptibility between coral species we replicate the simulations for a more complex community structure consisting of (i) a thermally tolerant, slow growing coral (characteristic of many Porities species), (ii) a thermally sensitive, fast growing coral (characteristic of many Acropora species), and (iii) algae. In the absence of thermal adaptation, we demonstrate a high likelihood of algal dominance in both the simple and more complex community structures by 2050 for all locations. We discuss the potential of a number of mechanisms to collectively raise bleaching thresholds to levels necessary for the maintenance of hard coral dominance.

A Dynamic Energy-Balance Approach to Coral Stress and Mortality Risks in a Variable Environment

*Kenneth ANTHONY**

Townsville, Queensland 4811 Australia

Kenneth.Anthony@jcu.edu.au

With predicted changes in the global environment, knowledge of the links between environmental variation and risks to ecosystems and species of high conservation value is becoming increasingly important. For predictions of organism stress and mortality risks to be successful in the real world, they must formally account for the temporal variation and history of the environment. One approach that enables predictions of coral performance over time is the analysis of energy balance and the dynamics of energy stores, as many stressors such as temperature anomalies (and associated bleaching) and sedimentation directly impact on coral energy intakes and losses. Here, I present a novel dynamic model that builds on the functional relationship between resource availability, energy balance, energy storage and mortality risks, using corals as a model system. I analyse the model's behaviour and predictions under two environmental scenarios: (1) periods of varying turbidity and light, simulating a sediment discharge or a passing flood plume, (2) periods of high temperatures and associated bleaching events. Two main conclusions arise from these analyses. Firstly, full energy stores can carry corals through extended periods (weeks-months) of high turbidity and low light, but repeated events may reduce energy stores to critically low levels because the rate of energy store (lipid) synthesis is slower than the rate of energy loss. Secondly, the probability of recovery from a bleaching event depends strongly on the size of energy stores prior to the onset of the event. The modelling framework provides a new set of tools with wide applications for the assessment of risks to corals under many environmental scenarios.

Biological, Economic and Social Impacts of Climate Change on the Great Barrier Reef

Ove HOEGH-GULDBERG, Hans HOEGH-GULDBERG*

St Lucia 4072 QLD Australia

oveh@uq.edu.au

The connection between climate change, reduced coral cover and resulting socio-economic implications is only sketchily known. In this study, we focus on how climate change is likely to affect the integrity of the Great Barrier Reef (GBR), and how these changes will affect regional economies. To include a wide range of possibilities, we developed scenarios for the GBR region from the four baseline scenarios in the Third Assessment Report of the Intergovernmental Panel for Climate Change (IPCC). These included scenarios in which (a) greenhouse gases increase rapidly under strong international economic growth (A1B), (b) regional economic drivers are paramount (A2), (c) global policy reform leads to reduced greenhouse gas emissions (B1) and (d) regional sustainability and sustainability dominate world trends (B2). Under all scenarios, mass coral bleaching continues to increase in scale and intensity over the next 30 years, and GBR coral populations dwindle. These changes will almost certainly impact on reef quality, productivity and biodiversity - and eventually GBR-related tourism, fishing and regional economies generally. After 30 years, however, impacts start to diverge with global environment policy reform providing what appears to be the only hope for long-term survival of coral on the GBR. Economic analysis reveals that knock-on impacts will depend on the region in question, and its dependence on GBR-interested tourism. The estimated GBR-interested tourism expenditure (70% for all regions along the Reef) is highest in Tropical North Queensland (90%), followed by the Whitsundays (72%), Northern (65%), Fitzroy (56%), Mackay (43%), and Wide Bay-Burnett (23 %). Changes GBR quality, therefore, will have a greater impact in Tropical North Queensland. The total cost of changes to the international attractiveness for tourism within these regional economies will ultimately depend on international economic trends, energy and pollution control policies, and how rapidly the world warms over the next fifty years.

Waikiki Aquarium: Resources and Comments on 20 Years of Coral Reef Education Programs and Materials

Mark B HECKMAN*

2777 Kalakaua Avenue, Honolulu, HI 96815 United States of America
mheckman@hawaii.edu

The Waikiki Aquarium, a part of the University of Hawaii, marks its 100th anniversary this year with over 20 years experience in creating coral reef education programs tailored specifically to the central and western Pacific. This includes outreach and onsite programs for schools, the general public, and age groups ranging from 1 - 3 year olds to adults and college level programs. Combining art, indigenous culture and science, programs include overnights, snorkels, and participatory research. With the Waikiki Aquarium's science and research orientation, materials and programs are carefully reviewed for scientific accuracy. This presentation will share the highlights and limitations of these programs and note the crafts, online marine life profiles, videos and other materials and support that the Waikiki Aquarium can offer other institutions and NGOs involved in coral reef management and education.

Protected Area Boundary Recognition - A Novel Method for Effective and Efficient Educational Efforts

Thorne ABBOTT, Joseph RUAK*

PMB#4162, PO Box#10002 Commonwealth of the Northern Mariana Islands
Thorneabbott@yahoo.com

For the peoples of the Northern Mariana Islands (CNMI), the Isle of Managaha, its protective barrier coral reefs and clean surrounding waters has served as a rich source of food fishes and medicinal plants. The Isle also serves as a place for family to congregate and conduct the sacred ceremony of fiirourow, in the Carolinian language. Burial site of Chief Aghurubw, the island stood as a 'quiet sanctuary' through cultural lines of enforcement for half a millennium. Now, with society changing from subsistence 'take' to a cash flow economy, the peoples of the CNMI have come to a cross-road. A balance between the traditional way of doing things and the realities of the new millennium must be reached. Maintaining a rich fishing ground, healthy medicinal plants, a place for respecting ancestors, as well as welcoming the economic revenues of tourists must both co-exist. The Managaha Marine Conservation Act created a Marine Protected Area (MPA) to conserve marine resources from over exploitation. Regulations were developed from stakeholder and traditional knowledge. Multi-lingual brochures and signs, school presentations, and active enforcement activities by patrol boats will help protect the area. But the co-existence of all parties that want to use the MPA can only occur if residents, commercial enterprise, non-resident workers, and tourists alter their behavior. This paper presents a method to rapidly determine if MPA boundaries are recognized and respected. The method can help determine if protection efforts are having their intended effect so that outreach, education, planning, management and enforcement activities can reflect actual user behaviors rather than assumed behaviors. By using such a monitoring tool, agencies can enhance their ability to ensure that MPA's will reach their intended objective and that MPA's boundaries are incorporated into human use activities.

The Use of the NOAA Coral Reef Information System (CoRIS) to Improve Access to Coral Reef Science: Challenges and Opportunities

Mark S MCCAFFREY*, C Mark EAKIN, Doug HAMILTON

325 Broadway, Boulder, CO United States of America
mark.mccaffrey@noaa.gov

As knowledge acquisition has shifted from remembering and repeating information to accessing and using information, new challenges and opportunities arise in meeting the new paradigm. One example of a current effort to provide access to information relating to the complexity of coral reef ecosystems and their social and environmental context is the NOAA Coral Reef Information System (CoRIS). Developed as a single web portal for managers, researchers and the public, CoRIS is an online tool providing access to NOAA's coral reef data and information for use in managing, preserving and understanding coral reef ecosystems. Released in 2002, CoRIS is a work-in-progress and will continue to evolve in the coming years. Its current content includes i) spatial and text search tools, ii) essays about various aspects of coral reef systems, iii) a library highlighting other coral online resources available through NOAA and other organizations, iv) a professional exchange to facilitate communication between coral reef researchers and advocates, v) a summary of NOAA coral reef activities and publications, and vi) an illustrated glossary. Future plans include adding more essays and providing scaffolded tutorials that offer a layered approach to data interpretation, from general overview to complex data analysis. In the summer of 2003 a workshop was held to review the usability of the website with representatives of user communities, and in October, 2003 a series of meetings with coral reef communities in Hawaii and American Samoa were held to solicit input from current and potential users on the site and how it can best serve various user groups' data and information needs. The feedback from these meetings will be incorporated in continued development of CoRIS in order to improve access to coral reef information. The CoRIS website is available online at <http://www.coris.noaa.gov>

Coral Reef Conservation through Outreach Education

Judith C LANG, Janie L WULFF, Carol R FRETWELL*, Keith A ROBERSON

125 Airstrip Lane, P.O. Box 539, Ophelia, VA, 22530 United States of America
jandl@rivnet.net

Climate change, overfishing, destructive fishing, pollution, and habitat degradation threaten coral reefs and undermine the capability of tropical coastal populations to meet basic health, economic, and social needs. An informed public is needed to bring about change and conservation. A traveling exhibit of lightweight modular design that can be easily transported and displayed in a wide diversity of settings (e.g., airports, ecological centers, cruise ships, auditoriums, libraries, museums, banks, community centers) can be targeted to reach all age groups, societal levels, and educational backgrounds. Qualified scientists and educators can collaborate to develop exhibit content around specific, local or regional threats. Key themes can be updated by simple replacement of display elements. Our broad-based education and public awareness project is designed to recreate the most successful features of the 1996 exhibition (*Nuestros Arrecifes: Unidos por el Caribe/Our Reefs: Caribbean Connections*) that was produced by Smithsonian Tropical Research Institute and opened in Panama City during the 8th International Coral Reef Symposium. With newer production materials, the exhibit can be more easily modified, transported, and displayed than the original. Its content is being revised to accommodate the many ecosystem and societal changes of the last eight years. This exhibit offers a scientific perspective of the continued deterioration of many coral reefs in the Western Atlantic and presents community-based attempts to conserve, sustainably utilize, or restore reefs and related ecosystems. It can provide a focal point for discussions among many members of society in order to deepen public understanding of complex issues that span the interfaces of science, technology, economics, and society. By being deliberately limited to the wider Caribbean, its content is readily identifiable to inhabitants and of immediate relevance to visitors. This project can serve as a model for regionally focused educational exhibits in other geographic areas.

Building Community Awareness and Management Capacity for the Control of Alien Algae in Hawaii

*Cynthia L HUNTER**, D Eric CO, Celia M SMITH, Jennifer E SMITH, Eric CONKLIN, Randy HONEBRINK, David GULKO, Matthew ZIMMERMANN
Dean 2, University of Hawaii, Honolulu, Hawaii United States of America
cindyh@hawaii.edu

An alliance of federally-funded researchers (Hawaii Coral Reef Initiative Research Program), state resource managers (Hawaii Department of Land and Natural Resources), non-governmental agencies (The Nature Conservancy and Reef Check), community volunteers (canoe clubs, campus clubs, school groups, and individuals) and private sector entrepreneurs (green-waste recycling, dive tour, and restaurant businesses) collaboratively organized to involve community volunteers in an educational and environmentally effective effort to remove alien algae from a state Marine Life Conservation District (MLCD) in Waikiki, Hawaii. Over the past 25+ years, the reef area within the MLCD has been increasingly overgrown by the alien alga, *Gracilaria salicornia*, introduced for aquaculture research in the 1970's. This reef once evidenced over 60 species of macroalgae with up to 7 kg of wet weight biomass per m². Only 29 macroalgal species were recorded in the same area in 2003, with *G. salicornia* alone accounting for over 10 kg of the wet weight biomass per m². Summer swells dislodge large amounts of this biomass from its attachment on the reef, producing asexually viable, rafting propagules and forming extensive wash-ups on Waikiki Beach. Community members (divers, snorkelers, beach toters, weighers, algal sorters, and recorders) have been organized to remove alien algae from the MLCD during weekend volunteer events. The algae is transported to a green-waste recycling company which uses it to produce composting tea; local gardeners and farmers are also experimenting with composting and nutrient-enrichment uses for the alien seaweed. Educational brochures, workshops, and press releases to prime media coverage have contributed to one of the most important outcomes of the effort: an increased public and political awareness of the ecological threat of alien algae to Hawaiian reefs. Over 35 tons of alien algae have been removed from the Waikiki MLCD in six morning efforts involving 400+ community volunteers.

A Survey to Assess the Needs of MPAs in Building Capacity for Effective Management and Coral Reef Conservation

*Tegan C HOFFMANN**

417 Montgomery Street Suite 205, San Francisco, CA 94104 United States of America
thoffmann@coral.org

Marine protected areas (MPAs) are recognized as one of the most promising solutions for the survival of coral reef ecosystems and the many benefits they provide people. As a partner of the International Coral Reef Action Network (ICRAN), CORAL is assisting selected MPAs sites with their coral reef management and outreach efforts by providing tools, resources, capacity building initiatives. 28 MPAs in East Asia, Wider Caribbean, East Africa, and South Pacific were surveyed to assess the reef threats, the management, education, and outreach needs of various stakeholders. Listed are examples of the types of open-ended questions asked: is the community supportive; who are the key stakeholders; what are the primary languages; what management materials are needed; what types of trainings are needed; are there user-fee systems; what do park practitioners think are the primary threats to their reefs; and more. We administered the first set of surveys August 2002 in East Asia with the help of the East Asia Seas United Nations Environment Program /Regional Coordinating Unit. We received detailed responses to over 40 questions from eight sites. In 2003, we received additional results from 16 sites in the Wider Caribbean, one site in East Africa, and three sites in the South Pacific. Results show that the three biggest challenges sites face is financial support (13 sites), staff shortages (nine sites), and enforcement of regulations (four sites). Our findings also show that the three most critical issues facing the sites, as perceived by the respondents, are over-fishing and destructive fishing (22 sites) followed by tourism impacts (14 sites) and sewage and waste disposal (14 sites). This talk will present detailed results from the survey and offer recommendations that will assist the efforts to foster management effectiveness and improve coral reef conservation.

Education and Conservation of Coral Reefs at Okinawa Churaumi Aquarium

*Hiromi YAMAMOTO**, Masanori NONAKA, Yoshiaki KAMEI, Senzo UCHIDA
424 Ishikawa, Motobu-cho, Kunigami-gun, Okinawa 905-0206 Japan
h_yamamoto@kaiyohaku.or.jp

The Okinawa Islands have well-developed fringing reef and high species diversity of hermatypic corals. Unfortunately, 46-69% of corals in Okinawa are estimated dead because of bleaching event in 1998. Okinawa Churaumi Aquarium has been kept 100 colonies of *Acropora muricata* . since 1996. Not only *A. muricata* . but 70 species, 800 live coral colonies in exhibition tank. *A. muricata* . keep spawning every year, around full moon in June. In order to conserve coral reefs in Okinawa, we are establishing three programs in the aquarium. Currently, we have two education programs; the first aquarists explain of corals and coral reefs in the aquarium and the second, in June, the aquarium hold "Coral spawning tour " at night. We provide facility of coral holding tanks for other researchers. Also we measure coral growth rate under several conditions and try to transplant *A. muricata* . to coral reefs front of the aquarium.

Knowledge Exchange to Support Coral Reef Management and Conservation

*Britta SCHAFFELKE**

PO Box 772 Townsville QLD 4810 Australia
britta.schaffelke@crcreef.com

To ensure research results can be used for policy and management decisions for coral reef protection, these results need to be effectively communicated to resource managers and industry, who often invested in funding the research. Users may not have the academic background or the time to digest information aimed at scientists. Also, different scientific studies may have conflicting results, often requiring interpretation and synthesis. Research information needs to evolve into knowledge, which is defined here as the application of information in the context of stakeholders educational, cultural and interest backgrounds. The success of initiatives to manage and protect coral reefs depends on the quality of the research on which they were based. It also depends on whether this information has evolved into knowledge that is shared by the variety of stakeholders affected by these management initiatives. Without effective knowledge exchange acceptance of and compliance with new environmental legislation and policy will be limited. I will present strategies used by the Cooperative Research Centre for the Great Barrier Reef World Heritage Area to improve knowledge exchange, including: - Synthesis of new research into a framework of existing knowledge, for example in form of brochures or specific briefing notes that educate and advise users on particular issues;- Workshops to foster dialogue between researchers and users, and result in new, shared, knowledge; - Modern interactive web-based tools that allow users to access research information about specific topics in different ways and at different levels of complexity, including modelling and simulation of future scenarios of environmental change; and- A program that connects individual researchers with individual users of the research to ensure structured, ongoing dialogue and knowledge exchange.

Corals and Colours: A Reef Monitoring Program for High School Students Using Coralwatch Coral Health Monitoring Charts to Assess Coral Bleaching

Sandra ZICUS, Kylie JENNINGS, Justin MARSHALL*

Bright Minds Project, Faculty of Biological & Chemical Sciences, Brisbane, QLD 4072 Australia

s.zicus@uq.edu.au

In the face of ever-increasing global environmental threats, there is a recognized need for greater public awareness and understanding of coral reef ecosystems and their importance. Involving children actively in the care and management of their community resources is an essential factor for long-term societal change in environmental attitudes and behaviour that is often overlooked and undervalued. We have developed and are currently pilot-testing a program to involve Australian high school students and teachers in marine studies, geography, and biology classes in a coral reef monitoring program. The students and teachers use specially-developed colour charts to assess levels of coral bleaching, while learning key concepts of coral reef biology and ecology. The program also raises awareness of issues related to human resource use and coral reef health. Through professional development programs, teachers are introduced to the methodology and ways to use it with their students. They are also given assistance in developing and incorporating related material and activities into their classroom instruction. This paper outlines the process followed in development and implementation of the program, relates the preliminary results of the pilot program, and discusses the lessons learned along the way.

The CCC Marine Environmental Education and Training Programme: A Multi-sectoral Approach to Community Awareness

Simon P HARDING, Jean-Luc SOLANDT, Dianne WALKER, Nicola J BARNARD, Joana I DOYLE, Jaqueline F TAYLOR, Tanya H BLACKBURN, Peter S RAINES*

The Tower, 13th Floor, 125 High Street, Colliers Wood, London, SW19 2JG. United Kingdom of Great Britain and Northern Ireland

sph@coralcay.org

Coral Cay Conservation (CCC) is widely recognised for its pioneering work in the assessment of tropical coastal habitats through the use of fee-paying volunteer divers to collect baseline datasets. In comparison, the environmental education and awareness programmes that run alongside biophysical data collection are less well documented. Here we summarise the techniques and approaches that CCC use to generate awareness and impart skills to the different sectors of local communities. CCC recognises the importance of including all resource users within a region in an awareness programme. Therefore the audiences targeted range from local schoolchildren to village community leaders, and both resort guests and staff including local diving instructors and guides. A combination of outreach visits and on site events is practised. Counterpart training is also offered as part of the CCC Scholarship programme or through specialised workshops. The awareness activities are common to all CCC projects but have been particularly prominent in the Mamanucas Islands of Fiji. Details of the programme currently running as part of the Fiji Coral Reef Conservation Project are provided.

The Effects of Pollutants on Reproduction, Recruitment and Populations of Corals

*Robert H RICHMOND**

41 Ahui Street, Honolulu, Hawaii 96813 United States of America
richmond@hawaii.edu

Tropical coral reef ecosystems possess a high degree of biodiversity that supports their ecological, cultural and economic value. Scleractinian corals are conspicuous and essential elements of these biological communities and their populations persist through the dual processes of reproduction and recruitment. Most reef-building corals reproduce during limited spawning events annually, during which time their gametes float to the oceans surface and intermingle. Pollutants carried in freshwater runoff from land-based sources as well as hydrocarbons from maritime activities can interfere with critical chemical cues affecting synchronization among conspecific reproductive coral colonies, egg-sperm interactions, larval development, larval recruitment and subsequent acquisition of zooxanthellae. Water-soluble compounds affect specific life-history stages, while lipophilic substances (e.g. organophosphate pesticides) can be particularly problematic for larval recruitment by interfering with settlement cues and metamorphic inducers found on appropriate substrata. Assays on adult corals provide limited information on the ultimate effects of pollutants, as these miss critical effects on population dynamics. Additionally, 100% survival of larvae but 0% recruitment resulting from a chemicals interference with metamorphosis translates into 100% mortality from an ecosystem perspective. Corals are important test organisms for a variety of chemicals being used on land as well as in the sea and it is essential to test for effects on all life history stages in order to understand and subsequently manage the effects of human activities on coral reefs. Ecotoxicology as well as developing technologies in the areas of genetics and molecular biomarkers provide valuable tools for understanding and mitigating the effects of pollution on coral reef ecosystems.

An Improved Approach to Locating Coral Recruits on Natural Surfaces and Settlement Plates

Charles H MAZEL, Alina SZMANT, David ZAWADA*

20 New England Business Center, Andover, Massachusetts 01810 United States of America
mazel@psicorp.com

A major challenge in studying coral recruitment and survivorship is the difficulty of locating recently settled specimens, especially on natural surfaces. While specimens a few millimeters in diameter can be found with painstaking effort, a practical limit for field studies has typically been a centimeter or more. By the time they can be routinely located with conventional techniques corals are six months to a year old, and little can be learned of early survivorship. Settlement plates are typically used to aid in locating smaller specimens in conjunction with a microscope in the laboratory, but the sampling is usually destructive. Many corals fluoresce when illuminated with the proper wavelengths of light, however, and using fluorescence techniques to view reef surfaces greatly increases the visual contrast between specimens and their background, making them easy to locate even when they are only one to two millimeters in diameter. Fluorescence techniques can be applied either in situ or in the laboratory, for both natural surfaces and settlement plates. Recent studies have shown that fluorescence viewing is superior to white light viewing for locating recruits in both circumstances. The ability to non-destructively locate recently settled specimens creates the potential to learn much more about the relative roles that recruitment and survivorship play in structuring the adult community. Application of fluorescence techniques requires only simple modifications to existing light sources and imaging devices. In this presentation we will discuss the application of fluorescence imaging technologies to the study of coral recruitment, including both benefits and limitations. The topics will include equipment and techniques for in situ viewing and photography, and laboratory examination of settlement plates using fluorescence microscopy. Results from field trials will be presented.

Settlement Competency Periods and Dispersal Potential of Scleractinian Reef Coral Larvae

*Peter L HARRISON**

PO Box 157, Lismore NSW 2480 Australia
pharriso@scu.edu.au

The extent to which larvae from broadcast spawning scleractinian reef corals are retained on their natal reef and contribute to localised recruitment, or are dispersed between reefs, and their potential for long-distance dispersal, are largely unknown. Larval development, survivorship and settlement competency periods were studied in reef and laboratory experiments using larvae reared from 11 broadcast spawning reef coral species from the Great Barrier Reef and at subtropical Lord Howe Island, Australia. Most larval cohorts had a Type 2 pattern of survivorship. In some tropical species, larvae began attaching to settlement tiles between 2-4 days after spawning (DAS), with larval metamorphosis and permanent settlement initiated shortly afterwards. This rapid development increases the probability of some coral larvae being retained close to their natal reef system, and may result in a degree of self-seeding in some tropical populations. In contrast, development rates were slower in subtropical coral larvae. Peak periods of larval metamorphosis and permanent settlement occurred within a few weeks after spawning in most species, hence some coral larvae are likely to be dispersed away from their natal reef, promoting genetic exchange among populations on separate reefs. Maximum settlement competency periods of 2-3 months were recorded for some planulae, indicating that these larvae have the potential for longer-distance dispersal and settlement on geographically distant reefs. Therefore, long-distance larval dispersal is likely to contribute to the broad biogeographic ranges of some coral species, and has important implications for managing coral populations that are potentially interconnected over broad geographic regions.

Larval Settlement and Lipid Content as Key Factors in Larval Dispersal Strategy for Two Corals: A Spawner *Acropora tenuis* and a Brooder *Heliopora coerulea*

Saki HARIU, Kazuo NADAOKA, Masanobu YAMAMOTO, Hajime KAYANNE, Kenji IWAO*

2-12-1 Ookayama, Meguro-ku, Tokyo 152-8552 Japan
harii@wv.mei.titech.ac.jp

Larval dispersal and recruitment play important roles in preserving coral communities and maintaining their connectivity. Corals have two types of larval dispersal strategy, wide and narrow dispersal. Larval dispersal is determined physically by currents and biologically by larval buoyancy and competency. Although both buoyancy and competency may be governed by lipid content, limited studies have been conducted to find their quantitative dependence. This study examined temporal change in settlement and lipid content of eggs and/or planulae of two corals: a spawner *Acropora tenuis* and a brooder *Heliopora coerulea*. Eggs of *A. tenuis* had appreciable buoyancy, whereas *H. coerulea* planulae were found close to the bottom. Experimental results showed that 54% of *A. tenuis* planulae settled on the 4th day after spawning while 74% of *H. coerulea* planulae settled within one day after release. At one month after spawning/release, the settlement rate of *A. tenuis* was higher than that of *H. coerulea*. Within one day after spawning/release, lipid contents were 91% in dry weight for *A. tenuis* eggs and 54% for *H. coerulea* planulae. On the 21st day after spawning/release, the larval lipid content decreased to 57% for *A. tenuis* and to 46% for *H. coerulea*. Percentage of wax ester, a major class of lipid in planulae, was initially higher for *A. tenuis* eggs than *H. coerulea* planulae, but decreased appreciably in *A. tenuis* planulae in one month after spawning. Therefore, the temporal decrease in lipid content for *A. tenuis* planulae is considered due to the decrease in wax ester. During the period showing the decrease in wax ester, *A. tenuis* planulae swam actively and sought their settlement place, and even at one month after spawning/release, *A. tenuis* showed higher settlement rate than *H. coerulea*. These results indicate that wax ester is a significant factor governing settlement-competency periods of planulae.

Spatio-temporal Patterns of Coral Recruitment around Moorea, French Polynesia

*Mehdi ADJEROUD**

Universite de Perpignan, avenue Paul Alduy, 66860 Perpignan France, Metropolitan
adjeroud@univ-perp.fr

The spatio-temporal variability of scleractinian coral recruitment was investigated from December 2000 to December 2003 around Moorea Island (French Polynesia). Nine stations, each composed of 20 terracota tiles, were disposed on the outer reef slope, at 3 sites (Vaipahu, Tiahura, Haapiti), and 3 depths (6, 12 and 20 m). Tiles were changed every 3 months. Recruits were largely dominated by Pocilloporidae (~60%), followed by Poritidae (~18%) and Acroporidae (~10%). A strong variation was found at several spatial scales. At the tile scale, recruits were predominantly found on the lower surface. At the station scale, the high variability among the 20 tiles suggest a patchy recruitment. Significant differences were also found among the 3 depths, with a total recruitment rate higher at 6 m. However, Poritidae were generally more abundant at 12 m depth, whereas Acroporidae showed no clear depth pattern. At a larger scale, a significant difference was found among sites, with a lower recruitment at the most exposed site (Haapiti). A marked seasonal and inter-annual variability was also found. The December-March period was the maximum recruitment period. However, recruits of Acroporidae may also be more abundant in the September-December period. Spatio-temporal patterns of coral recruitment in Moorea were compared to those obtained in other Pacific reefs. Recruitment rates in Moorea appear to be particularly low, similar to the minimum rates obtained on other Pacific islands (Hawaii, Fiji), and highly lower than rates recorded on the Great Barrier Reef. These results point out another distinctive characteristic of coral assemblages in French Polynesian islands.

Settlement Patterns of Scleractinian Coral Larvae before and after the 1998 Coral Bleaching Event in East Africa

*Christopher A MUHANDO**

Institute of Marine Sciences, P.O. Box 668, Zanzibar - TANZANIA
muhando@ims.udsm.ac.tz

From March to May 1998, an El Nino-related increase in sea surface temperature in East Africa resulted in unprecedented coral bleaching and subsequent mortality of corals. In order to assess effects on temporal settlement patterns of scleractinian corals, settlement tiles were placed on Chumbe reefs, Zanzibar, from June 1998 to March 2000 and results compared with tiles placed before the bleaching event. Results indicated that settlement of coral larvae was continuous throughout the year with two peaks occurring during the northeast monsoon; before the bleaching, a higher peak occurred between January and March and a lower peak in between October and December, but in 1998/99 and 1999/2000 the higher peak shifted to October-December. Unlike in previous years, there were no larvae settlement recorded in the June-September 1998 period. The coral settlement density (all spats) decreased significantly from an average of 95.5 spats per square meter in three months (m-2 3mo-1) before bleaching event to 36.4 m-2 3mo-1 and 38.5 m-2 3mo-1 in 1998/99 and 1999/2000, respectively. Averaged over the year, the relative contribution of Acropora and Montipora larvae was 64 % and 1 % before the bleaching event but changed to 67 % and 16 % in 1998/99 and to 35 % and 16 % in 1999/2000, respectively. The abundance of Pocilloporidae changed from 32 % to 10 % in 1998/99 and increased to 39 % in 1999/2000. The 1998 coral bleaching and mortality event appeared to have a profound negative impact on coral settlement density and changed the coral larval composition to include more taxa groups than before the bleaching event.

Patterns of Coral Recruitment, Growth and Survival on Artificial Reefs in Maldives

Alasdair J EDWARDS, Susan CLARK*

School of Biology, Ridley Building, University of Newcastle, Newcastle upon Tyne NE1 7RU, United Kingdom of Great Britain and Northern Ireland
a.j.edwards@ncl.ac.uk

Patterns of "visible" coral recruitment, growth and survival on concrete artificial reef structures deployed on a reef flat that had been severely degraded by coral mining were monitored over a period of 3.5 years in Maldives. Initial recruitment occurred 6 mo after deployment and was by monthly brooders (*Pocillopora damicornis* and *P. verrucosa*). Mass recruitment by presumed broadcast spawners (primarily *A. cytherea*, *Acropora digitata*, *A. divaricata*, *A. gemmifera*, *A. humilis*, *A. hyacinthus*, *A. nasuta*) was not apparent until over one year after deployment. Over 3000 recruits of some 23 species were recorded on the structures and their growth rates and survival followed. Approximately 50% were surviving at the end of the 3.5 yr monitoring period. Recruitment was dominated by acroporids and pocilloporids (94%). The effects of surface orientation and type and height above seabed on both recruitment and subsequent survival are analysed. Survival curves for different species are compared. Implications of results for reef rehabilitation interventions are discussed.

Long-term Decline in Coral Recruitment at the Coral Nature Reserve, Eilat, Northern Red Sea: 1997 to 2003

*Nanette CHADWICK-FURMAN, Zvy DUBINSKY, David ZAKAI**

P.O. Box 667, Eilat, Israel
dudu.zakai@nature-parks.org.il

Two sites at a depth of 5 m, on the shallow slope of the reef, were chosen to assess settlement rates of stony corals on reefs at the Nature Reserve of Eilat. One site was in an area closed to tourist activity since 1996 (Japanese Gardens), and the other in an open, heavily-visited area (Northern Reserve). At mid 1997, six racks containing a total of 80 settlement terra-cotta tiles were placed in each site. For the next 6 years, tiles were removed from the sea every 4 months and replaced by new ones. All tiles were examined under a binocular microscope for the number and size of juvenile stony corals settled. The results indicate a sharp decrease in coral settlement at the Japanese Gardens site between the years 1997 and 2003: mean settlement rates, dropped by 83% during July to October, and by 71% from November to February. Mean settlement rates from March to June were not significantly different, but there also was a trend of decrease in coral settlement. A similar phenomenon was observed during the same period at the Northern Reserve site: mean settlement rates during July to October declined by 95%, by 76% from November to February, and by 68% from March to June. Our results indicate that the observed long-term decline in coral settlement rates appears to relate to deterioration in water quality rather than to the effects of recreational activities.

Do Trophic Cascades Facilitate Coral Settlement on Caribbean Reefs?

*Robert S STENECK**, *Lindsay HARRINGTON*, *Michelle J PADDACK*, *Suzanne N ARNOLD*

Darling Marine Center, 193 Clarks Cove Rd., Walpole, Maine, 04573, USA
steneck@maine.edu

Coral settlement and post settlement survival was quantified from 1236 terracotta settlement plates distributed among Caribbean reefs in the Bahamas, Belize, Bonaire, Mexico and the Virgin Islands (St. John and St. Croix). In most regions, plates were deployed inside unfished (MPA) and fished (control) areas at two depths (5 and 10 m) on replicated reefs. Plates were elevated one cm off the substrate and were deployed for one year so all surfaces could become colonized by local reef-dwelling organisms. Top, bottom and side surfaces were analyzed microscopically to identify colonizing organisms and to quantify the settlement density, size structure and substrate selectivity of settling corals. Over 90% of the coral settlement occurred in the subcryptic underside of the settlement plates. The highest rate of coral settlement was in Bonaire (3.2 spat per plate) and the lowest settlement was in St. Croix (0.5 spat per plate). Coral settlement among and within regions corresponded to environments where rates of parrotfish grazing were high, macroalgal abundance adjacent to the plates were low and colonization (by a myriad of organisms including corallines that facilitate settlement) was high. We will also present evidence that some plate-colonizing organisms create poor nursery habitats for coral settlement while others facilitate settlement and post-settlement survival. Collapsed trophic cascades that steer succession toward organisms hostile to settling corals may jeopardize the resilience of coral reefs to recover from disturbances

Invertebrate Recruitment Patterns Inside and Outside Discovery Bay, Jamaica

*Norman J QUINN**, *Barbara L KOJIS*

PO Box 35, Discovery Bay, St Ann Jamaica
norman_q@hotmail.com

Coral and motile invertebrate settlement patterns were examined from collectors placed both within and outside Discovery Bay, Jamaica on the west fore reef. The numbers of species and individuals settling on mid-water Witham collectors and on terracotta tiles were recorded at Columbus Park reef within Discovery Bay and on collectors and tiles placed outside Discovery Bay on the West Fore Reef. Protected inshore waters are the preferred settlement habitat for spiny lobster (*Panulirus argus*) pueruli in other Caribbean studies. No pueruli settled on collectors within Discovery Bay. As well, fewer numbers of individuals and species of other invertebrates settled on collectors within the bay. Tiles were deployed where healthy coral reefs had existed over 25 years ago. Today the Columbus Park reef is characterized by coral rubble, zooanthids and *Millepora* coral. Outside the bay on the West Fore Reef the reefs are characterized by high algal cover and low percent coral cover.

Growth Process of Coral Communities on Artificial Structures and Conditions of Surrounding Environments

*Shuya OOKA**, *Seizou HANASHIRO*, *Ryouta GUSHI*, *Shinichi URABE*, *Naoki HAYASHI*, *Yoshihiro TAKAHASHI*

2-21-7 Maejima Naha City, Okinawa, 900-8530 Japan
ooka710@ogb.cao.go.jp

Okinawa General Bureau of the Cabinet Office has been conducting surveys on coral communities established on the breakwaters and other artificial structures in Naha Harbor. Reviewing the data from these surveys, we analyzed the relationship between the growth process of coral communities on artificial structures and environmental factors. The analysis of the data from the wide-area survey conducted in 1994 showed that coral communities on artificial structures entered a stable-growth period in 6 to 8 years after settlement. It also showed that the coverage of coral communities during the stable-growth period was affected mainly by the conditions of wave movement and light. The data from the monitoring surveys conducted from 1990 to 2003 at 30 survey points at different depths on the breakwaters was also used to analyze the growth process of coral communities on artificial structures as well as the recovery process from the 1998 bleaching. The growth rate of corals on the breakwaters at different depths was observed by the change in coral coverage and the analysis showed the corals grew fast at the depths of up to 5m but slow at deeper depths. The analysis of the recovery process of coral reefs from the bleaching showed that the corals were recovering slowly in a shallow-water zone but quickly in a deeper zone. This is because the corals at deep waters were less damaged during initial phases of the bleaching. The growth process of corals was also compared between the colonies on old artificial structures on which corals were damaged by the 1998 bleaching and the colonies on the structures newly constructed around 1998. The comparison revealed that the corals on the latter was growing fast whereas those on the former were experiencing slow growth.

Timing, Patterns and Speed of Inter-reef and Inter-island Coral Larval Dispersal as Elucidated by Acoustic Profilers and Radio-tracked GPS Drifters

*Curt D STORLAZZI**, *Eric K BROWN*, *Michael E FIELD*

USGS Pacific Science Center, 400 Natural Bridges Drive, Santa Cruz, California, 95060 United States of America
cstorlazzi@usgs.gov

A large-scale experiment was carried out along the reefs off West Maui, Hawaii, by the U.S. Geological Survey to understand the coastal circulations effects on the movement of sediment, nutrients and contaminants. The timing of the experiment was chosen to coincide with the spawning of the reef-building coral *Montipora capitata*. In this way, we could attempt to track coral larvae and determine the role of currents in aiding or inhibiting recruitment to local reefs, and concurrently provide information on key environmental factors. Bottom-mounted instrument packages were deployed prior to the spawning to measure waves, tides, currents, temperature, salinity, and optical and acoustic backscatter. Radio-tracked differential-GPS (DGPS) drifters were deployed over the study reef on four successive nights following the coral spawning event at 9:00 p.m. local (HST) time. Each night two sets of paired drifters were deployed following in situ observations of coral spawning. One drogue in each pair was set for surface currents and the other drogue was set for currents 3 m below the surface. Replicate 1-minute plankton tows were conducted within an hour of spawning over the reef to estimate densities of the buoyant eggs and planula at the surface. Both the timing and relative magnitude of the coral spawning were identifiable in the acoustic backscatter data and correlated to the abundance of coral egg and planula larvae collected in the plankton tows. The drifters tracks showed that the water containing eggs and planula larvae were transported among numerous reefs off West Maui and crossed the 15+ km inter-island channel within the time period that the larvae were still viable. These findings quantitatively documented the interconnectivity among Hawaiian reef systems over relatively large spatial and short temporal timescales where impacts on the reefs on one island may possibly have unanticipated effects on the reefs of neighboring islands.

Early Onset and Expression of Fluorescent Proteins in the Larvae of the Mushroom Coral, *Fungia scutaria*

Lea L HOLLINGSWORTH*, Teresa D LEWIS, David A KRUPP, Jo-Ann C LEONG

P.O. Box 1346, Kaneohe, Hawaii 96744, USA United States of America
lealh@hawaii.rr.com

Fluorescent proteins (FPs) have been described in a variety of scleractinian corals by a number of researchers. Several of these studies have identified the genes responsible for encoding various Fps, while others have quantified the concentration of FPs in adult corals. Little has been done, however, to document the occurrence and functions of FPs in developing coral larvae. Our study investigated the temporal onset and expression of FPs in the larvae of the mushroom coral, *Fungia scutaria*. Using fluorescence microscopy, we observed that the larvae of the mushroom coral, *Fungia scutaria*, express intense green and red fluorescence several days after spawning. Green fluorescence was frequently concentrated in and around the mouth region of the larvae, while red fluorescence appeared most intense in or around the gastrovascular cavity. The presence of FPs in the larvae was confirmed using SDS-PAGE, immunoblotting and immunoprecipitation with commercially available anti-GFP antibodies. Studies of the expression of GFPs in coral larvae, correlated with other ecological, physiological and behavioral observations, may help elucidate the functions of these proteins in scleractinian corals. This work was supported by the Hawaii State Biomedical Research Infrastructure Network (HS-BRIN; NIH/NCRP grant RR-16467), University of Hawaii Sea Grant Marine Science Undergraduate Research Fellowship program (NSF REU grant 0243600), and the University of Hawaii Investing in Multidisciplinary University Activities through Hawaii EPSCoR program (NSF RII grant 0237065).

Molecular Analysis of Egg Proteins in Reef-building Corals

Hideki HAYAKAWA*, Shuzo IMAGAWA, Yoshikatsu NAKANO, Tadashi ANDOH, Toshiki WATANABE

1-15-1, Minamidai, Nakano-ku, Tokyo Japan
hayakawa@ori.u-tokyo.ac.jp

Recently, many reports have shown perturbations on sex determination or maturation by pollutants in various aquatic animals. Genes with sex-specific expression patterns such as vitellogenin genes are useful in detecting such disturbances. In corals, however, there is no report for sex-specific molecular markers. In this study, we analyzed egg proteins and identified a cDNA encoding one of the major egg proteins in the dioecious hermatypic coral *Galaxea fascicularis*. Female colonies of *G. fascicularis* spawn bundles consisting of eggs, whereas bundles released by functional male (also called hermaphroditic) individuals contain sperm as well as sterile pseudo-eggs. Eggs and pseudo-eggs were collected from bundles released by female and functional male colonies, respectively, and soluble proteins were extracted and analyzed using SDS-PAGE. Three major proteins were present in the egg extract, but not observed in the pseudo-egg. Partial amino acid sequences were determined in one of the major proteins named GfEP-1 (88 kDa), and a cDNA containing the partial coding sequence was isolated. The translated GfEP-1 sequence did not exhibit similarity to FcEP-1, one of the major egg proteins in the hermaphroditic reef coral *Favites chinensis* (previously reported by our group; Imagawa et al., *Comp. Biochem. Physiol.*, 137B:11-19, 2003). GfEP-1 and FcEP-1 exhibited sequence similarities to different parts of vertebrate and invertebrate vitellogenins, suggesting that the coral egg proteins evolved from the same ancestral gene as vitellogenin genes in higher animals. *GfEP-1* transcripts were detected about a month before spawning both in the female and functional male, but the expression levels were significantly higher in the former. Although the *GfEP-1* expression is not strictly female-specific, it may be utilized to monitor effects of environmental factors such as marine pollutants on sex determination and vitellogenic activity.

Studies on Parent-Offspring Relationship of the Coral *Pocillopora damicornis*

Diah Permata WIJAYANTI*, Michio HIDAHA

1-Senbaru, Nishihara, Okinawa 903-0213 Japan
k028554@eve.u-ryukyu.ac.jp

The coral *Pocillopora damicornis* was reported to display a wide range of reproductive options. It has been suggested that planulae of *P. damicornis* of Western Australia and Hawaii are produced asexually since planulae and their mother colonies consistently displayed the same allozyme pattern even at heterologous loci. However, early embryonic stages were observed at least in Okinawan population. This suggests that planulae of the coral are produced sexually. If planulae are produced sexually, sibling planulae are expected to be genetically different from each other and also from their mother colony. To detect possible genetic difference between sibling planulae and between planulae and their mother colony, histocompatibility assay between siblings and between parent and offspring was performed. The genetic relationship between parent and offspring was also examined by DGGE analysis of ITS2 region of ribosomal DNA. Siblings derived from the same mother colony always fused (74 pairs of 13 combinations including 28 pairs in one combination). Parent-offspring grafting showed fusion in 18 pairs of 9 combinations except one pair. However, we observed unexpected high percentage of allogeneic fusion (34 out of 57 pairs from 21 combinations). Present observation that siblings always fused with each other suggests either that sibling planulae are genetically identical or that fusion occurs if two partners share at least one allele of the histocompatibility locus as in colonial ascidians. Another possibility is that polymorphism of allorecognition loci is too low to detect genetic difference between closely related colonies of *P. damicornis*. Five parent-offspring pairs were used for DGGE analysis. In one pair, planula and its mother showed different banding patterns in DGGE gel, suggesting genetic difference between the parent and offspring. The mode of planula production in *P. damicornis* will be discussed based on the combined results of histocompatibility assay and DGGE analysis.

Patterns of Association between Juvenile Scleractinian Corals and Macroalgae in the Caribbean

Shauna N SLINGSBY*

PO Box 1462, Wrightsville Beach, North Carolina, 28480 United States of America
shaunans@yahoo.com

Caribbean coral reefs have become endangered ecosystems as they have shifted from coral to macroalgal dominated communities within the past few decades. Degradation appears to be exceeding recovery and one of the major aspects of this is juvenile coral survivorship. Little is known about interactions between juvenile corals and macroalgae even though juvenile coral survivorship is crucial to coral population growth and recovery. Macroalgae have been suspected to interfere with juvenile coral growth and survivorship yet few studies have sought to quantify this in nature. This investigation focuses on patterns of association between juvenile corals and macroalgae. Research was conducted at 17 reef sites throughout the Western Caribbean between March 2002 and March 2003. The two major geographical regions studied were the Mesoamerican Barrier Reef along the Yucatan coast of Mexico and the island of Bonaire in the Netherlands Antilles. Reef sites were chosen to represent a range of habitat types and conditions. Results indicate that there may be a functional relationship between juvenile coral density and macroalgal percent cover and height in the Caribbean. Juvenile coral density and macroalgal abundance (percent cover and height) were inversely correlated among sites. Both juvenile coral and macroalgal diversity were relatively low. Three coral genera accounted for 78% of all juvenile corals observed. Two macroalgal genera comprised 50% of the percent cover at all 17 sites and accounted for 75% of direct contacts with juvenile corals observed. It was concluded that the presence of juvenile corals may be the result of the microhabitat in which they can survive, as opposed to the microhabitat where they can recruit.

Effects of Overfishing on Coral Dynamics: A Large-scale Experimental Approach

Maria RODRIGUES, Terry HUGHES*

School of Marine Biology and Aquaculture, James Cook University 4811 QLD Australia

Maria.Rodrigues@jcu.edu.au

Despite the general acceptance of herbivory as an important process controlling algae abundance and mediating competition for space between algae and corals, most evidence is circumstantial, correlative and non-experimental. Here we report results of a 2.5 year herbivore exclusion experiment that was conducted to examine the effects of large herbivorous fishes on the coexistence of corals and algae and on the demography and life history traits of coral species. The experiment consisted of twelve 5 × 5 m areas distributed among 3 treatments (fenced, partially fenced and unfenced plots) and positioned along the reef crest of Pioneer Bay, Orpheus Island, Great Barrier Reef. Herbivore exclusion caused a forty-fold increase in mean macroalgal cover after 45 weeks whereas control plots remained consistently low. Macroalgal cover remained high inside the fenced plots for the duration of the experiment despite some seasonal variation. Coral cover was initially low in all treatments as a result of high mortality from recent bleaching. Coral cover initially increased in all three treatments but began to diverge 30 weeks into the experiment with recovery significantly lower inside plots that excluded herbivores. In addition, survivorship and recruitment of corals was significantly lower inside plots that excluded herbivores. We conclude that the removal of large herbivorous fishes from reef eco-systems will cause a dramatic increase in macroalgal abundance which may inhibit the ability of coral assemblage to recover from bleaching. This result provides strong empirical evidence that overfishing can damage reef resilience.

Density Dependence in the Rate of Sex Change, Age and Size of Sex Change, and Population Sex Ratio in a Protogynous Harem Reef Fish

Stefan P WALKER*, Mark I MCCORMICK

University Dr. Douglas, Townsville, QLD. 4812 Australia

stefan.walker@jcu.edu.au

A substantial portion of fishes occupying tropical reefs form polygamous mating systems. These fishes typically have complex sexual ontogenies that involve sex change from female to male. Recent advances in fish reproductive biology and behavioural ecology has highlighted the primary involvement of social cues in mediating sex change, specifically the ratio of interactions between dominant individuals and subordinate individuals. As a consequence, size and age at sex change is often highly variable and determined by external processes such as population density. Population density strongly influences the rate of intraspecific interactions, and also the potential benefit of changing sex. In this study, we investigate the effect of population density on the rate of sex change (ie: the willingness of individuals to change sex), the mean size and age of sex change, and population sex ratio in the harem sand perch *Parapercis cylindrica*. This information is important in assessing the interrelationship between the evolution of social systems, sexual ontogeny, and individual fitness variability.

Selective Predation on, and Differential Survival of, the Coral *Porites astreoides*

Randi D ROTJAN*, Sara M LEWIS

163 Packard Avenue, 120 Dana Hall, Medford, MA United States of America

randi.rotjan@tufts.edu

Because scleractinian corals are key components of tropical reef systems, factors affecting their survivorship have been widely studied. Vertebrate coral predators may be a major agent of coral mortality, however few studies have looked at these predator-prey interactions in detail. We examined the incidence and extent of predation on *Porites astreoides* by the parrotfish *Sparisoma viride* in Belize, and monitored coral recovery over a 3-week period. We found that *S. viride* predation can have profound effects on *P. astreoides* survival: 13.8% of over 3000 *P. astreoides* colonies displayed evidence of *S. viride* predation, and of these, 10.3% suffered total colony mortality. Colonies varied in the extent of predation, although predation often destroyed more than 50% live coral tissue per colony. Of the corals examined, 30.3% showed signs of re-growth within 3 weeks, whereas 69.7% showed signs of algal colonization indicating that parrotfish predation can lead to increased algal competition for the remaining coral tissue. We also investigated variability in colony nutritional quality and associated macrobore density as possible explanations for differential susceptibility of *P. astreoides* colonies to parrotfish predation. There were no differences in C:N ratios of coral tissue between bitten and unbitten colonies. However, presence of coral-associated macroborers such as endolithic barnacles and tube-dwelling polychaetes was significantly correlated with *S. viride* predation, suggesting that *P. astreoides* colonies hosting surface-visible macroborers are more susceptible to predation. Measured C:N ratios of various components of *S. viride* diet suggest that parrotfish gain nutritional benefits from consuming coral-associated macroborers. This study suggests that parrotfish predation may represent an important selective force for scleractinian corals.

Nutrient Dynamics of the Kaneohe Bay Barrier Reef, Hawaii*Marlin J ATKINSON**, *Jim FALTER*

PO Box 1346 Kaneohe, HI United States of America

mja@hawaii.edu

This oral presentation will summarize the last decade of research on controlling mechanisms for nutrient uptake of both dissolved and particulate nutrients (nitrogen and phosphate) on coral reef communities of Hawaii. These mechanisms are combined in a biogeochemical model of the Kaneohe Bay Barrier Reef, corroborated by two decades of in-situ nutrient sampling. Briefly, uptake of dissolved nutrients is governed by diffusion through nutrient-depleted boundary layers and can be parameterized in two ways: 1) an engineering approach, where nutrient uptake rate ($\text{mmol m}^{-2} \text{d}^{-1}$) is proportional to concentration and water velocity by the dimensionless Stanton number; or 2) a physical approach where uptake is proportional to concentration and the fourth root of energy dissipation. Uptake of particles, on the other hand, is governed primarily by the biomass of filter feeding organisms, including sponges, ascidians and corals, and the composition of the plankton, not water velocity. On the Kaneohe Bay barrier reef, uptake of dissolved phosphate is variable and about $1 \text{ mmol m}^{-2} \text{d}^{-1}$, whereas uptake of dissolved nitrate and ammonia are close to $5 \text{ mmol m}^{-2} \text{d}^{-1}$. The removal of particles however can be highly variable and nitrogen uptake via particles can be upwards of $20\text{-}25 \text{ mmol m}^{-2} \text{d}^{-1}$. The re-mineralization of these particles creates higher concentrations of dissolved nitrate, ammonia and organic nitrogen over the reef than concentrations in the incoming ocean water, creating an apparent export of dissolved nitrogen from the reef. Given these basic mechanisms, we expect coral reefs to demonstrate a variety of responses to nutrients, depending on the basic environmental parameters: water motion (velocity and bottom friction, or energy dissipation), concentration of dissolved nutrients, relative concentration and size of particles, and community composition of filter feeders.

Nitrogen Uptake, Assimilation and Regulation in Coral Patch-reefs, One Tree Island, Great Barrier Reef*Andrew D L STEVEN**

80 Meiers Rd, Indooroopilly, Queensland 4068 Australia

andy.steven@epa.qld.gov.au

Understanding the physical and biological mechanisms governing nutrient uptake and assimilation is fundamental to any assessment of the resilience and stability of coral reefs to anthropogenically derived changes in nutrient delivery. At One Tree reef we routinely added nitrogen, as ammonium chloride to whole patch-reefs, and conducted labeled ^{15}N experiments to measure nitrogen uptake, assimilation and regulation (fixation and denitrification). Nitrogen uptake rates, averaging $129 \pm 74 \times 10^{-6} \text{ m s}^{-1}$ over a range of seasonal and meteorological conditions were proportional to concentrations (first-order) variable, and likely to be close to mass-transfer limited rates. ^{15}N tracer experiments confirm not only uptake and assimilation of the added nitrogen by a variety of organisms, but also the generality of mass-transfer relationships to organism morphology. Rapid uptake and assimilation were measured in organisms that actively pump water-such as clams-or those with high surface area: volume morphologies, such as macroalgae and branching corals. Changes in the elemental composition of coral tissues confirm that nitrogen was acquired from the water column and incorporated mainly into zooxanthellae. Nitrogen fixation rates increased by $\sim 80\%$ in response to phosphorus enrichment, whereas nitrogen enrichment increased denitrification rates 2-fold. Nitrogen enrichment also stimulated alkaline phosphatase activity, consistent with an increased requirement for phosphorus. These differences persisted for several months after nutrient enrichment ceased, and demonstrates positive and negative feed-backs in coral-reef nutrient recycling.

Nitrogen /Carbon Isotopic Composition of *Madracis* spp. as Indicator for Nitrogen /Carbon Assimilation and Utilization in Shallow and Deep Reefs*Conny MAIER**, *Juergen PAETZOLD*, *Markus G WEINBAUER*, *Rolf P M BAK*

1790 AB Den Burg Kingdom of the Netherlands

connymaier@yahoo.de

The branching corals *M. mirabilis*, *M. carmabi* n. sp. and *M. formosa* are abundant species in coral reefs of Curacao, Netherlands Antilles. The three species are confined to different depths, growing in shallow ($<20 \text{ m}$), intermediate (ca. 30 m) and deep waters ($>40 \text{ m}$), respectively. We measured ^{13}C and ^{15}N of holobiont tissue as well as ^{13}C in zooxanthellae and animal host separately. Stable isotopes were measured in corals from different depths, 5 to 47 m, at two distinct positions at each colony: the upward-facing tip and the sideward-facing side or base of a branch. ^{13}C and ^{15}N values both tend to decrease with increasing water depth - a result related to increasing isotopic discrimination with lower photosynthesis at greater depths. However, at shallow and deep reef a divergent behavior of ^{13}C and ^{15}N was observed. Shallow (5 to 20 m) the ^{15}N curve forms a plateau indicating that corals are nitrogen-limited. This may be due to high photosynthetic rates and diffusion constraints. However, ^{13}C values from shallow decrease with depth indicating changing rates of photosynthesis. The divergent behaviour of carbon and nitrogen isotopic data in shallow water suggests a shift in the ratio of carbon to nitrogen assimilation with a surplus of carbon in the shallow. This surplus in carbon supply may explain the fast calcification rates of *Madracis mirabilis* at shallow depths. At greater depths ^{13}C of zooxanthellae and host polyp indicate that the inevitable loss in carbon supply, by decreasing photosynthesis, was not compensated by an increase in heterotrophic food uptake. We conclude that changes in calcification rate may play a major metabolic compensatory role comparing shallow reef high-light, nitrogen-limited with deep reef low-light, nitrogen-sufficient environments.

Coral Mucus Functions as Energy Carrier and Particle Trap in the Reef Ecosystem*Christian WILD**

Celsiusstr.1, 28359 Bremen, Federal Republic of Germany

cwild@mpi-bremen.de

Zooxanthellae, endosymbiotic algae of reef-building corals, substantially contribute to the high gross primary production of coral reefs, but corals exude up to half of the carbon assimilated by their zooxanthellae as mucus. We show that released coral mucus efficiently traps organic matter from the water column and rapidly carries energy and nutrients to the reef lagoon sediment, which acts as biocatalytic mineralizing filter. At Heron Island, Great Barrier Reef, Australia, we found that the dominant genus of hard corals, *Acropora*, exudes up to $5 \text{ L mucus m}^{-2} \text{ reef area d}^{-1}$. The main fraction of this mucus dissolves in the reef water that is filtered through the lagoon sands. Here, coral mucus is degraded at turnover rates of at least $7\% \text{ h}^{-1}$. Detached undissolved mucus traps suspended particles increasing its initial organic C and N content by three orders of magnitude within two hours. Tidal currents concentrate these mucus aggregates into the lagoon, where they rapidly settle. Coral mucus provides light energy harvested by the zooxanthellae and trapped particles to the heterotrophic reef community, thereby establishing a recycling loop that supports benthic life, while reducing loss of energy and nutrients from the reef ecosystem.

Organic Nitrogen in Coastal Coral Reef Skeletons Reveals Isotopic Traces of an Agricultural Revolution

*Guy S MARION**, Robert B DUNBAR, David A MUCCIARONE

for Marine Studies, University of Queensland, St. Lucia, QLD 4072 United States of America
g.marion@uq.edu.au

Eutrophication and nutrient studies have employed a range of techniques to identify nutrient sources, including assessment of ^{15}N in coral tissues and other bioindicators. Such methods identify current nitrogen sources but cannot serve as long-term proxies for water quality. This study introduces a new method of historically tracing the ^{15}N of intercrystalline residual organic nitrogen in the skeleton of the scleractinian coral *Porites lobata*. Corals were collected in Bali, Indonesia from reefs exposed to high levels of nitrogenous fertilizers in agricultural run-off, from lagoonal corals impacted by untreated industrial sewage, and from an offshore coral reef affected by neither. ^{18}O , ^{13}C , and annual ultraviolet luminescent and density bands were used in conjunction with local SST and precipitation data to develop accurate age models. Skeletal ^{15}N varied significantly between sites from 1993-2001 ($P=0.005$, $n=36$), as did ^{13}C ($P=0.03$, $n=36$). The agricultural site was most depleted in ^{15}N (3.9ppm), the sewage-exposed core most enriched (7.8ppm), while the control core was reflective of background oceanic nitrogen. Skeletal ^{15}N in the agriculture core declined significantly from pre-fertilizer enrichment in 1970 (9.9ppm) to isotopically light ^{15}N by 2001 (3.6ppm). No correlation existed between skeletal nitrogen concentration and ^{15}N , arguing against skeletal diagenesis. We suggest that the ^{15}N of residual organic nitrogen in long-lived *Porites* skeletons can serve as a historical environmental proxy for water quality by identifying nitrogen point sources. In Bali, this tracer reveals that an isotopic signal derived from fertilizer and sewage-rich river discharge is evident in near-shore coral reefs.

Coral Cavities Are Sinks of Dissolved Organic Matter (DOM)

*Jasper M DE GOEIJ**, Fleur C VAN DUYL

P.O. Box 59, 1790 AB Den Burg, Texel Kingdom of the Netherlands
jdegoeij@nioz.nl

Coral cavities are among the largest but least explored habitats of coral reefs. We studied DOM removal in coral cavities of 50 up to 150 L in the fore reef slope of coral reefs along Curacao, Netherlands Antilles. We found significant dissolved organic carbon (DOC) depletion in cavity water compared to ambient reef water. Sampling was done in 20 different open coral cavities. Water was taken in the center and approximately 2 m outside of the cavity opening. Differences in concentrations between cavity and reef water varied between 1.2 and 47.1 μM (with an average of 18.2 μM) at average reef water DOC concentrations of 84.9 μM . In a second experiment we closed the cavity opening to reduce water exchange. After closure significant reductions in DOC concentrations (17 to 33%) were assessed in cavity water within 30 min. Largest concentration drops were observed in the first 10 min. With bioassay experiments, using 0.8 μm filtered reef and cavity water, we determined the decrease in DOM due to bacterioplankton activity. After a 32 day incubation the DOC concentration was reduced with 17 to 27%. A comparable reduction was achieved in closed cavities in 30 min. These results demonstrate that bacterioplankton plays a minor role in the total DOM removal in cavity water. We conclude that coral cavities are net sinks of DOC and we suggest that encrusting suspension feeders, which cover more than 50% of the cavity walls, play a significant role in DOC removal in these cryptic habitats.

Evaluating Cycling of Carbon and Nitrogen by *Porites* Using *in Situ* Aquarium Experiments

*Allison Y BEAUREGARD**

700 Pilottown Rd., Lewes, Delaware United States of America
isopod@udel.edu

In situ chamber experiments were used to quantify photoautotrophic processing of carbon and nitrogen by two *Porites* species. Use of closed chambers allowed me to close off the advective transfer that is present in the reef, allowing us to estimate mass balances of carbon and nitrogen. These experiments allow assessment of uptake by the zooxanthellae symbiont, transfer to the coral host tissue, and production of DOM in relation to total carbon drawdown. By comparing the drawdown of dissolved inorganic carbon to the incorporation of C-13 into the tissue and buildup of DOC in the water, I have estimated the photosynthetic loss of organic carbon. Results show that ~10% of the DIC drawdown shows up as DOC in these corals. Additionally, nitrogen is released as DON. Based on results of previous experiments, urea concentration was also measured throughout the incubations. Estimates reveal that urea may account for as much as 30% of the released DON.

Roles of Microbes in the Carbon Flux for Evaluating Potential CO_2 Fixation in Coral Reef Ecosystems

*Kimio FUKAMI**, Saori TOTTORI, Yoshimi SUZUKI, Beatriz E CASARETO, Yutaka IKEDA, Katsumi YOSHIDA, Yutaka TATEDA

Monobe-Otsu 200, Nankoku, Kochi 783-8502 Japan
fukami@cc.kochi-u.ac.jp

INTRODUCTION Corals produce and release significant amount of dissolved organic matter (DOM) into seawater, a certain part of which would be transformed to microbial biomass and be transported to offshore with tidal cycles. Although estimation of carbon flux from coral reef ecosystems to offshore is essential for evaluating CO_2 fixation potential of coral reef, very few information is available, so far. This study aims to estimate the productivity of microbes on DOM released by coral, to estimate the carbon flux from the coastal to offshore as microbial biomass, and to give some additional information for estimating CO_2 fixation potential of coral reef ecosystems. **MATERIALS AND METHODS** Seawater samples of coral reef area were collected from Bora Bay, Miyakojima Island, Okinawa Prefecture. Surface water samples of two sampling sites (Stns. M1, M3) were collected, and abundances and carbon biomass of microbes were determined using an epifluorescence microscopy equipped with image analyzer. **RESULTS AND DISCUSSION** Biomass of both bacteria and heterotrophic nanoflagellates (HNF) were always higher in the lagoon than in offshore area. Average bacterial abundance and carbon biomass of Stn. M3 (offshore water is coming into lagoon) were 2.6×10^8 cells L^{-1} and $10.4 \mu\text{g-C L}^{-1}$, respectively, while those of Stn. M1 (lagoon water is going out to offshore) were 8.1×10^8 cells L^{-1} and $23.4 \mu\text{g-C L}^{-1}$, respectively. The difference between the two Stns. was due to the production of microbes on coral DOM during stay in the lagoon. From the results obtained in this study, microbial biomass produced in the lagoon and transported to offshore water was estimated as 7-11 kg-C per day or 3700-6600 kg-C per year at the coral reef ecosystem of Bora Bay, Miyakojima Island. These estimations should be taken into account for evaluating the potential productivity of coral reef ecosystems.

Organic Matter Dynamics in Coral Reef in Miyako Island, Okinawa

*Yoshimi SUZUKI**, *Beatriz E CASARETO*, *Loïc CHARPY*, *Jean BLANCHOLT*
836 Oya Shizuoka, 422-8529, Japan
seysuzu@ipc.shizuoka.ac.jp

Coral reef ecosystem has the dynamic interactions between the photosynthesis and respiration of organic matter and nutrient cycle. Organic matters are consisted of various compounds, various size and molecular weight, and also different elemental compositions. Organic matter is produced and released by many coral reef organisms such as microphytoplankton, nano-, picophytoplankton, macro-,micro-algae, coral, benthic organisms, etc.. We had studied to clarify main primary producer for dissolved organic matter (DOM), respiration and turn-over time of DOM, and imbalance of C/N ratio of DOM in Miyako Island (Bora Bay), Okinawa in July, 2001 and July, 2002. We had three different experiments: 1)water incubation for plankton, 2)dome incubation for coral (*Montipora digitata*) and benthos, 3)skeleton incubation for endolithic and epiphytic algae. We had taken water samples for measurement of DOC/DON, nutrients (NO₃, NH₄, PO₄), carbohydrate, protein, humic and fulvic acids and ¹³C. Results showed that dissolved organic carbon (DOC) concentration in phytoplankton incubation increases during daytime and decreases during nighttime, but dissolved organic nitrogen (DON) decreases during daytime and nighttime. This suggests that behavior of DOC is different in that of DON. Net DOC production is 0.8μmol/l, hr as an average value. DOC concentration in dome incubation increases during early morning, and decreases rapidly during daytime and increase of DOC during early morning is 20μmol/l, hr While DON increases slightly with time. DOC and DON concentration in skeleton incubation for endolithic and epiphytic algae increased with 8 to 180μmolC/l, hr and 1 to 8μmolN/l, hr. These results suggest that endolithic and epiphytic algae may be important primary producer for DON and DOC in coral reef.

Pelagic-Benthic and Oceanic-Neritic Coupling in a Red Sea Fringing Reef

*Claudio RICHTER**

Fahrenheitstrasse 6, Bremen Federal Republic of Germany
richter@zmt.uni-bremen.de

Mass transfer rates of organic matter and nutrients between oceanic and coastal waters and between the pelagic and benthic phase govern the structure and productivity of fringing reefs in the desert-enclosed Red Sea. Cross-shore transport in the low-advective northern Gulf of Aqaba is driven by buoyancy resulting in a two-layered flow across the reef face: a net inflow of oceanic plankton at the surface and a net outflow of nutrient enriched waters near the bottom. Accrual rates of organic matter - regulated by a diverse filter-feeding macrofaunal community living above, on and within the coral reef framework - are balanced by mineralisation rates through macro- and microbiota in the reef framework and permeable sands, and are equivalent to roughly 1 gC m⁻² d⁻¹ for various parts of the reef flat, crest and slope. Seasonal deviations from the balance in allochthonous materials result in seasonal enrichments in nutrients and macroalgal biomass.

A 3D Coupled Physical-Biogeochemical Model to Simulate Biogeochemical Recycling in a Pelagic Ecosystem in the South-West Lagoon of New Caledonia

*Vincent FAURE**, *Christel PINAZO*, *Jean-Pascal TORRETON*, *Pascal DOUILLET*

BP A5, 98848 Noumea Cedex New Caledonia
vincent.faire@noumea.ird.nc

The knowledge of physical processes and biogeochemical cycles in the south-west lagoon of New Caledonia allowed us to develop a determinist model of the oligotrophic sub-tropical ecosystem. This work is an extension and improved version of the model presented by Bujan et al. (2000) and Pinazo et al. (*Coral Reefs, in press*). A 3D hydrodynamic model with a spatial grid of 500 m was coupled with biogeochemical equations. Simulations were forced by wind, light, temperature and freshwater inputs. This new ecological model was developed to including an explicit description of the microbial loop and several plankton sizes. The model was based on the Nitrogen and Carbon cycles described by 11 biological states variables, relating the variable stoichiometry of the elements in each biological compartment. Additional variables included bacterial production and dissolved organic matter and a better description of the recycling of organic matter. A particular effort was made to calibrate parameters of the model for the area studied using representative field measurements and experiments. The resulting model was used to calculate phytoplankton biomass, bacterial production, dissolved organic matter concentrations and nutrient recycling in the 2000 km² wide south-west lagoon of New Caledonia. Spatial distributions of key physical and ecological variables taken from the 3D coupled model simulations are presented and compared with the relevant field measurements, to illustrate the role of the physical processes in determining the evolution and variability of the ecosystem. Furthermore, a study of the remineralisation processes using simulations highlighted the role of the microbial loop in the study area. Further work will compare several realistic simulations with field data from the CAMECAL Program in order to validate the model and build an operational tool, capable of describing and predicting the spatio-temporal dynamics of organic fluxes in the ecosystem.

Understanding the Human Dimension of Coastal Management: How Socioeconomic Information Can Benefit Coral Reef Conservation Initiatives?

*Leah L BUNCE**

N/IP #5839, NOS International, 1315 East West Hwy, Silver Spring, MD 20910 United States of America

leah.bunce@noaa.gov

The ability to balance biodiversity goals with stakeholder interests is critical to the success of coral reef conservation initiatives. Understanding the socioeconomic context of the coastal management, including local demographics, use patterns, community members' perceptions, and governance measures enables managers to determine the value of the resources, the potential impacts of management measures, and the effectiveness of existing policies. This presentation will discuss the priority socioeconomic information that needs to be collected as identified in the Socioeconomic Monitoring Guidelines for Coastal Managers in Southeast Asia and the Caribbean (SocMon). SocMon was published by the World Commission on Protected Areas - Marine, the National Oceanic and Atmospheric Administration and the Global Coral Reef Monitoring Network in collaboration with the World Fish Centre, Southeast Asia Fisheries Development Centre and University of West Indies. The presentation will draw on case studies from around the world to discuss how this information has benefited coral reef management conservation initiatives.

Assessing Coral Reef Condition: Eliciting Community Meanings

*Elizabeth A DINSDALE**

School of Tropical Environment Studies and Geography, James Cook University, Townsville Qld 4811 Australia

elizabeth.dinsdale@jcu.edu.au

Ecosystem management includes people as an integral part of the environment. Therefore, an understanding of how people and the environment relate is required. How people perceive their environment and how a change in its condition affects their views, feelings, values and ultimately behaviour is unknown. Understanding the relationship people have with the environment during management processes incorporates values and belief, increases collaboration between stakeholders and produces innovate and flexible strategies. A modified repertory grid analysis was used to understand how people interpret coral reefs. Seventy-six participants were asked to describe photographs of coral reefs that were associated with different intensities of anchoring, a potentially damaging process. Three important meanings for coral reefs were elicited. The most important meaning was evaluative, whether the scenes were perceived positively or negatively. The second was activity, whether the scene depicted variation in the number of corals and fish. The third was diversity, describing a difference between scenes that were highly diverse and those that either showed monocultures of corals or sparsely covered substratum. Participants with and without a working association with coral reefs ascribed these meanings and had remarkably consistent conceptualisation of the coral reef scenes, suggesting similar values for the coral reef environment. Both groups were able to discriminate coral reef scenes associated with different intensities of anchoring. Coral reefs associated with high levels of anchoring were associated with the constructs unhealthy, boring, lack luster and dead, suggesting these reefs had lost their value. Perceptual information could be used in the management of natural resources to identify differences in values and provide assessments of the condition of the resource. The perceptual study of coral reefs showed that changes in the condition of the environment, brought about by the activities of people, changed the meaning and value that the participants ascribed to the reef.

Community-based Marine Resource Management in Fiji : From Yesterday to Tomorrow

*Annette MUEHLIG-HOFMANN**, Nicholas V C POLUNIN, Selina STEAD, Nicholas A J GRAHAM

Newcastle upon Tyne, NE1 7RU, England United Kingdom of Great Britain and Northern Ireland

n.polunin@ncl.ac.uk

With fisheries under increasing pressure world-wide from attempts to maximise coastal economic productivity, weaknesses in management regimes have to be recognised. Devolution as a management alternative however is pragmatic in both fiscal and regulatory senses. Fiji constitutes a unique case study because the 411 customary fishing-rights areas (*qoliqoli*) constitute a form of dual ownership between local users and central government, and these areas have been accurately mapped. We seek to collate work to date, to critically review the origins and definitions of practices in the past and in use today. While the arrangement constitutes a connection between state and local populations for management purposes, the cooperative co-management approach has not been uniform across communities in Fiji; there are different levels of community involvement and a variety of approaches, and it has been a source of confusion and disputes (e.g. revenue distribution from commercial fishing). At a time when both participatory management and fiscal devolution are in vogue, and Fiji is reviewing its constitution, we take the opportunity to look at what happens when co-management is codified and allowed to evolve. One issue is as to whether "ownership" of the *qoliqoli* should include both the local marine resources and the seafloor. The effects and potential benefits of such devolution can at present only be speculated upon, but this paper will take a critical look at issues of "traditional conservation", the origins of the existing *qoliqoli* system, perceptions of it by the people primarily concerned, the forces driving its evolution and its impact on marine resource use.

The (Dis)Connection between Internationally-led Initiatives Assessing the State of Coral Reefs and Local Policy-making: A Fijian Case Study

*Jane TURNBULL**

P O Box U63 (Laucala campus), Suva, FIJI New Zealand

jjh15@student.canterbury.ac.nz

Coral reefs are becoming increasingly commodified for tourism and an expanding range of fish, invertebrate and coral products. This, as well as other anthropogenic disturbances plus recent mass coral bleaching episodes have caused concern about the extent to which coral reefs are degraded worldwide, and biodiversity lost. This concern is generating a further type of reef commodification designed to accumulate information about the extent of degradation. This information, which is collated into international databases or otherwise shared internationally, is considered a necessary input to policy processes, to help save the world's coral reefs. The Republic of the Fiji Islands, where customary owners have legal, proprietary fishing rights over reefs (an area-based system called *I qoliqoli*) provides a case study of initiatives collecting information about the state of reefs in the Fijian archipelago. These reefs cover an estimated 10,020 square kilometres and are located in the central South Pacific. The initiatives gathering information about the state of Fijian reefs are the Global Coral Reef Monitoring Network (the Fijian and Southwest Pacific nodes based at the University of the South Pacific in Fiji), Reefbase, Reef Check, the Global Marine Aquarium Database and the Convention on Trade in Endangered Species (regarding collection sites for the marine ornamentals trade) and the Fiji Locally Managed Marine Areas Network (FLMMA) which encourages communities to monitor their coastal resources. The information being collected in these initiatives is not readily accessible to Fijian state policy-makers, and with the exception of FLMMA, is even less accessible to the customary owners of *I qoliqoli*. I examine how these data collection initiatives operate in the Fiji Islands, and how they have been structured to benefit the international community rather than local ones. I look at the factors constraining the use of this data within the Fiji Islands.

Factors Influencing the Attitudes of Fishermen and Park Personnel Towards Closed and Gear Restricted Area Management

Tim MCCLANAHAN, *Jamie G DAVIES**, Joseph MAINA, Stephen MANGI
Wildlife Conservation Society, The Bronx, New York
jamied@ceredigion.gov.uk

Given the poor success of marine protected areas (MPAs) in achieving their management goals there is a need to determine factors that influence positive attitudes among stakeholders. We report the attitudes of park service personnel and fishermen living adjacent to three marine protected areas in Kenya that differed in age and history of community participation. We tested the hypotheses that positive attitudes towards the management of fisheries exclusion and gear restricted areas would increase with wealth, education, period of employment, degree of community participation, and the age of the MPA. All respondents agreed that closed and gear-restricted areas benefited the nation most, park personnel saw communities and fishermen benefiting from closed and gear-restricted areas but fishermen did not share this view. The strongest factor was employment in either the park service or fishing, with fishermen having significantly less positive attitudes towards fisheries closed areas than park management staff. Wealth and community participation were not associated with more positive attitudes towards closed areas. Gear-restricted areas were viewed more positively by fishermen, and increased with education and the age of the protected area. Individuals with a secondary education were more common in the park service, and had a more positive perception of the value of gear restricted areas to fishers than less educated individuals but did not have significantly more positive perception of the value of closed zones. Fishermen exploiting the oldest MPA held significantly more positive attitudes towards the designations than fishermen living adjacent to the newest MPA, although only a slight majority agreed that they and their communities benefited from the designation. The results indicate a need for patience in expecting change in resource users attitudes, adopting an approach in which fishermen are more aware of MPA functions, particularly closed areas, and to increase opportunities for formal and informal education.

Management Intervention for Coral Reefs in the Gulf of Thailand

Nisit RUENGSAWANG, *Thamasak YEEMIN**
Faculty of General Education, Rajamangala Institute of Technology, Bangkok
Technical Campus, Bangkok 10120, Thailand
nrungsawang@hotmail.com

Causal chain analyses were applied for identification of causes of change in environmental conditions, levels and scales of threats at a particular site and alternative points of management intervention. The analyses were performed at four distinct coral reef sites in the Gulf of Thailand, namely Mu Koh Chang (Trat Province), Mu Koh Chumphorn (Chumphorn Province), Mu Koh Anghong and Mu Koh Samui (Surat Thani Province). Coral reef degradation was the final outcome of ecological problems. Public participation in several meetings at the coral reef sites with the involvement of stakeholders identified root causes and provided management intervention for coral reefs at local level. Given Mu Koh Chang as an example, the root causes were clarified as: lack of awareness and greed; lack of ecological knowledge; failure of coordination among institutions; inappropriate tourism management; inadequate numbers of government staff, researcher and site manager for coral reef management; weak law enforcement; poverty and degradation from natural disturbances. The proposed management intervention for coral reefs in the Gulf of Thailand could be summarized into eight categories as: building awareness; providing knowledge of coral reef ecosystem; better coordination among agencies; sustainable ecotourism development; capacity building; livelihood development and monitoring and rehabilitation. Thirty two projects with a total of 642,363 US\$ have been proposed in a demonstration site for a period of three years in order to reverse the coral reef degradation trend according to the identified management interventions. Co-financing by the Global Environment Facility (GEF) and the Thai Government may be possible under the UNEP/GEF South China Sea Project.

Is Coral Reef Conservation Possible without Science Education in Melanesia? Is Science Education Possible without Development?

*Simon FOALE**
RMAP, RSPAS, ANU, Acton 0200, Australia
simonjf@bigpond.com

The largest areas of highly biodiverse coral reefs that are still in good condition are in the Independent Melanesian states of Papua New Guinea and Solomon Islands, whose population densities are currently estimated at 11 and 16 people/km² respectively. However, rapid population growth rates, weak national governance, and coral bleaching forebode major stresses on Melanesian reef systems within 50 years. Networks of permanent, no-take closures, believed by many to be the most versatile management tool, are problematic in Solomon Islands and PNG. This is because of the mismatch between the scale of Customary Marine Tenure (CMT) territories, and the scale at which stocks of most economically important reef fauna are self-recruiting. Thus, any one tenure holding group cannot benefit economically from permanently closing even part of their reef, because most of the larvae spawned by their stocks will disperse beyond their territorial boundaries. Therefore, unless all tenure-holding groups in the region can be convinced to do the same (which is very unlikely), this approach will not work. Local management is also hampered by low levels of formal scientific education, and most Indigenous Knowledge (IK) frameworks are based on maximizing, rather than sustaining, catches. Crucially, IK is weak, or non-existent, on the biology and ecology of population replacement for most marine fauna, and therefore most fishers are unaware of the link between over-harvesting and recruitment failure. In this paper I argue that rural education programs that improve understanding of population replacement processes in reef fauna provide a necessary but insufficient response. A much stronger engagement by environmental NGOs and donors with the root causes of poverty, under-development, aid dependency and chronically weak governance is also needed. I also critique the preservationist approach of some environmental NGOs, which in this socio-political context is not only morally questionable, but unlikely to succeed.

Evaluating the Effectiveness of Coral Reef Management Strategies in the Indo-Pacific

*Michael J MARNANE**, Tim R MCCLANAHAN, Joshua CINNER, Tracy H CLARK, William KIENE, Rizya ARDIWIJAYA, John BEN, Ian LIVIKO, Shinta PARDEDE, Joni WIBOWO, Ruby YAMUNA
c/- Dept. Tropical Environmental Science and Geography, James Cook University, Townsville. QLD. 4815. Australia.
mmarnane@wcs.org

Conservation of the high diversity reefs of the Indo-Pacific could be improved by understanding interactions between social and cultural institutions that promote successful management. An integrated ecological and socioeconomic sampling program examined effectiveness of management regimes within 13 management areas throughout Papua New Guinea and Indonesia. Management regimes studied included: i) national park systems, ii) community-based protected areas (externally assisted), iii) traditional management systems (instigated and maintained by the community with no external assistance), and iv) customary marine tenure regimes (where enforced ownership over the reefs existed but no other management regimes were present). Only average fish size and fish biomass were found to be significantly higher within some of the managed areas compared to control areas. The most significant finding was that three out of four of the regimes with higher fish size and biomass inside managed areas were traditional forms of management. Interestingly, none of the traditional management regimes contained permanent reef closures. Each involved systems whereby protected reefs were occasionally or periodically opened to fishing. Socioeconomic data suggested that the success of management was due largely to factors driving compliance. Management regimes that had high levels of acceptance and awareness achieved greater compliance with regulations. For the traditional management sites, greater awareness and acceptance of the management was likely to have resulted from the integrated nature of the regime in the communities cultures and traditions, as well the ability of communities to periodically fish these areas and reap the benefits of the management system. This study suggests that in situations where resources are lacking for proper and continuous enforcement of management regulations, alternative regimes, such as traditional management systems, may provide valuable management and conservation tools.

Socioeconomic Factors Influencing Traditional Coral Reef Management

*Joshua E CINNER**

40 Stokes St Townsville, QLD, 4810 Australia

joshua.cinner@jcu.edu.au

For generations, communities in the Western Pacific have employed a range of resource management techniques (including periodic reef closures, gear restrictions, limiting entry, and the protection of spawning aggregations) to limit marine resource use. Because of their high potential to meet both conservation and community goals, these traditional resource management techniques are being revitalized by communities, governments, and NGOs as an integral part of national and regional marine conservation plans in the Pacific. However, the foundation upon which these national and regional conservation strategies are being built may be eroding, as the resilience of these systems in the face of the profound social and economic changes sweeping the Pacific region remains unclear. Numerous studies have suggested that changes in marine tenure or traditional management regimes are attributed to social and economic factors, however, specific relationships between socioeconomic conditions and traditional management are still not well understood. This paper examines the social and economic characteristics of 12 coastal communities in Papua New Guinea, and explores the characteristics of the communities that employ traditional reef closures and exclusive marine tenure. A logistical regression model is developed to explore whether household socioeconomic characteristics influence the odds of traditional management and marine tenure being present. Twelve of the fourteen socioeconomic factors were significant and could be used to correctly classify between 76-84% of the cases. Village-level socioeconomic factors were also examined using non-parametric statistics. Distance to market, percentage of fishing bartered or sold, fishing effort (measured in fishing trips per week), and the presence of conflicts over marine resources were all significant. Understanding these relationships will help conservation practitioners to implement conservation strategies in communities (that lack management) which are tailored to the local socioeconomic conditions.

Marrying Traditional Resource Management Practices and Modern Science in an Effort to Effectively Conserve and Sustain Local Fisheries at Village Level in Fiji

Alifereti TAWAKE, Ratu Pio RADIKEDIKE*

Institute Of Applied Sciences, University of the South Pacific, P.O.Box 1168, Suva, Fiji

tawake_a@usp.ac.fj

The concept of fisheries refugia and Marine Protected Area is not new to communities in Fiji, as it has been part of their traditional management practices. Taboo placed on sea areas for certain periods on the death of the chief, food totems and seasonal harvests are still being practiced in some parts of Fiji, but knowledge and practices of such traditional management strategies and its influences are rapidly being lost in Fiji during this era of modernization. However, many coastal communities depend on the sea for their livelihood and the use of "tabu" or refuge areas are increasingly being revitalized by resource owners as a tool to sustain local fisheries in Fiji. Through a Biodiversity Conservation Network (BCN) project, people in the Verata district in Fiji have developed scientific skills to help assess the impacts of their management actions. Using participatory techniques, communities determined threats and developed a marine resource management plan. Community members were then trained to perform simple biological monitoring techniques to assess the effectiveness of the use of refuge areas. Two target species, mud lobsters (*Thalassia anomala*) and clams (*Anadara* sp.) have been monitored. Since the baseline surveys in 1997, there has been a 13-fold increase in clam abundance in the refuge area and a 4-fold increase in the harvest area indicating the success of these interventions. Mud lobster numbers have also increased. Consequently, new refuge areas involving five target species have been set up and monitored by the community. In collaboration with the government and other NGOs, efforts are also underway to replicate this 'Veratavou model' in other parts of Fiji and to create a learning network of community-managed refuge areas. This will help determine conditions under which the declaration and monitoring of community-managed fishery refugia can be an effective tool in sustaining local fisheries.

Importance of Involving Land-less Villagers Who Depend Heavily on Coastal Resources in the Management of MPAs in Tonga

Seiji NAKAYA, 'Asipeli PALAKI*

POBox 917, Nuku'alofa Kingdom of Tonga

nakayaseiji@hotmail.com

A series of 5 no-take MPAs was established in 1979 for conservation and sustainable use of the valuable coastal resources on the northern reefs of Tongatapu, the main island of the Kingdom of Tonga. Management of these MPAs has been, however, inadequate, if not non-existent, mainly due to lack of government initiative. Status of resources use in the MPAs and adjacent waters is poorly understood. A survey through semi-structured interviews was administered to distinct stakeholder groups in the region, including 43 subsistence and artisanal fishers/gleaners, 2 diving operators, 5 resorts, 5 aquarium fish/coral harvesters, to find out the use pattern of resources, compliance with related laws, perceptions of resources and environment as well as opinions on the management. The survey showed that there is no customary tenure of coastal resources. Villagers without customary farm lands, many of whom have migrated from outer islands, are likely to depend heavily on coastal resources. Fishing activities distribute over a wide range of coastal areas, including MPAs due to limited awareness and compliance of MPAs. The lack of management and free access to the coastal resources have sustained the life of landless people. Conflicting uses, for example, diving operation and aquarium fish/coral harvesting occur concurrently. Fifty-three % of the fishers perceived decline in catch and 15% perceived degradation of reef environment during the last decade. Although the public has seldom been involved in any stage of management of coastal resources, a large number of people support strict enforcement of conservation-related laws. Comparison with MPAs established in the South Pacific countries strongly suggests that Tonga's unique free-access system to coastal resources and scarcity of bottom-up decision making make it difficult to promote resource conservation. Community-based, government-assisted management of coastal resources, involving those without lands, will be the only way to improve resources use.

Marine Resource Management Challenges in Traditional Societies: Managing and Conserving Resources at the Community Level

Christopher HAWKINS, Selaina VAITAUTOLU, Fatima SAUAFEA*

Executive Office Building, Utulei, American Samoa 96799 American Samoa

amsamoacrag@yahoo.com

There is a detailed and diverse history of traditional controls over the allocation of coastal space and resources. Traditional fishing societies found in many coastal regions have historically limited effort and catch, as well as outsider access in their home territories, as a means of protecting their stocks. However, the advent of contemporary markets and associated societal behaviors, as well as drastic increases in population, has necessitated a more coordinated approach to coastal resource management. One method that has been successfully implemented in several societies in the South Pacific is a cooperative arrangement between village and territorial or regional governments. The overriding rationale for such collaboration is the obvious need to utilize government sponsored science and management expertise, as well as funds for enforcement and monitoring capabilities, while ensuring a bottom-up, village driven scheme. American Samoa, the only US possession in the South Pacific, has successfully initiated a Community-based Fisheries Management Program (CBFMP) that is actively addressing many areas of coral reef decline, especially fisheries and fish habitat. This program is a unique marriage between traditional and cultural methods of marine conservation and the talents and resources available at the territorial Department of Marine and Wildlife Resources. Featured aspects of this management effort are the establishment of marine protected areas under the control of village leadership, sustainable fishing practices, and long-term management plans. There have been numerous challenges to full implementation, including funding for equipment, staffing issues, enlisting village support, and missing program components. Discussed herein are some of these challenges, lessons learned, and recommendations for future directions of the CBFMP.

Marine Protected Area Plan for American Samoa: Status, Effectiveness, and Future Steps

*Risa G ORAM**

PO Box 8067, Pago Pago, AS 96799 American Samoa
risaoram@hotmail.com

The Marine Protected Area (MPA) Plan for American Samoa is presented by analyzing historic and current efforts in coordination, design, implementation and evaluation of marine protected areas in Territorial waters of American Samoa. This paper begins with a discussion of the rationale for utilizing MPAs as a management tool for coastal and marine resources in American Samoa. This is placed within the context of the encompassing goals of the United States Marine Protected Area Federal Advisory Committee. Among these goals are to: a) Facilitate the design of a science-based national system of MPAs; b) Enhance MPA stewardship and effectiveness; and c) Improve the national and regional coordination and consultation of MPA efforts. Next, this paper analyzes current management regimes of the marine protected areas in American Samoa, including details about the various stakeholders involved with stewardship and management. This paper also discusses the plan to apply the MPA Report Guide and database (as utilized by the Coastal Conservation and Education Foundation, Inc. and other collaborators in the Philippines) to the American Samoa context as a means to gather, store and analyze information on marine protected areas. If completed yearly, the MPA Report Guide and database will provide MPA managers, local government, non-government organizations, academe, or other interested parties with information on the status and quality of management, the status and quality of the environment, and benefits being derived from the MPA. It will also provide feedback on how the MPA is rated compared to other MPAs and on how to improve management of the MPA. Finally, this paper concludes with a discussion of future steps that will be taken to finalize the MPA Plan for American Samoa. This includes a methodology and timeline for implementation, reporting and information sharing.

Marine Protected Areas and Biodiversity Conservation; Bunaken National Park, Indonesia and Palolo Deep Marine Reserve, Samoa

*G Robin SOUTH**, *Posa A SKELTON*, *Lyndon DEVANTIER*, *Emre TURAK*, *Grevo GERUNG*

PO Box 1539, Townsville, Queensland 4810 Australia
robin.south@impac.org.au

Bunaken National Park, Indonesia (BNP: 80,000 ha) lies in the centre of marine biodiversity in the Indo-Pacific region, whereas Palolo Deep Reserve (PD: 137.5 ha) in Samoa lies well to the east. Both sites are major tourist attractions, and both are juxtaposed to urban centres. BNP is a strategically important MPA, protecting some of the world's most important marine biodiversity, including more than 390 species of scleractinian corals and 100 species of benthic algae. A comprehensive zonation scheme and management plan are in place, although anthropogenic impacts including illegal and destructive fishing, poor waste management, and unsustainable tourist developments need to be reduced, and the management plan must be effectively enforced. PD plays an important role in conserving the biodiversity of Samoa, including 143 species of scleractinian corals and 114 species of benthic algae. Evidence from past catastrophic events (cyclones in 1990 and 1991) shows that it acts as a reservoir of larvae and spores that assist in the replenishment of nearby reef systems. The biota of PD has now fully recovered from these two cyclones, suggesting that a 10-year period is required for recovery from such events. The plan to extend the marine reserve from PD to include the shoreline of the Apia district will be effective only if sufficient resources are provided to manage the area, and protection of the biodiversity of PD will require full enforcement of the draft Management Plan; management is currently left to a family resident on the site. Illegal fishing continues, and anthropogenic factors are increasingly affecting the reserve, resulting in increases in sedimentation and waste management problems. Documentation of the biodiversity of both sites is incomplete, and the world-wide shortage of marine biosystematists hinders progress in this area. Effective conservation will require sustained implementation of management plans into the foreseeable future.

Local Stakeholders Diverse Management Approaches of Marine Protected Areas in Two Coastal Provinces in the Central Philippines

*Kai-J KUHLMANN**

P.O. Box 50, 5600 Kalibo, Aklan Republic of the Philippines
kuhlmann.kp@eudoramail.com

At two distantly located coastal provinces of the Philippines, one facing the Leyte Gulf opening to the Pacific Ocean (Eastern Samar) and the other facing the Sibuyan Sea (Aklan), 11 marine protected areas (MPAs) have been assessed respectively in terms of surface composition and standing fish biomass by manta tow and transect dives to highlight their ecological shape to local stakeholders. Nine MPAs from Eastern Samar resulted in fair (Reef Condition Index = RCI 0.26 to 0.40) and two in poor conditions (RCI 0.20 to 0.24) compared to one in very good (RCI 0.81), one in good (RCI 0.52) and four in fair (RCI 0.35 to 0.46) conditions from Aklan. At five spots, flat sand bottom but no corals reefs dominated. After a series of community capacity building and development and, in cognizance to the rising socio-ecological conflict in rural coastal areas, the local stakeholders designed plans and programs supportive to the management of these MPAs. Fishers and farmers from Eastern Samar coordinated by a local NGO decided for rearing of *Haliotis sp.*, *Siganus sp.*, or *Scylla sp.* in mangrove-friendly aquaculture systems and rice farming in small-scale livelihood development nearby MPAs, suitable to local conditions. The Aklan stakeholders of fishers together with local government units, NGOs and academe focused on governmental networking, environmental education campaign and, mangrove-coral garden integrated eco-tourism. Potential benefits of these livelihoods (Eastern Samar) as well as the successful province-wide awareness raising on coastal management (Aklan) may ameliorate income generating support, environmental law enforcement and awareness in conserving the marine resources, that may enhance the quality of life of the coastal populace under strong multi-sectoral cooperation.

The Coral Reef Management Plan for Mu Ko Chumphon Marine National Park, Thailand

*Sakanan PLATHONG**

15 Kanchanavanich, Kohong, Hatyai, Songkhla, 90112 Kingdom of Thailand
psakanan@ratree.psu.ac.th

The Mu Ko Chumphon Marine National Park is a part of a system of National Parks in Thailand. The distinguished aquatic resources, which qualify the area for the status of a Marine National Park include, coral reefs, mangroves, seagrass beds, and the rich marine life supported by these marine habitats. The living coral reefs, mangroves and seagrass beds are not only aesthetically appealing, but they serve a more basic function in providing shelters and food source for several commercially important species. The coral reef has undergone several changes during the past decade, which have resulted in degradation of the ecosystem, in terms of productivity, health, and stability of its living marine resources. Since the coral reef of the park that qualify the area as a Marine National Park contribute to the high quality of life in the park, without these unique marine resources the quality of life and the economy of the park will decline. The procedure for analyzing the situation of the park was to approach each category sequentially at the start of the planning. Public involvement is considered to be an important part of the plan. The basic information including habitats, resources, uses, and conflicts were gathered and analyzed. This project aims at providing comprehensive information for the formulation of issue-based management plans and strategies. The five years management plan for the the Park contains some of the most innovative tools available for protecting marine national park and its surrounding marine communities for the use and enjoyment of future generations. Zoning is being implemented in the park to assist in the protection of the coral reef and other marine ecosystems in the park while allowing the traditional uses and tourism. Local advisory committee is proposed to be established at the start of management implementation.

Putting Reef Check and SocMon to the Test: Cost-effective Approaches and Results to Improved Reef Monitoring and Marine Protected Area (MPA) Management in a Complex "Urban" Environment

Michael A ROSS, Nora E ROSS, Mario AMORES, Alfonso AMORES, Dewey MONSATO, Wilson MARIBOJOC*

Buyong Beach, Maribago, Mactan Island, City of Lapu Lapu, Cebu, Republic of the Philippines

mikeross@mozcom.com

Traditional, community-based approaches to reef conservation and marine protected areas (MPAs) in the Philippines have tended to focus on fisheries and reef area management and benefits. The results to date have been described as mixed and generally costly in terms of development time and external assistance required in relation to actual reef areas protected and benefits generated. In more complex, "urban" settings, such community-based approaches are further challenged by the community structures, actual reef area uses, socio-political interests and potential benefits, such as coastal and diving tourism. Building on work completed to date in assisting to establish, plan and monitor the first "urban" MPA in the Philippines (Ross et al 2003; Hodgson and Ross, 2003), innovative and cost-effective applications of available tools, such as Reef Check and Socio-Economic Assessment Monitoring (SocMon), supported through public - private partnerships and small-scale grants, are demonstrated and documented within the City of Lapu Lapu, Cebu, Philippines. Focused, participatory surveys, followed by rapid feedback and presentation of key results and recommendations have supported the design, planning, establishment and enforcement of an expanding network of MPAs within this City since 2002. Current status and proposed plans for the City's MPA network are presented to further expand upon the "urban" MPA model, approaches and results reported to date.



Poster Session
June 29 (Tue)



Species Diversity and Dispersal Pattern of Crinoidea at Pramuka Island, Thousand Island-Indonesia on June until July 2003

*Heri CHIN**

Jl. Bekasi Timur VI/5 RT 02/08, Jatinegara, East Jakarta, DKI Jakarta Province
Republic of Indonesia
bakpau_mono@yahoo.com

A study of Crinoidea had been carried out during June until July 2003. Methodology used for data collecting was random sampling within belt transect of 5 meters wide laid along a reef slope. The reef slope was divided in four direction, Site I North to East, Site II East to South, Site III South to West and the last West to North. A total of 1076 individuals of Crinoids belong to 9 species were observed during the survey. *Capilaster sentosus* and *Craspedometra acuticirra* are two dominant species found at the observation sites. The impact of Southeast Monsoons on the distribution of Crinoids fauna was observed, the distribution pattern have a tendency to clustered especially on branching *Acropora* only at two sites; Site III (South to West) and Site IV (West to North). The current at the East-side of the island was very strong and it could be the cause of the absence of the Crinoid fauna since there were a lot of damaged branching *Acropora* founded. The species diversity index on Site III is 0.609 and Site IV are 0.777. The evenness of Site III are lesser than Site IV (Site III 0.278 and Site IV 0.353). The species found in Site III and Site IV are similar (the similarity index is 0.995).

Biogeography on Azooxanthellae Corals in the Western Pacific

*Gabriela CRUZ-PINÓN**

Carretera Cheutmal-Calderitas Km. 5.5 Chetumal, Mexico
maltrataflores@hotmail.com

Although azooxanthellae are widely distributed, biogeography patterns of this corals its poor development and practically unknown its relationship with the oceanographic aspects who explained the causes of bathymetrical arrangement. In way to approach a general description of azooxanthellae trends in a deep-gradient we analyzed species richness in five latitudinal degrees squares with oceanographic data in bathymetric gradient, at the same time for conspicuous families a long western Pacific (60°N to 60°S). We did run a multiple regression analysis to obtain the best model who explained the species richness. The species richness model results better explain for temperature at 30 m deep (60%) following nitrogen at 500 m and temperature at 2000 m deep. Although endemic taxa recognize two important factors, nitrogen at 500 m and temperature at 2000 m deep, relationship was not significant. For Rhizangiidae and Dendrophylliidae families we were found that temperature at 30 m deep was determinant for distribution of those groups. This factor explained the 55% and 80%, respectively; subsequently nitrogen at 200 m (approximately 36% in each case). Caryophyllidae family richness shown, that silicates at 1000 m and temperature at 100 m in deep were negatively influence, meanwhile phosphorus and temperature, at 2000 m were positively related. In the Flabellids, silicates in 30 m deep, was influenced negatively, but temperature at 1000 m and nitrogen at 2000 was positively related. General pattern showed that temperature, nitrogen and silicates (when it's present) were important factors to establish the species richness. In analysis per family, we could observe that temperature at 30 m, nitrogen at 200 m, phosphorus at 2000 and temperature at 2000 m were relevant parameters to determine the richness. The specific richness model was the best ($r^2 = 0.6378$) following Family Caryophyllidae model ($r^2 = 0.5950$).

Ecological Assessment of the Coral Communities on Bunaken National Park: Indicators of Management Effectiveness

*Lyndon DEVANTIER, Emre TURAK, Posa A SKELTON**

PO Box 1539, Townsville, Queensland 4810 Australia
Ldevantier@aol.com

Bunaken National Park (N Sulawesi, Indonesia) is located in the centre of tropical marine biodiversity. 390 species (63 genera, 15 families) of reef-building (hermatypic) scleractinian corals were recorded. Exceptional within-location (area ca. 1 ha) diversity (mean 155 spp., max. more than 200 spp.) was recorded. Richest locations host some 25 - 30 % of the reef-building coral species compliment of the entire Indo-Pacific region. Hard coral cover in 2003 was c. 42 %, with a strong overall positive ratio of live : dead coral (mean 4 %) cover of 10 : 1. Destructive fishing, boat and diver damage all occur, although effective policing and increasing awareness are proving successful in minimizing these impacts. The corals form four major community types, broadly distributed in relation to depth (influencing illumination and exposure), slope angle and other environmental factors. The four communities were widespread within Bunaken NP, yet show significant dissimilarity with communities from adjacent areas (e.g. Sangihe - Talaud Islands to the NE). Three of the four communities are well represented in Bunaken NP protected zones, and thus should receive adequate protection, assuming MPA regulations continue to be adhered to. The fourth community, including some of the most diverse coral assemblages with high replenishment potential, is less well represented at present, and should be further conserved in current and future zonation revisions. Bunaken NP's reefs lie in the path of strong oceanographic current flow, facilitating larval dispersal, enhancing connectivity locally and among other populations in the region (source and sink function), and alleviating heat stress. Coral cover, diversity and status all indicate that resilience and resistance to disturbance (e.g. bleaching) are high, and that present management initiatives are proving effective. Bunaken NP's selection as a flagship MPA in Indonesia's developing MPA network provides a useful model for other functional and planned MPAs.

Recent Investigation of the Coral Reef Twilight Zone between 60-150m, at Kwajalein Atoll, Marshall Islands

*Brian D. GREENE**

2871-C Manoa Rd., Honolulu, HI United States of America
Brian.Greene@noaa.gov

The deep reef habitat between 60-150m, termed the coral reef *Twilight Zone*, contains a substantial percentage of the reef fish diversity in the Indo-Pacific. Recent investigations employing technologically advanced mixed-gas closed-circuit rebreathers have allowed researchers to probe the depths of the coral reef *Twilight Zone*, discovering over one hundred fish species previously unknown to science. This poster will present the results of a recent survey of the deep reefs of Kwajalein Atoll, Marshall Islands.

Introduction to the Tremendous Diversity of Y-larvae (Crustacea: Maxillopoda: Thecostraca: Facetotecta) in Inshore Coral Reef Plankton at Sesoko Island, Okinawa, Japan

*Mark J GRYGIER**, *Jens T HOEG*, *Yoshihisa FUJITA*

Oroshimo 1091, Kusatsu, Shiga Japan

grygier@lbn.go.jp

Recorded very rarely from Atlantic or Arctic waters, crustacean y-larvae (nauplius and cypris stages) were found in the 1980s to be abundant and diverse in Tanabe Bay, Honshu, Japan. The late Dr. Tatsunori Ito described many naupliar forms from there and assigned some cypris larvae to his new genus *Hansenocaris*. The adults of y-larvae remain unknown but may be parasites. In 1988-90, 1992-93, and 1996, one of us (MJG) frequently collected y-larvae by tossing a plankton net off the pier of the University of the Ryukyus laboratory at Sesoko Island, Okinawa, where there is a narrow fringing reef. Nauplii mostly collected during a single 24-hour period in 1989 were examined by SEM; 15 distinct forms, assumed to be species, were recognized, but many more occur in other samples. In 1996, nauplii of many, mostly lecithotrophic species were reared to the cypris stage. Each cypris was mounted together with its last naupliar (NV) molt on a slide as part of a reference collection. The present authors jointly collected and reared y-larvae at Sesoko in October, 2003, and took digital photographs and videos of living specimens. As vouchers for cypris larvae preserved for SEM, TEM, or DNA sequencing, NV molts (also some NV-molt/cypris pairs) were mounted on slides. Some mounted specimens were digitally photographed (interference contrast) as optical section series. Most plankton-caught y-nauplii are at the NI stage. This and the rapid molting to cypris (about 3-7 days for lecithotrophs) indicate that the unknown adults are also abundant in the vicinity, likely as parasites of reef-dwelling organisms. Surveys of y-larvae at other coral reef sites are desirable (known to be present at Ishigaki Is., Taiwan, Guam, Hawaii, Red Sea).

Molecular Aspects of Calcification in Scleractinian - Some Properties and Protein Components of the Exoskeletal Organic Matrix of *Galaxea fascicularis* and *Tubastrea aurea*

*Yeishin ISA**, *Isao FUKUDA*, *Katsunori CHINA*, *Toshiki WATANABE*

1-Senbaru, Nishihara-cho, Okinawa Japan

isaesin@sci.u-ryukyu.ac.jp

Exoskeletons calcified with CaCO_3 crystals are commonly distributed in marine invertebrates. In these biomineral are found to contain organic substances (matrix) which play regulatory roles in formation of crystal nuclei and determination of crystalline forms. Biochemical and histological studies on the exoskeleton of scleractinian corals had demonstrated presence of the organic matrix containing proteins, lipids and chitin. Ultrastructure had showed the initial phase of calcification occurred in close association with organic substances secreted by calcicoblastic cells. The possibility was thereby proposed that certain acidic organic substances induce formation of CaCO_3 crystals, presumably functioning as a template for nucleation. From these, functional and molecular analysis were initiated on organic matrix extracted from the calcified exoskeleton of two coral species, *Galaxea fascicularis* and *Tubastrea aurea*. By recording the decline of pH, organic matrix from the exoskeleton of *T. aurea* showed the inhibitory effect on CaCO_3 precipitation. It was also revealed that the skeletal organic matrix contained certain components which have carbonic anhydrase activity and the ability of Ca^{++} binding. In SDS-PAGE analysis of the organic matrix, one major protein as well as a few other minor bands were detected in each of the species. A cDNA encoding the major protein (named galaxin) in *G. fascicularis* was cloned and its primary structure was deduced. It consisted mostly of tandem repeats of a unit sequence of about 30 residues, and its sequence did not exhibit significant similarity to known proteins. Partial amino acid sequences of the peptide fragments of *T. aurea* protein showed one functional domain similar to a CO_2 catalyst of carbonic anhydrase.

The Association of Two Cryptochiridae Species (Brachyura: Decapoda) with the Scleractinian Coral *Siderastrea stellata* Verrill, 1868

Rodrigo JOHNSSON, *Elizabeth G NEVES**, *Georgia M O FRANCO*, *Fabio Lang DA SILVEIRA*

Rua do Matao, trav. 14, no. 321, Cidade Universitaria, CEP: 05508-900, Sao Paulo - SP Federative Republic of Brazil

johnsson@ib.usp.br

The family Cryptochiridae includes a small group of cryptical crabs that inhabit cavities of scleractinian corals, and in Brazil they are represented by two species. *Troglocarcinus corallicola* is found from Maranhao to Bahia States occurring in many members of the coral families Mussidae, Faviidae, Caryophyllidae and Siderastreidae. While *Opecarcinus hypostegus* has been restrictedly reported to Pernambuco State, mainly associated with *Agaricia fragilis*, an incrusting coral colony. Reproductive patterns may be found on the same colony but inside distinct holes. Due to a striking sexual dimorphism, the males are smaller and contact among couples is likely to occur during breeding period. Intending to contribute to the knowledge of the distributional pattern and host preferences of Cryptochiridae, we describe the association of *O. hypostegus* and *T. carallicola* with colonies of *Siderastrea stellata*, an endemic reef coral widespread along the Brazilian coast. The results were based on the analyses of four pregnant females and two males recorded inside distinct cavities on colonies of *S. stellata*.

Structure and Functional Organisation of the Sclerom in the Octocorals *Briareum stechei* (Kuekenenthal, 1908) and *Pachyclavularia violacea* (Quoy & Gaimard, 1833)

Lars JUERGENS, *Goetz B REINICKE**

Katharinenberg 14/20, 18439 Stralsund Federal Republic of Germany

Goetz.Reinicke@meeresmuseum.de

Within the morpho-functional connex of octocoral colony structure Ca-carbonate sclerites are stabilizing elements in the coenenchyme. They control e.g. the mobility of certain colony sections and thus reflect the functional differentiation. Apart from the information of the genome, development is further affected by ecological conditions. Relations between morphological set-up of the scleroms and their functional integration within the colony were examined for two species of soft corals: *Briareum stechei* and *Pachyclavularia violacea*. Eleven specified parameters of the sclerites form and size were analysed, as well as their orientation and position within the colonies. Five different sclerite types were differentiated, featuring their form characteristics and structural connex within the colonies to re-assemble a functional model of the tissue-sclerom architecture. Other than Kuekenenthal's historical interpretation of a two-layered structure the results demonstrate a three-layered organisation, with a functionally differentiated sclerite framework. From its structure it could be concluded that some sclerites support stability of colony sections, e.g. the polyps and tentacles, while other spindle shaped sclerites limit tissue movements, e.g. the hydraulic expansion of internal canals. Sclerites and tissues thus form an interacting functional structure organizing the colony. Comparison of the closely related species *B. stechei* and *P. violacea* revealed overall resemblance in the general set-up of scleroms. Differences between the species exist in two constructional variants of polyp storage: In *B. stechei* polyps are withdrawn into a thick colony coenenchyme, while in *P. violacea* polyps are retracted into calices standing up on the colony surface. Also parameterisation of sclerite characteristics allows clear definition of specific differences. Thus obvious differences concerning the organization of the colony morphology are supplemented by subtle, but significant differences between sclerites. Nevertheless, the view of Fabricius and Alderslade (2001) considering *Pachyclavularia* sp. a junior synonym of the genus *Briareum*, was supported as another result of the study.

Molecular Phylogeny of Serranid Fishes (Serranidae: Percoidei) Based on Mitochondrial 16S rDNA Sequences

*Marc KOCHZIUS**, *Lynne VAN HERWERDEN*, *Howard CHOAT*, *Christine DUDGEON*, *Rachel PEARS*, *Madeleine VAN OPPEN*, *Arturo DOMINICI-ROSEMENA*, *Dietmar BLOHM*
Leobenerstrasse, 28359 Bremen Federal Republic of Germany
kochzius@uni-bremen.de

The family Serranidae is a large group of marine fishes with 449 species and 62 genera, which have a distribution in tropical and temperate oceans. Taxonomy of serranids is impeded by the paucity of museum specimen for many of the species, which leads to paraphyletic genera. This was shown in molecular studies for *Epinephelus*, *Cephalopholis*, *Mycteroperca*, and *Serranus*. The taxonomic status of the subfamily Grammistinae is not clear and some authors place these fishes in the family Grammistidae. This study adds new sequences of Indo-West Pacific groupers, as well as Western and Eastern Atlantic species of the genus *Serranus* to the available sequence dataset of serranids. Phylogenetic relationships are inferred on the basis of 359 bp 16S rDNA with Neighbour Joining (NJ) and Maximum Parsimony (MP). Based on the species studied the subfamily Serraninae is monophyletic supported by high bootstrap values (NJ: 90%; MP: 89%). NJ analysis suggests that the subfamily Anthiinae is basal to the Serraninae, but MP analysis can not reveal this relationship. The two grammistine species studied are sister taxa to the three studied *Plectropomus* species (Epinephelinae), placed basal to all other Epinephelinae included in the analysis. This position of the Grammistinae is concordant to the status of a subfamily within the Serranidae. However, due to the position of the Grammistinae the subfamily Epinephelinae is paraphyletic. The analysed species of the Western Atlantic genus *Hypoplectrus* are monophyletic (bootstrap for NJ and MP: 100%) and the Western Atlantic *Serranus tortugarum* and *S. tabacarius* are placed basal as sister taxa with high bootstrap values (NJ: 97%; MP: 92%). Within the Serraninae, the three studied *Serranus* species from the Eastern Atlantic form a monophyletic clade supported by bootstrap values of 93% (NJ) and 95% (MP).

Evolution and Phylogeography of an Unusual Group of Coral-dwelling Barnacles, the Family Pyrgomatidae

*Maria Celia D MALAY**

University of Florida - Dickinson Hall, P.O. Box 117800, Gainesville, FL 32611-7800, USA
malay@flmnh.ufl.edu

Pyrgomatids are a unique group of balanomorph barnacles that are specialized to live on the surface of living scleractinian corals. These coral-dwelling barnacles are highly adapted to their obligately symbiotic lifestyle; indeed, one subgroup has become completely parasitic on their coral hosts. The relatively small size of the family (69 extant nominal species), coupled with the striking diversity in morphological and ecological specialization displayed by the different species, make the pyrgomatids a good model system for applying molecular phylogenetic methods towards the investigation of an array of different evolutionary hypotheses.

Morphological studies indicate evolutionary trends leading to reduction and fusion of skeletal parts, increased coral host fidelity, and possibly increased trophic dependency among putatively more "derived" pyrgomatid species. These trends appear to have occurred independently across several different lineages. To test such hypotheses in a rigorous manner, the phylogeny of the family must first be established. The work I will be presenting represent the preliminary results of a phylogenetic revision of the Pyrgomatidae using mitochondrial DNA markers.

A second objective of this research is to investigate patterns of genetic structuring in different species of pyrgomatid barnacles across their ranges in the Indo-West Pacific. By surveying genetic variation across different regions and between different species of host corals, I hope to gain valuable inferences regarding the processes that have shaped the evolutionary radiation of the Pyrgomatidae in the Indo-West Pacific. Are ecological specialization and host-switching more important in pyrgomatid speciation than geographic factors such as vicariant and dispersal effects? Molecular phylogeography promises to provide key insights into the diversification of the Pyrgomatidae in the Indo-West Pacific, which in turn will lead to a better understanding of the evolution of the present-day Indo-Pacific reef fauna.

Diversity of Corals at Eleven Remote Atolls and Reef Islands in the Central Pacific

*James E MARAGOS**

300 Ala Moana Blvd., Rm 5-231, Box 50167, Honolulu, Hawaii United States of America
jim_maragos@fws.gov

Surveys of corals were accomplished 1999-2002 at 7 remote central Pacific atolls and reef islands in the Line Islands (Kingman Reef, Palmyra A., Jarvis I.); Phoenix Islands (Howland I., Baker I.); and American Samoa (Swains I., Rose A.). These supplement earlier studies at 4 nearby atolls: Johnston, Tabuaeran, and Kiritimati in the northern Line Is. and Kanton in the northern Phoenix Is. All occur between 16° N. and 14° S. Latitude and 160° and 177° W. Longitude and were uninhabited until the 20th century except Swains. All but Tabuaeran, Kiritimati, Kanton (Republic of Kiribati), and Swains (U.S.) are U.S. National Wildlife Refuges. The 9 visited during the past decade (except Kanton and Tabuaeran) showed evidence of damage from coral bleaching, wave action, and sea-star (*Acanthaster*) predation. Reef island coral species richness is lowest at Johnston-35, Jarvis-49 and Swains-40, although higher in the Phoenix Is. (Baker-80, Howland-92), 1,500 km further west. Atoll coral species richness is higher (Rose-95, Kiritimati-83, Tabuaeran-75), especially those in the path of the westward moving Equatorial Counter Current (ECC), (Kingman-157, Palmyra-169). The same patterns apply to generic richness at reef islands (Johnston-16, Jarvis-21, Swains-17, Baker-30, Howland-26) and atolls (Rose-36, Tabuaeran-33, Kiritimati-31, Kanton-34, Kingman-46, Palmyra-46). Habitat variety is higher at atolls whose lagoons also shelter corals. Coral bleaching depressed coral diversity at Rose, and bleaching and tropical cyclones depressed diversity at Swains. Baker and Howland are located closer to the more bio-diverse western Pacific, perhaps enhancing their coral diversity, but Johnston's geographic isolation limits its diversity. The ECC likely provides larvae of more coral species to Palmyra and Kingman from the western Pacific, enhancing their coral diversity.

Rhodolith-forming Coralline Algal Assemblage on the Deep Fore-reef to Insular Shelf Areas off Okinawa-jima and Kikai-jima, Ryukyu Islands, Japan

*Shinya MATSUDA**

Nishihara, Okinawa, 903-0213 Japan
smatsuda@edu.u-ryukyu.ac.jp

Pebble- to cobble-sized rhodoliths, composed mainly of multiple individuals/species of nongeniculate coralline algae and multiple individuals of the encrusting foraminifera *Acervulina inhaerens*, are common constituents of the sediments on the deep fore-reef to insular shelf areas of the Ryukyu Islands. I examined frequencies of 11 major species by observing a total of 1,048 thin sections. The species can be assigned to the genera *Sporolithon*, *Lithothamnion*, *Lithophyllum*, *Lithoporella*, *Hydrolithon*, and *Pseudolithophyllum* according to the traditional paleontological classification. The rhodoliths were collected at 8 sites off Okinawa-jima and 2 off Kikai-jima, ranging in depth from 40 to 102 m. Two species show characteristic depth distribution in contrast to that the others are found growing in the whole depth range investigated. One *Sporolithon* species (*Sporolithon* sp. A) occurs at depths deeper than 79 m and is dominant ranging in depth from 96 to 102 m. The frequency of warty form of *Lithophyllum* sp. A exceeds ~15% at depths of <50 m, but it decreases with increasing depth and is <5% at depths of >50 m. Three rhodolith-forming coralline algal assemblages can be discriminated. Assemblage A is delineated by abundance of warty form of *Lithophyllum* sp. A. This assemblage is found at the depths of <50m. Assemblage B, with a depth range from 50 to 79 m, is characterized by low frequency (<5%) of warty form of *Lithophyllum* sp. A and absence of *Sporolithon* sp. A. Assemblage C is distinguished by presence of *Sporolithon* sp. A and found at depths of >79 m.

Phylogeny of Commensal Shrimps of the Subfamily Pontoniinae (Crustacea: Decapoda: Palaemonidae)

*Masako MITSUHASHI**, Masatsune TAKEDA

3-23-1, Hyakunincho, Shinjuku-ku, Tokyo, 169-0073 Japan

masako@kahaku.go.jp

The subfamily Pontoniinae is a large group of shrimps with 86 genera and over 450 species, being mainly distributed in tropical and subtropical shallow waters of the Indo-West Pacific. Many species of them are associated with various invertebrate animals such as sponges, sea anemones, corals, bivalves, feather stars, sea stars, sea urchins, sea cucumbers, and sea squirts. In spite of the interest in the evolution of commensal life of these shrimp, the phylogenetic relationships among species are not clear. One of the reason is that the deep gaps of morphology that adapt to host animals association in obligate commensal species. To know the phylogenetic relationships and estimate the evolution of commensal in these shrimps, we made molecular analyses of about 40 species based on partial sequences of mt DNA. It is noted at present that *Ischnopontonia lophos* and *Platycaris latirostris* which are considered to be phylogenetically close to each other probably due to similar symbiotic life with oculinid coral, *Galaxea*, are referred to different clades. Some other genera represented by shrimps associated mainly with branching corals, *Acropora* or *Pocillopora*, are analyzed to be polyphyly. The present preliminary study shows that the shrimps associated with the same host animal were derived not always from the same ancestor.

The Fish Fauna in Chuuk, Micronesia

*Jung G.MYOUNG**, Soon K YI, Rae S KANG, Heung S PARK

Ansan P. O. Box 29, Seoul 425-600, KOREA

jgmyoung@kordi.re.kr

The study were planned to understand of the fish fauna in Chuukish waters, Federated States and Micronesia. As the result of the study from Feb. 11 to 18, 2003, more than 264 species were observed in 12 research sites of Chuuk atoll and Quop atoll which was located 6 km south from southern margin of Chuuk atoll. The study areas can be divided into three types such as drop off habitat of outside atoll, channel habitat and shallow habitat of inside atoll. In the first (drop off type), we observed many Serranidae spp., Lethrinidae spp., Lutjanidae spp., *Cheilinus undulatus*, *Naso* spp., and *Pseudanthias* spp. In the second (near channel type) having fast current, the stations showed the high diversity with *Caranx* spp., and small reef fishes such as *Scarus* spp., *Naso* spp., *Ctenochaetus* spp., and *Epinepelus* spp.. In the third (shallow and sandy bottom type in the atoll), many small and young fishes such as wrasse, *Naso* spp., Pomacentridae spp., were observed. The third seemed to be used for spawning and nursing grounds by many reef fish. Among groupers (Serranidae), abundant species in Chuuk atoll were *Epinepelus polyphekadion*, *Cephalopholis miniata* and *C. argurus*.

Coral Fauna and Other Cnidaria from Coastal Reefs of Gravata and Coroa Grande, (Pernambuco, Brazil): Diversity on Evidence

*Elizabeth G NEVES**, Fabio Lang DA SILVEIRA, Rodrigo JOHNSSON, Leila L LONGO

Rua do Matao, trav. 14, no. 321, Cidade Universitaria, CEP:05508-900, Sao Paulo - SP Federative Republic of Brazil

egneves@ib.usp.br

The "Northeastern Coastal Region" is characterized by the occurrence of reefs and estuaries associated to mangrove vegetation, and the warm Brazil Current provides an optimal temperature for coral thrivingness. An inventory shows evidence of considerable coral diversity in the reef complex Gravata-Coroa Grande at southern Pernambuco State. The shoreline extends for about 5 km being limited on the left and on the right by Una and the Perssinunga rivers, respectively. During the low tide, the reef surface is exposed, and it is possible to observe a reefal arc surrounding a large sandstone bank. Between Recife (Pernambuco State, 8°47S, 35°06W) and Maceio (Alagoas State, 9°66S, 35°71W), the adjacent development of sandstone banks and coral reefs forms na extensive and extraordinary linear coastal structure. However, information on faunistic assemblages of reef communities located in this area is scarce. Nevertheless, the scleractinian corals recorded in the shallow water system of Gravata-Coroa Grande represent 50% of the total of the species found along the Brazilian littoral. Zoanthids, corallimorpharians, octocorals, and hydrocorals have been also identified.

Sessile *Fungia*: Morphology, Ecological Distribution and Population Structure on Okinawan Coral Reefs

*Moritaka NISHIHIRA**

1-117-9, Shuri-Ishimine cho, Naha, Okinawa, 903-0804, Japan

moritaka@mail.meio-u.ac.jp

In the genus *Fungia*, adult corals are free living. However, in the moat of Okinawan coral reefs, there is a unique solitary *Fungia* coral that permanently attaches to hard substrates. Field studies conducted in a moat at Horikawa in Okinawa Island showed that: 1) The sessile *Fungia* corals occur from 0 to 1 m depth at low tide. 2) All of observed corals (more than 350 individuals) were monostomodaal, and the longer disc diameter ranged from 5 mm to 114 mm. Even the largest coral was found attaching to the substrate and free corals found on the bottom had a stalk and lacked a detachment scar, suggesting that such free corals had been detached from the substrate accidentally. 3) Shape of the umbrella was almost elliptic, circumference irregular, and margin undulating. The irregular shape of the umbrella seems to have been caused by the limitation in space for growth at attachment sites. 4) Attachment sites or settlement sites of larvae covered various conditions from well-lit site to hidden places such as under an overhang and interstitial space among dead coral branches. Many large corals were found on vertical or oblique surfaces. Small corals were found abundantly in the interstitial space of the dead branches of a coral such as *Pavona*. Observations of many dead specimens of small individuals in such space suggest that only corals attaching to the substrate with sufficient space for growth seem to survive to matured adult size. 5) Permanent attachment suggests that during its entire lifetime this coral does not perform asexual reproduction that is basic trait of congeners. Furthermore, permanent attachment might have allowed the coral to explore the new habitat such as vertical surface, which cannot be used by adult corals of free living forms.

The Genus *Paralcyonium* (Octocorallia: Paralcyoniidae) in the Indo-West Pacific

*Leen Van OFWEGEN**, John STARMER, Yehuda BENAYAHU

PO Box 9517, 2300 RA Leiden Kingdom of the Netherlands

ofwegen@naturalis.nmm.nl

The Indo-West Pacific is home to the world's richest, most diverse octocoral fauna. Around 90 genera have been described from the tropical Indo-West Pacific at diving depths. Undoubtedly, many more await description. However, due to a lack of taxonomic study, the diversity patterns for soft corals and sea fans in this region are still poorly known. Here we present four new species of the genus *Paralcyonium*, a genus up till now only known to occur in the Mediterranean and E Atlantic, with only one representative, *P. spinulosum*. New species in this genus were found in Thailand, Japan, Papua New Guinea, and Tonga. Species of the genus *Paralcyonium* have a remarkable growth form among octocorals, with a distinctive capsule-like base into which the lobes and branches can be withdrawn. The genus is compared with the related genus *Studerioties*, the only other octocoral genus with similar growth form, and known to occur in the Indo-West Pacific. The apparently disjunct distribution pattern of the species of *Paralcyonium* is discussed.

The Organic Matrix in the Skeletal Spicules of Two Alcyonarian Corals, *Lobophytum crassum* and *Synularia polydactyla*

*Azizur M RAHMAN**, Yeishin ISA

903-0213 Okinawa, 1 Senbaru, Nishihara-cho, Dept. of Biology, University of the Ryukyus, Japan

k018346@eve.u-ryukyu.ac.jp

The organic matrix of spicules from two alcyonarian corals, *Lobophytum crassum* and *Synularia polydactyla* were studied to investigate the functional properties and molecular characteristics. The shape of the spicule in both cases was identified by SEM. The collected spicules were decalcified in 0.5M EDTA and then centrifuged to remove the insoluble residue. Subsequently, the decalcifying solution was passed through SEP-PAK C₁₈ cartridges and the absorbed macromolecules were eluted in 50% acetonitrile. The eluant was freeze-dried and used for the preparations of the organic substance in spicule. By recording the decline of pH in the experimental design, the inhibitory effect of the matrix on CaCO₃ precipitate was revealed. In the SDS-PAGE analysis of the preparations showed four bands of proteins with the apparent molecular weight of 102, 67, 48 and 37 kDa for *L. crassum* and seven bands with 109, 83, 70, 63, 41, 30, and 22 kDa for *S. polydactyla*. These results reveal the proteinaceous organic matrices of spicules in *S. polydactyla* are much various in composition than that of *L. crassum*. A major band of about 67 kDa protein in *L. crassum* was determined the N-terminal amino acid sequence. On the other hand, the 70 and 63 kDa proteins in *S. polydactyla* were detected for the determination of amino acid sequences. Periodic acid schiff staining indicated the 67-kDa protein in *L. crassum*, 83 and 63-kDa proteins in *S. polydactyla* were glycosylated. Assay of carbonic anhydrase that catalyzes the HCO₃⁻ formation revealed the specific activity. The interpretation of these results indicates that the spicule of alcyonarian corals have proteinaceous organic matrix to be related to the calcification process.

The Role of Tetrodotoxin for Prey Capture in a Polyclad Flatworm

*Raphael D RITSON-WILLIAMS**, Mari YOTSU-YAMASHITA, Valerie J PAUL

701 Seaway Dr. Fort Pierce, Florida, 34949 United States of America

williams@sms.si.edu

Free living polyclad flatworms are diverse, and their ecological role in coral reef ecosystems is often overlooked. The flatworm, Planocericid sp. 1 (Turbellaria: Planocericidae) preys upon gastropods. Planocericid sp. 1 envelops an animal, inverts its pharynx, and uses its pharynx to remove the gastropod body from its shell. In the laboratory this flatworm consumed gastropods from 11 families. Planocericid sp. 1 killed and removed the body of *Cypraea moneta* in 12 to 45 minutes, which was significantly ($p=0.037$) related to the size of the cowry. In chemical analysis we found Planocericid sp. 1 contained tetrodotoxin (TTX) and the analog 11-nortetrodotoxin-6(S)-ol as the major toxins. We dissected 7 flatworms and found high concentrations of TTX and 11-norTTX-6(S)-ol in the pharynx. There were also high levels of TTX in the flatworm's egg masses. We measured toxin concentrations in whole flatworms before feeding, one day, 4 days, and 8 days after feeding. There was no significant difference in the concentration of TTX over time, however the concentration of 11-norTTX-6(S)-ol did change after feeding. The lowest concentration of 11-norTTX-6(S)-ol was immediately after feeding, and the highest concentrations were before and 8 days after feeding. Our data suggest that 11-norTTX-6(S)-ol is the active toxin in prey capture for these flatworms. A similar ecological role for TTX is also found in the blue-ringed octopus (*Hapalochlaena maculosa*) which is known to use TTX in prey capture. Many studies assume that tetrodotoxin and its analogs are defensive compounds in marine and terrestrial animals. When tested in field feeding experiments at two locations 3 of 5, and 8 of 9 flatworms were eaten by natural assemblages of reef fish. Tetrodotoxin and its analogs have multiple ecological functions, perhaps leading to the prevalence of these compounds in a variety of organisms.

Antimicrobial Resistance in the Hybrid Soft Coral *Sinularia maxima* X *S. polydactyla*

*Marc SLATTERY**, Haidy N KAMEL, Deborah J GOCHFELD,

Robert W THACKER

411 Faser Hall, University, Mississippi 38677 United States of America

slattery@olemiss.edu

The evolutionary importance of hybridization cannot be ignored; this process leads to genetic diversity potentially resulting in phenotypic variability and novelty. Resistance mechanisms of hybrids can be more, less, or equal to those of the parent species. The tropical Pacific soft corals *Sinularia maxima* and *S. polydactyla* have formed a hybrid zone on the reefs of Guam, USA. These broadcast spawning species have some degree of overlap in their reproductive periodicity, and this has apparently resulted in the development of these hybrid zones. Antimicrobial assays, using ecologically-relevant marine microbes, have shown that the hybrids produce defensive extracts that are more resistant to microbes than those of either parent species. Assays were conducted at natural concentrations, as well as standardized concentrations to assess the impacts of different constituent compounds and novel bioactive metabolites have been isolated from these hybrids. The hybrid zone expanded by 27% over a period of 4 yrs; this increase occurred during a time when both parent species populations were contracting possibly due to anthropogenic stresses. Our results to date indicate that under the present conditions this hybrid may be more fit than either parent species.

Alga-Herbivore Interactions in Tung Ping Chau Marine Park, Hong Kong, China

*Erica KY SO**, *Put O ANG*

Marine Science Laboratory, The Chinese University of Hong Kong, Shatin, Hong Kong
s020482@mailserv.cuhk.edu.hk

Alga-herbivore interactions in coral communities have never been studied in Hong Kong. Monthly general surveys on the species diversity, species richness and abundance of algae and herbivores were conducted in three sites in Tung Ping Chau Marine Park from November 2002 to December 2003. The species compositions in these three sites are different. At least 24 species of algae were recorded in the monthly general survey, *Sargassum* spp. were most dominant in the relatively exposed site and *Lobophora variegata* was dominant in the more sheltered sites. Among the herbivores, the gastropod *Pyrene* spp. were abundant in the sheltered sites, and the sea urchin *Anthocidaris crassispina* and gastropod *Chlorostoma rustica* dominated in more exposed site. Algae were most abundant during winter. Their number started to increase in January 2003 and peaked in March 2003. They became sparse in summer when low tides occurred at daytime. The relationships of the most dominant algae and herbivores were evaluated by canonical correlations. Based on the canonical loadings, *Pyrene* spp. correlated negatively with turf algae and *Hypnea charoides*, but positively with *L. variegata* in the sheltered sites. This suggested that *Pyrene* spp. probably fed on turf algae and *H. charoides*, thus freed up the space for *L. variegata*. The relationship was different in the exposed site. *A. crassispina* correlated negatively with *Sargassum* spp, but positively with *L. variegata*, suggesting that *A. crassispina*, being a relatively large herbivore, may be able to feed on chemically defended *Sargassum*. Highly mobile herbivore, e.g. hermit crabs, had negative relationship with turf algae and positive relationship with *Sargassum* spp, suggesting that hermit crabs regarded turf algae as a food source and *Sargassum* spp as a shelter to hide against wave action.

Coral Community on Artificial Structures in Nahari, Kochi Prefecture

*Takuma MEZAKI**

102 2-2-7 Ygiyamahoncyo Taihakuku Sendai city Miyagi Japan
cdh04700@par.odn.ne.jp

To prevent the disaster and beach erosion, a lot of wave-dissipating breakwaters are constructed along the shore of Japan. It is not a little to form a coral community on the structure in the reefal and non-reefal region either. The construction of the breakwaters started from 1975 in this study area and now there are fifteen breakwaters in total that were constructed at one year to four-year intervals. A coral community corresponding to each elapsed years can be observed excluding the breakwaters near the river. To examine the coral community change according to elapsed years on the breakwaters, a coral species on each breakwater is listed between January and March, 2003 and a coral population, the coverage, and the size on the block that had been arbitrarily chosen from an outside and inside the breakwaters were recorded in detail from July to October, 2003. As a result, twenty-five genera and 58 species were recorded, the number of coral species reached in the maximum for 18 years on the outside block, for 16 years on the inside block after constructed. In the case of coral coverage reached in the maximum for 18 years on the inside, for 16 years on the outside.

Chemical Diversity of Secondary Metabolites in Sponges and Soft Corals

*Junichi TANAKA**

Senbaru 1, Nishihara, Okinawa 903-0213 Japan
jtanaka@sci.u-ryukyu.ac.jp

Sponges and soft corals are prolific sources of novel bioactive molecules and have been the targets for new drug leads and reagents. On our project for searching new bioactive compounds from coral reef organisms in Okinawa and Indonesia, we encountered a number of secondary metabolites. There are widespread species having the same bioactive molecule such as the sponge *Theonella swinhoei* containing swinholide A, while there are species with high chemical diversity. The sponge *Fasciospongia rimosa* was found to contain cytotoxic metabolites: latrunculin A (actin-targeting), laulimalides (microtubule-targeting), zampanolide, and mycothiazole. Latrunculin A was found in all the specimens of this sponge, while other compounds are depending on the collection sites. Soft corals of the genus *Sarcophyton* contain cembrane class diterpenes (e.g. sarcophytoxide). *S. glaucum* is the most common species along Ryukyu islands and was found to be diverse on these metabolites. Other species, e.g. *S. trocheliophorum* and *S. crassocaulis*, have less diversity. We will report chemical diversity of these organisms.

Cnidarians and Other Benthic Organisms from the Beach Rocks of the Enseada Dos Corais Beach (Pernambuco, Brazil)

Selma VASCONCELOS, *Fernanda AMARAL**, *Marcelo RAMOS*, *Camila VILELA*, *Juliana IMENIS*, *Flavia LEAL*, *Luciana MARQUES*, *Joao AMARAL*, *Susan SILVEIRA*, *Cristiane COSTA*, *Michelle SANTOS*
 Av. Dom Manoel de Medeiros, s/n. Dois Irmaos Federative Republic of Brazil
fdamaral@novaera.com.br

The aim of this study was to appraise the composition and the spatial distribution of the benthic fauna from the beach rocks of the Enseada dos Corais beach, located between 08° 20' S and 34° 56' W, 46 Km from the south of Recife city (Brazil). From July to September 2003, 10 transects, each 10 m in length, were made, 5 at the reef flat and 5 at the fore reef, resulting in a total of 2010 points observed in all transects. At the reef flat, the group with the greatest percent cover was the Echinodermata, with 49.31%, represented by the species *Echinometra lucunter* (Linnaeus 1758). Filamentous and calcareous algae showed very close covering percentage around 11.77% and 11.17%, respectively. The stony corals covered 7.79%, and they were represented by the species *Siderastrea stellata* Verrill 1868 and *Favia gravida* Verrill 1868. In relation to the Zoanthids found at this flat area, the species observed were *Palythoa caribaeorum* (Duchassaing & Michelotti 1860) and *Zoanthus sociatus* (Ellis 1767) with 12.97% of covering. At the fore reef, the Echinodermata group represented a lower covering percentage (6.06%), and there was also a reduction of the percentage of corals (3.22%). The more expressive group in this area was the fronded algae (63.03%). There was some increase at the Zoanthidea group (17.6%). The corals represented the largest covering at the reef flat and the Zoanthids were more common at the fore reef, where there was also a greater amount of algae. There is a perceptible difference in spatial distribution of different taxa found at the study area, however, this study needs to be continued to a better clarify the ecological relationships of the functional groups analyzed.

Distribution of the Benthic Covering of Saint Peter and Saint Paul Archipelago (Brazil), with Special Attention to the Cnidarians

Selma VASCONCELOS, *Fernanda AMARAL**, Susan SILVEIRA, Gloria ABAGE, Andrea STEINER, Marco HUDSON, Eduardo ESTEVES, Marcelo RAMOS, Bertran FEITOZA

Av. Dom Manoel de Medeiros, s/n. Dois Irmaos Federative Republic of Brazil
fmdamaral@novaera.com.br

The objective of the present study was to describe the benthic communities distribution on a bay located at the Saint Peter and Saint Paul Archipelago (ASPSP), which is a group of 15 islets located in the Atlantic Ocean at approximately 1010 Km from Natal city (Rio Grande do Norte State), and 330 miles from Fernando de Noronha Archipelago (Pernambuco State), Brazil. In May 2003, 8 transects were made, each one had 10 m in length, which resulted in 1608 observed points in all transects. The data were collected through visual observation during SCUBA diving and notes were taken using PVC plates and pencil. The most frequented groups were the filamentous and calcareous algae, presenting 100% of occurrence in all transects. The analyses of the dominant group and the importance indices of the organisms demonstrated that the filamentous algae were the more expressive group in the studied area. The Zoanthids *Palythoa caribaeorum* (Duchassaing & Michelotti 1860) and *Zoanthus nymphaeus* (Lesueur 1847) were common in depth from 5 to 10 m (8% of the covering), having a value of 7% between 10 to 15 m and 15 to 20 m. They were not found in transects located at 20 to 25 m. Other research done with these animals showed that Zoanthids were more common above a depth of 9 m, as happened on this study. The Zoanthidea species *Zoanthus sociatus* (Ellis 1767) and *Parazoanthus* sp. were not found on the transects, even though they were referred to before in other studies done at Saint Peter and Saint Paul Archipelago. This indicates that the occurrence of these species at the Archipelago bay is low. Further studies about this ecological relationship between the benthic fauna and flora are necessary, in areas where the covering indices are higher in the filamentous algae.

Scleractinian Corals of India

*Krishnamoorthy VENKATARAMAN**

130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
duhong@md2.vsnl.net.in

In India, all the three major reef types (atoll, fringing and barrier) occur, and the region includes some of the most diverse, extensive and least disturbed reef areas of the Indian Ocean, many of which are among the least scientifically known. Pillai recorded a total of 199 species divided among 37 genera, from India, which includes both hermatypic and ahermatypic corals recorded by him from the four major coral reefs of India. The present study includes 15 families, 60 genera and 208 species of Scleractinia from the four major reefs of India such as Gulf of Kachchh (36 species, 20 genera) Lakshadweep (91 species, 34 genera), Gulf of Mannar and Palk Bay (82 species 27 genera) Andaman and Nicobar Islands (177 species, 57 genera). The scleractinia corals of India have rich diversity as compared to the other reefs of the tropical world. Among the four major reef areas of India, Andaman and Nicobar Islands are found to be very rich and Gulf of Kachchh is poor in species diversity. Lakshadweep Islands have more number of species than the Gulf of Mannar. There are 18 families have been reported from the world of which 15 are represented in India. This diversity is almost same when compared biogeographically to all reefs in the world. However, of the 111 genera reported from the world, India has only 61, which is slightly less when compared to Indo-Pacific centre of diversity (82 genera). Of the 793 species reported from the world, India has 208+ species (it is expected to increase up to 400 when intensive studies are carried out), which is far less when compared to 581 species reported from the neighbouring Indo-Pacific centre of diversity. This emphasizes more intensive studies on the inventorization of scleractinian fauna of India.

Complete Nucleotide Sequence of the Mitochondrial Genome of the Crown-of-thorns Starfish, *Acanthaster planci* and *Acanthaster brevispinus*

*Nina YASUDA**, Masami HAMAGUCHI, Miho SASAKI, Masaki SABA, Kazuo NADAOKA, Saki HARI

Kitazawa 1-35-6 206, Setagaya-ku Tokyo Japan
yasuda@wv.mei.titech.ac.jp

The coral predator *Acanthaster planci* has high fecundity and long larval phase that sometimes lead to large population explosion throughout the tropic Pacific and Indian Ocean and caused mass coral mortality. To assess the genetic connectivity among populations over large distances of the crown-of-thorns starfish, *A. planci* is important for the effective management of coral reefs. On the other hand, distinguishing *A. planci* larvae from other coral reef asteroids based on reliable DNA marker is also essential for developing field plankton sampling. Complete nucleotide sequence of the mitochondrial genome of *A. planci* and *Acanthaster brevispinus* that belonging to the same genus can offer powerful opportunities to meet both demands. For example, the non-coding regions of mitochondrial DNA, which gives high mutation rate, tend to be useful in population genetic studies and species identification for other animals. In this study, we sequenced mitochondrial genome of *A. planci* and *A. brevispinus* based on the information on mitochondrial nucleotide sequences of *Asterina pectinifera* and other animals. Although their morphological features are different from each other, this result suggested that both species are genetically closely related species.

High Diversity at Small Spatial Scale - An Example from Bivalves in a Single Shallow-water Bay in the Northern Red Sea

Martin ZUSCHIN, Peter G OLIVER, *Johann HOHENEGGER**

Althanstrasse 14, A-1090 Vienna Republic of Austria
martin.zuschin@univie.ac.at

An intense survey was conducted on benthic molluscs > 1mm in the Northern Bay of Safaga, Egypt. One hundred quantitative and 106 qualitative samples were taken from different soft bottom types (coral-, seagrass- and mangrove associated sands, muddy sands and muds) and reef associated hard substrata (e.g., reef flats, reef slopes, coral patches, coral carpets) in water depth ranging from intertidal to >50m. A total of 243 species of bivalves, which represent 55% of the total number of species known from the Red Sea, were identified from more than 16000 individuals. Forty-one species are new to science or new records for the Red Sea. Seven families are represented by more than 10 species each. Most species are rare. 69 species (28.4%) are singletons (represented by single specimens), 19 species (7.8%) are represented by only 2 specimens, 85 species (35%) are unique to a single station and 45 species (18.5%) are represented at only 2 stations. The maximum size of 220 species (boring species excluded) collected in Safaga ranges from 2-300mm, but most species are rather small. The corresponding mean value is 36mm, the median 25mm, and the mode only 17mm. The high diversity of bivalves reported in this study can be related to several factors: We included small shells (down to 1mm sieve size), the habitat diversity in the bay is large, and the sampling intensity was great. Despite the great sampling intensity, the full range of bivalve species in the bay was not covered. Species richness estimates for the bay range between 281 (Bootstrap) and 367 (Jack 2). From our experience any species additional to our list will either be rare, endolithic, small or from a sampling station deeper than 10-20m.

Coral Recovery after Bleaching on 1998 at West Sumatera Waters Indonesia

Muhammad ABRAR*, Yempita EFENDI

01 Pasir Putih St, Ancol, Jakarta Indonesia

gorgorian_id@yahoo.com

Coral bleaching event was happened at all over Indonesian waters on first 1998. More of all the coral bleaching become coral mortality particularly at Hindia and Indonesia Coral Reef. The research about coral recovery after bleaching very important with the research to coral juvenil founded. Research of coral juvenil dinamica (structure, composition and distributian) was carried out at Mentawai Island Waters and Western of Sumatera Coastal Waters in 2001, three years later after bleaching. The result of research showed that coral recovery with coral colonies founded in small size (< 10 cm). From 8 site of research to each location founded 25 genera from 12 family with the number of total was 770 colonies on Mentawai Island Waters, while 30 genera from 12 family with the number of total was 313 colonies. The range of coral cover variation was 7.85 % to 22.89 % with the range of diversity indeks was 0.25 to 0.26. The average of growth rate variation were 8 to 44.3 colony/year/m² on Mentawai Island Waters, but 1.6 to 4.43 colony/year/m² on Western Sumatera Coastal Waters. The data of this result very important for Coastal Resources Management, almost marine nature reserve.

Continental and Oceanic Coral Reefs in Colombian Caribbean after a Decade of Degradation

Alberto ACOSTA*, Silvia MARTINEZ, German ARANGO

Cra. 7 No. 43 - 82 Ed. 53 Of. 106B, Bogota, Colombia

laacosta@javeriana.edu.co

Several predictions have been made about temporal changes in coral community structure after perturbations; few studies, however, have demonstrated it quantitatively. Such changes were evaluated over more than 10 years on five reefs; four continental (CR) and one insular oceanic (OR) in the Colombian Caribbean. The hermatypic coral composition and cover were estimated by 20m linear transects. In 2002, 59 transects were quantified in baseline studies, at 1.5 - 43m. A total of 42 coral species were found on the five reefs. The principal temporal changes in coral community structure were related to composition and cover. Composition changed at the generic and species levels for all reefs, due to the loss and substitution of species. This change was greater in CR (17 to 22 % at the generic level and 31 to 46 % at the species level) than in OR (5 % and 13.8 %, respectively). Four of the five reefs showed a significant decrease in coral cover over time ($P < 0.05$, t student), where coral skeletons were colonized by sponges (CR) and macroalgae (OR). Absolute and relative cover decreased drastically in CR (6.0 to 22.0 %; 29.7 to 44.9 %, respectively) and OR (11.4 and 42.7 %, respectively). A greater loss in coral cover occurred in shallow water for OR (i.e. *Acropora*), than in middle and deeper water for CR (i.e. *Montastrea*; $p < 0.05$; Mann Whitney). Each reef showed temporal differences in coral community structure up to 38 % (20 % min; Bray Curtis index), also suggesting changes in coral reef function. Deterioration in the coral community quantified here is within the range estimated for the Caribbean; the loss rates, however are unsustainable. Urgent management measures are needed to avoid future local extinction of continental and oceanic corals.

Comparison of Community Structure and Functional Diversity of Fishes at Cabo Pulmo Coral Reef, B.C.S. Mexico between 1987 and 2003

Lorenzo ALVAREZ-FILIP*, Hector REYES-BONILLA

CICESE, Ecologia. Km. 107 Carr. Tijuana-Ensenada, Ensenada, Baja California. 22860 Mexico

alvarezf@cicese.mx

Cabo Pulmo reef is known as one of the richest areas in the Gulf of California. In recent years the reef has suffered diverse environmental perturbations such as hurricanes and El Nino events. In addition, the area was declared a Marine Protected Area until 1995. Considering that, the objective of this study was to conduct a long-term evaluation of community structure and functional diversity of the ichthyofauna. We compared data from May to August 1987, and May 2003. The composition was described with standard diversity indices (rarefaction curves, Shannon-Wiener diversity, Pielou evenness and Average Taxonomic Distinctness). The second task was to estimate functional diversity of the fish assemblage. We defined groups which members play similar ecological roles on the basis of multivariate analysis of ordination. Information about the following characteristics was obtained: trophic level, egg type, TL, relationship between length of the maxilla and head, shape of the caudal fin, relationship between SL and body height, residence, and position in water column. From these characters a dendrogram was plotted using the Bray-Curtis similarity index and the UPGMA algorithm, in which we identified 6 terminal branches that were considered as functional groups (FG); the groups were much influenced by total length and trophic position of the component species. To confirm if there were changes in community function we selected a set of species which best explain community structure by applying the BVSTEP algorithm, and compared relative richness of all FG with contingency tables. Our results suggest that although community structure has changed in time, functional and taxonomic diversity did not. This can be interpreted as evidence that there should be a relatively high degree of ecological redundancy in this community, and then it is possible that persistence and stability are maintained by compensation and shuffling of species of the same group.

Do Natural and Anthropogenic Impacts Help or Hinder Ecosystem Stability of Deep versus Shallow Fore Reef Corals at Discovery Bay Jamaica?

Peter GAYLE*

P.O. Box 35 Discovery Bay, St. Ann, JAMAICA

peter.gayle@uwimona.edu.jm

Hughes (1994) claims that coral cover has declined from more than 50% to less than 5% between 1970 and the present time at Discovery Bay, Jamaica. CARICOMP data indicates that an increase from 9% to 12% since 1994. The shallow Discovery Bay forereef has been negatively impacted by the effects of two hurricanes, the mass mortality of the urchin *Diadema antillarum* and continues to experience impacts from overfishing. CARICOMP data records the invasion of the shallow fore reef by the urchin *Tripneustes* sp followed by *D. antillarum*. Algal biomass and diversity decline simultaneously with an increase in coral recruits. Urchin numbers have not been maintained and algal biomass is increasing in the immediate vicinity of the CARICOMP transects. Variability in the data from CARICOMP transects may be an artifact of the small size of the site or its location in a transition zone between shallow water where urchins are abundant; algae are limited and coral recruits do well and mid reef depths where urchins are absent; coral cover is depressed and algae are abundant. In deeper water the algae are sparse despite the absence of urchins. Video transects from the deep fore-reef indicate that coral cover between 35 & 40 metres has increased from those reported by Andres and Witman (1995) to exceed 35%. While fishing pressure and nutrient levels at both sites are comparable, the light levels, numbers of urchins as well as algal biomass vary significantly. This paper discusses the differences and similarities in substrate composition between the shallow and deep fore reef communities at Discovery Bay and the probable reasons for these findings. The possibility that the greater percentage coral cover by deep corals facilitates the production of coral larvae which may recruit in deep or shallow water is examined.

Fish Movement under Reduced Resources: Fundamental Ecology for Conservation

*Lisa IWAHARA**

369 Science and Research Bldg II, Houston, Texas 77204-5001 USA

liwahara@uh.edu

Movement is a large missing piece in the area of fish population dynamics, and this lack of knowledge is becoming difficult to ignore. As the complex interactions of processes that shape fish communities became apparent, a more comprehensive approach to understand these mechanisms replaced former single-factor debates. However, movement has been largely neglected in past discussions, and has fallen behind in terms of understanding. One way to bridge the knowledge gap is to start with an empirical approach using model organisms at a manageable scale. I plan a two-year study using artificial reefs to examine fish immigration to destination reefs after experimentally decreasing available shelter on the reef of origin. I hypothesize that coral dwelling fish will migrate to low-density destination reefs when fish to shelter ratios on the reef of origin are high. Additionally, the following variables are hypothesized to have an effect on this migration success: distance to destination reef, fish size, predator presence, and the movement capabilities of each species. In order to unequivocally show movement, common coral reef fish in the Caribbean that have settled on artificial origin reefs will be tagged. A second set of destination reefs will be deployed, the sheltering holes on the reef of origin will be plugged, and the movement of the tagged fish will be observed. Basic ecological understanding is the foundation for a large range of studies including the advancement of movement models, and substantiating the spillover of adult fishes from no-take areas to fishing grounds. Furthermore, the experimental design of reducing sheltering holes parallels natural and anthropogenic changes that are affecting the coral reef ecosystem, and can provide insight into the effects of habitat alteration on coral reef fishes.

Distributional Patterns and Community Structure of Coral Reef Fishes in a Fluvially Impacted Reef System, Rio Bueno, Jamaica

*Jennie MALLELA**, *Chris HARROD*, *Caroline A ROBERTS*

Room E402, Env and Geog, John Dalton Ex., Manchester Metropolitan University, Chester St., Manchester, M1 5GD, England United Kingdom of Great Britain and Northern Ireland

j.mallela@mmu.ac.uk

Decades of chronic overfishing on Jamaican coral reefs, combined with the recent widespread mortality of the keystone herbivore *Diadema antillarum*, has resulted in a reduction in grazing organisms and a well documented phase shift from coral to algal dominance. Overfishing on Jamaica's northern coast has resulted in a decrease in both fish biomass (> 80%) and fish size. Large bodied predatory fish have become extremely rare and catches are dominated by small herbivorous fish of low commercial value. This study focuses on Rio Bueno, a small river-impacted embayment on Jamaica's northern coast. Sites near to the river mouth were highly turbid (mean Secchi depth: 9.4 m) with high sedimentation rates (17.0 mg cm⁻² d⁻¹), whilst outer sites reflected a clearer water environment (mean Secchi depth: 52.8 m, sedimentation rate: 7.1 mg cm⁻² d⁻¹). As part of a wider study detailing the effects of river impacts on the reef ecosystem (e.g. sediment), we examined how these effects may have influenced the structure and distribution of fish communities, and the potential for turbid, river impacted areas to act as a refuge for i) exploited and, ii) bioeroding species. We examined benthic communities using a linear intercept method and fish communities by visual belt transects at turbid (n = 1) and non-turbid (n = 2) sites. Although median fish lengths were significantly larger at the turbid site, few fish were observed larger than 20 cm at any site, an observation consistent with the effects of over fishing. Marked differences were observed in community structure with disturbed sites being dominated by *Carangidae* and clear water sites dominated by *Labridae* and *Pomacentridae*. Fish species richness varied little between sites, however, fish abundance was found to be significantly lower at the impacted site.

Complex Systems and Multivariate Analysis of the Production of Fishes in Nearshore Habitats: Examining the Linkage of Coastal Environments and Land Use Change to Coral Reef Ecology

Vanessa L NERO, *Kathleen M SULLIVAN SEALEY**, *Kathleen L SEMON*

1301 Memorial Drive, Rm 25, Cox Science Centerm University of Miami, Coral Gables, Florida 33146 USA

ksealey@miami.edu

Coral reefs are recognized as complex systems that often defy simple descriptions in terms of scale and function. Reef fish assemblages represent one element of coral reef systems, and the study of fish assemblages with different trophic modes and life histories can help elucidate temporal and spatial scales of interactions with between onshore and offshore environments. A multi-year study to characterize the complex system of nearshore fish habitats as related to offshore reef fish assemblages for the Central Bahamas is presented. This study sought to define relationships between key ecological elements, interactions across land-sea interfaces and onshore-offshore gradients to understand variability in fish diversity, abundance and size-frequency distribution with changes in habitat structure and availability. We present some of the characteristics of complex island systems and assign each system characteristic some level of function and interaction in terms of observed fish assemblages. Multiple variables of the coastal substrate, wave energy, vegetation cover, degree of human land use change in the coastal zone, nearshore algae diversity, and nearshore algal structure are modeled against fish diversity, abundance and biomass. This multivariate analysis provides some insights as to when and what fish species are lost due to habitat change, and how fish production may be altered by habitat loss. Spatial datasets of nearshore habitat availability and quality are correlated to fish diversity and abundance on adjacent reef systems. The implications for assessment and monitoring of reef fish communities on a broad geographic scale and beyond the reef habitat itself are considered.

Susceptibility of Marine Macroalgae and Cyanobacteria to Herbivorous Fishes and the Sea Urchin *Diadema antillarum*

*Valerie J PAUL**, *Raphael RITSON-WILLIAMS*, *Amy Anne ERICKSON*

701 Seaway Drive, Fort Pierce, FL 34949 USA

paul@sms.si.edu

Marine algae and cyanobacteria are important competitors for space in tropical reef habitats. Of increasing concern on coral reefs worldwide is the overgrowth of corals by macroalgae and benthic cyanobacteria resulting in algae proliferating in formerly coral-dominated habitats. To determine the relative palatabilities of a variety of macroalgae and cyanobacteria we conducted multiple choice feeding assays with natural assemblages of reef fishes and the sea urchin *Diadema antillarum* and assessed the role of algal chemical defenses at Carrie Bow Field Station in Belize. Some macroalgae, such as *Halimeda tuna* and *Rhipocephalus phoenix*, were not eaten at all by fishes even when left in areas of high herbivory for 1-2 days. Cyanobacteria were not readily consumed by reef fishes, which is consistent with previous observations on Pacific reefs. There was considerable intrageneric variation in the susceptibility of different species of *Dictyota*, *Halimeda* and *Caulerpa* to herbivory. For example, *Halimeda incrassata*, collected in the seagrass beds, was readily eaten by fishes even though *Halimeda* spp. are generally considered to be grazer resistant because of chemical and structural defenses. *Dictyota pulchella*, collected from the reef slopes of South Reef, was also readily consumed by fishes. Intraspecific differences in susceptibility to herbivores were observed between shallow and deep water forms of *Styopodium zonale* and between ruffled and decumbent forms of *Lobophora variegata*. In general, *Diadema antillarum* individuals were less discriminating in their preferences than fishes and consumed some of almost all species offered to them. They readily consumed *Styopodium zonale* and *Lyngbya majuscula*, which fishes did not eat. Urchins did not distinguish between different forms of *Styopodium zonale* and *Lobophora variegata*. These observations support the hypothesis that herbivorous reef fishes and *D. antillarum* have different algal preferences, and therefore, they can have a differential effect on macroalgal composition on Caribbean coral reefs.

Coral-Algal Competition as Determined from Stable Carbon and Nitrogen Isotope Compositions in their Live Tissues

Eduard A TITLYANOV*, Serguei I KIYASHKO, Tamara V TITLYANOVA, Eitaro WADA

17 Palchevskogo St., Vladivostok 690041, Russian Federation
titlyanov@hotmail.com

Carbon and nitrogen stable isotope ratios (SIRs) were analyzed in live tissues of the massive coral *Porites lutea* and the branched coral *P. cylindrica*, and in algal communities, competing with these corals. Materials were collected from the fringing reef of Sesoko Island (Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, Japan) at sites with different light intensity (from 15-30% to 80% PAR₀). Carbon and nitrogen SIRs of coral tissues showed no significant intraspecific differences, but differed in accordance with light intensity: ¹³C values were -10.8 ± 0.3 and -14.4 ± 0.3 per mil, and ¹⁵N values were 6.0 ± 0.1 and 5.0 ± 0.1 per mil, under high and low light intensity, respectively. It was shown that the tissues of coral polyps, living in direct contact with algal community, did not differ from the other live tissues of the coral in their carbon and nitrogen SIRs, irrespectively of species composition of the algal community. Isotope composition of algae did not depend on the location (direct or indirect contact with the live coral tissue), but it depended on light intensity. Results of SIR analysis suggest that: (1) the coral polyps, situated along the border with competing algal communities, are in the same physiological conditions and have the same possibilities for growth and nutrition, as the polyps in other parts of the coral; (2) the light conditions have more influence on the physiological state of coral polyps, particularly on the predominance of heterotrophic or autotrophic nutrition of coral polyps, than competitors for substrate; (3) the formation of algal communities (their composition and growth) more depends on abiotic conditions (light, temperature) than on the competition with coral polyps.

Transition of *Acropora tumida* Communities and its Affecting Factors in Suruga Bay, Central Japan

Shinpei UENO*, Yoshitaka FUNAKOSHI

3-20-1 Shimizu-Orido, Shizuoka 424-8610, Japan
cowries@scc.u-tokai.ac.jp

The surface of Suruga Bay is under the influence of the warm Kuroshio Current, but because of the low water temperature in winter, both the species number and quantity of the hermatypic coral are few, and therefore coral reefs are not developed. Uchiura Bay in Suruga Bay is an inner bay topographically, but the water quality in more of oceanic because a branch of the Kuroshio Current flows in. The hermatypic coral community in Uchiura Bay extends to 5-10m in depth, areal distribution is about 5,000m², the largest scale in the north of Izu Peninsula. *Acropora tumida* is dominant in the community, and the areal coverage was extremely high with 80-100%, when community's periphery was not considered. The largest abiotic factor that affects on *A. tumida* community is water temperature especially low temperature in winter. The average water temperature at the depth of 5m in winter 1996 lowered to 12.6°. Consequently, a large quantity of *A. tumida* was bleached and died. It resulted in the coral coverage of the community decreasing from 85% before the bleaching occurred to the 40%. Also, the grazing by *Diadema setosum* affects on *A. tumida* community. The highest record of *D. setosum* individuals in a 5,000m² *A. tumida* community was 21,000 in April, 2000. And large seaweeds grow with the coral in the same place affect the community. *Colpomenia sinuosa* and *Undaria undarioides* of the brown alga grow thickly in *A. tumida* community in Uchiura Bay during December-June. *C. sinuosa* causes the shading rate of 90% or more on coral community for as many as five months, decreasing the zooxanthellae density of *A. tumida* to 40-50% of the normal state. Under such circumstances, *A. tumida* become bleached and die at times.

Patterns of Change in Reef Communities Revealed by the Monitoring Programme for the Semporna Island Reefs, Sabah, Malaysia

Elizabeth M WOOD*, Frances A DIPPER, Adrian A ANGKALI

Hollybush, Chequers Lane, Eversley, Hook, Hants RG27 0NY United Kingdom of Great Britain and Northern Ireland
ewood@globalnet.co.uk

Following detailed survey and assessment of the Semporna Island reefs, seven permanent monitoring sites were established. These sites include representative habitats from within the proposed protected area. The monitoring sites have been surveyed annually since 2000, and a number of conclusions can be drawn. The sites are very different from each other, but with the exception of one, there have been no significant variations over time in fish populations and percentage cover by living and non-living components. The site that has changed is one that was dominated by an aggressive sponge (*Chondrosia* sp) which coated rock and rubble surfaces and the base of live corals. In the year 2000, percentage cover by *Chondrosia* was 36.8%, live hard coral was 12.5% and rock was 10%. By 2003, cover by *Chondrosia* had declined to 6.8%, rock had increased to 28%, but live hard coral remained low at 10.6%. The reasons both for the initial infestation and the recovery are discussed. The monitoring programme also involves tracking individual hard corals, soft corals, sponges and other prominent organisms in order to get a better understanding of the dynamics of some of the main components of the reef communities. Results so far show that the fastest cycles of change are associated with *Acropora*, especially *Acropora* tables. Mortality rates are higher than in other genera, probably due to crown-of-thorns predation, but may be balanced by rapid recruitment and growth of new colonies. One reason for this is that the dead *Acropora* tables are relatively resistant to erosion and provide a stable, elevated surface for re-colonisation.

Fish and Epibenthic Community Structure in Eight Reefs with Contrasting Environmental Conditions

Anabella ZULUAGA-MONTERO*, Alberto SABAT

University of Puerto Rico, Department of Biology, Box 23360 Rio Piedras PR 00931-3360 Puerto Rico
abzuluaga@yahoo.com

The composition and abundance of macroalgae and fish communities and their interaction were measured in eight coral reefs with contrasting environmental conditions in the Caribbean island of Puerto Rico. Macroalgae preference of herbivorous fishes was measured with a selection assay using four macroalgae species based on their availability in the study reefs and according to a palatability gradient. Sites with high water transparency exhibited macroalgae cover of less than 45%, and *Dictyota* as the dominant macroalga. Reefs with low water transparency, showed macroalgae cover above 65%, dominated by *Halimeda* and turf red algae. The fish community showed high diversity but low abundance for reefs with high water transparency. The sites with low water transparency showed low diversity with high abundance of Acanthurids and damselfish of genus *Stegastes*. Our results suggest that water transparency, sedimentation rates and SPM have a stronger influence in producing phase-shifts toward macroalgae dominated reefs. Macroalgae preference experiment showed that *Padina* was the preferred alga while *Halimeda* was the least preferred. *Sparisoma aurofrenatum* was the most active grazer. Preference for macroalgae depends on its nutritional quality and its relative toxicity. We conclude that sites with high water transparency, low sedimentation and low SPM are dominated by corals. Sites with high water transparency, high sedimentation and high SPM are in the initial phase shift toward dominance of macroalgae. And sites with low transparency, high sedimentation and high SPM the shift to macroalgae dominance is evident. Herbivory could be affecting the composition of macroalgae in the study sites, but not its cover.

Environmental Reservoirs of Free-living Zooxanthellae

Megan M D BLACK*, F ROHWER, D KLINE, M BREIBART, R W LITAKER, M. PAPINA, M. TSUCHIYA
North Life Sciences, 5500 Campanile Drive, San Diego, CA 92182-4614 USA
MeganBlack@ecobottom.com

Free-living zooxanthellae (*Symbiodinium* spp.) dinoflagellates should be important components of the coral life cycle and reef microzooplankton dynamics. Using fluorescence *in situ* hybridization (FISH) and PCR we surveyed the water column, epilithic algal mat, and sandy areas of two reefs to find free-living zooxanthellae. *Symbiodinium* spp. were associated with the epilithic algal mat covering dead corals, and in the sand between corals in Okinawa, Japan, when analyzed with a novel LSU rRNA FISH probe. Very few *Symbiodinium* spp. were observed in the water column above the same reef. Using *Symbiodinium* spp.-specific PCR on samples from Puerto Rico, we were able to detect *Symbiodinium* spp. present in 100% of the water column samples and 3 of 15 sediment samples. These free-living zooxanthellae reservoirs are potentially important for adaptive bleaching and initial infection of planulae larvae.

Differential Sensitivity of Photosynthetic Electron Transport to Elevating Temperature among Cultured *Symbiodinium* Genotypes

Brigitte U BRUNS, Mark E WARNER, Daniel J THORNHILL, Jennifer MCCABE, William K FITT*, Gregory W SCHMIDT
Department of Plant Biology and Institute of Ecology, University of Georgia, Athens, Georgia 30602 USA
fitt@sparrow.ecology.uga.edu

We previously reported that damage to Photosystem II is a conspicuous site for the thermal impairment of the physiology and survival of symbiotic dinoflagellates of some, but not all, cnidarians in hospice and in culture (Warner et al. 1998). Toward a more complete understanding of the extent to which this phenomenon contributes to global coral bleaching, we have undertaken reconstruction experiments with cultures of *Symbiodinium* isolated from a broad range of cnidarian hosts and that entail representatives of A, B and C subclades. Cultures were subjected to graduated increases of temperature from 26 to 32°C over a period of 14 days in a 10/14 light/dark regime using moderate illumination. Monitoring of photosynthetic efficiency by pulse-amplitude modulated fluorometry was coupled with a refined polyacrylamide gel electrophoresis procedure and immunoblot assays for thylakoid membrane proteins. Surprisingly, marked differences within each clade were found for the temperature thresholds and kinetics of Photosystem II deterioration coupled with degradation of its D1 reaction center protein. It becomes apparent that past generalizations of the thermal resistance vs. sensitivity of photosynthetic electron transport on the basis of symbionts genotypic A, B or C classification are overly simplistic. Instead, differential *Symbiodinium* responses to elevated temperature stress probably reflects divergent evolution of mechanisms for photosynthetic repair and/or protection processes that are independent of nuclear ribosomal RNA gene divergence.

Seasonal Availability of Symbiotic Dinoflagellates (*Symbiodinium* sp.) in Reef Water: A Bioassay

Mike W DANIEL, Daniel J THORNHILL, Todd C LAJEUNESSE, Gregory W SCHMIDT, William K FITT*
Institute of Ecology and Department of Plant Biology, University of Georgia, Athens, Georgia 30602 USA
fitt@sparrow.ecology.uga.edu

Scyphistomae of the mangrove jellyfish *Cassiopea* are aposymbiotic upon larval settlement and metamorphosis, and therefore must acquire their symbiotic dinoflagellates (*Symbiodinium* sp.) from seawater. The longer scyphistomae were maintained in reefal environments, the greater percentage of animals were infected with symbiotic algae. Percent of animals maintained in seawater for 5 days and subsequently infected with symbiotic algae showed seasonal highs (100%) during the spring (May) and summer (August), and lower infectivity (less than 50%) during the fall (December) and winter (March), suggesting changes in either availability of symbiont types or quantities in seawater. All symbiotic scyphistomae eventually strobilated ephyra, an ontogenetic event requiring a symbiosis with *Symbiodinium* for many Rhizostome jellyfish. Several types of *Symbiodinium* that infect scyphistomae of *Cassiopea* have been identified.

Identification of a Fifth Common Type of Zooxanthella Associated with Caribbean Corals in the *Montastraea annularis* Species Complex

Melissa GARREN*, Nancy KNOWLTON
New Haven, CT USA
melissa.garren@yale.edu

Members of the *Montastraea annularis* species complex are renowned for the diversity of zooxanthellae that they host. In clear water in Panama, they typically host members of clade A or B in high light environments and clade C in low light environments, whereas in near-shore environments they also routinely host type D (previously referred to as E). When disturbed by experimental bleaching, they have also been observed to host a different type of C (earlier referred to as C2) that is associated with a number of other Caribbean corals. However, this zooxanthella type has not previously been observed with undisturbed *M. annularis*. Here we report that in the lagoonal environments of Bocas del Toro, Panama, C2 is a common associate of these corals. In RFLP analyses of ssRNA, it resembles type D when digested with Dpn II and typical *Montastraea* type C when digested with Taq I, as previously described for C2. Sequence analysis places it clearly within clade C, but not with the cluster of sequences of "typical" *Montastraea annularis* type C. In samples taken to date (at depths ranging from 2-10 m), it was the most common of all zooxanthella types (40%); type A was nearly as common (35%), whereas D, "typical" C and B were rarer (14%, 7% and 4% respectively). These results suggest that lagoonal environments may harbor unusual assemblages of zooxanthellae whose ecological roles in these marginal reef environments merit additional study.

Seasonal Patterns of Symbiotic Dinoflagellate Diversity, Density and Chlorophyll Content in the Octocoral *Briareum* sp.Andrew R HANNES, *Mary-Alice COFFROTH**Department of Biological Sciences Hochstetter 661 University at Buffalo
United States of America
coffroth@buffalo.edu

To understand the phenomenon of coral bleaching it is imperative to understand the natural seasonal fluctuations in symbiotic dinoflagellate density, chlorophyll content and diversity experienced by cnidarian hosts. This information will provide a baseline from which comparisons can be drawn between natural seasonal fluctuations and suspected bleaching events. Two populations of the octocoral *Briareum* sp. were sampled throughout one year and cell densities, chlorophyll content and *Symbiodinium* type were determined. Cell density was significantly lower during summer months when sea surface temperatures are the greatest. Variation in cell density variation, but not chlorophyll *a* content, was similar to that previously reported for scleractinian corals. *Symbiodinium* genotype, based on length variation in domain V of the chloroplast large subunit ribosomal DNA (cp23S-rDNA), was invariant over the course of the study. This suggests stability in the symbiosis between this octocoral and its symbionts over seasonal environmental fluctuations.

Characterization of the Dark Reduction of Fv/Fm : Evidence of Chlororespiration in Coral Symbiotic Dinoflagellates*Xavier HERNANDEZ-PECH**, *Roberto IGLESIAS-PRIEYO*Av. Niños Heroes s/n Unidad Académica Puerto Morelos Quintana Roo,
Mexico
xpech@ifc.unam.mx

The quantum yield of charge separation at photosystem II (Fv/Fm) has been used extensively to evaluate the physiological status of symbiotic dinoflagellates. Fv/Fm shows a characteristic diurnal pattern; a reduction during the morning inversely proportional to increments in irradiance, after a minimum at noon, Fv/Fm raises to its original values in the afternoon. This pattern has been attributed to the induction of photoprotective mechanisms during exposures to super-saturating irradiances. Recently, a second oscillation in the Fv/Fm values has been reported to occur in corals during the night. This event has been described as a monotonous reduction in Fv/Fm at dark with a dramatic recovery during the early hours in the morning and has been tentatively attributed to the dark reduction of the plastoquinone pool by chlororespiration. Using biochemical and physiological methodologies, we characterize this phenomenon in intact corals and in cultured symbiotic dinoflagellates. The results indicate that in corals maintained in the dark during 8 hours, the rate of reduction of Fv/Fm was dependent on the frequency of the measuring saturating flashes. In contrast, control samples maintained in the dark for the same period of time, but assayed for photosystem II activity only at the beginning and at the end of the incubation period did not show significant reductions of Fv/Fm. Analyses of the rate of reoxidation of Q_A , indicate that control samples have smaller rates at the end of the dark period relative to the beginning. The results indicate that although the dark reduction of Fv/Fm values appear to be an artifact, chlororespiration in the under hypoxic conditions results in the reduction of the plastoquinone pool. Dark reductions of Fv/Fm can be generated in cultured dinoflagellates under hypoxic conditions with the addition of glycerol and ammonium. The potential use of this signal in stress studies would be discussed.

Phylogenetic Classification of *Symbiodinium* Dinoflagellates in Soritid Foraminiferans*Xavier POCHON**, *Jan PAWLOWSKI*, *Louissette ZANINETTI*30 Quai Ernest Ansermet, 1211 Geneva 4, Switzerland
xavier.pochon@zoo.unige.ch

Soritids, large calcareous foraminiferans abundant in coral reef ecosystems, depend on symbioses with *Symbiodinium* dinoflagellates for their growth and survival. Molecular phylogenies constructed with *Symbiodinium* ribosomal genes, collected from numerous cnidarian and several molluscan hosts reveal divergent lineages or clades, A, B, C, D, and E. Similar investigations show that *Symbiodinium* dinoflagellates inhabiting soritids evolved in several distinct lineages or clades designated C, F, and G. The latter lineages were further dissected into sub-clades or phylotypes Fr1-Fr6, which are now believed to be "foram-specific" *Symbiodinium* dinoflagellates. In contrast, *Symbiodinium* from clade C are common in soritid foraminiferans and other invertebrates from the Indo-Pacific. Phylogenetic analyses of the highly variable ITS 2 rDNA shows that clade C members inhabiting soritids belong to a distinctive sub-lineage of clade C specialists that associate primarily with Pacific corals in the genus *Porites*, which provides further evidence for specificity of foraminiferan symbionts. Here is presented a general phylogeny of the genus *Symbiodinium*. The significance of the different clades and phylotypes is discussed.

Genotoxicity Studies on Zooxanthellae in a Coral (*Galaxea* sp.) Collected from Polluted Environment, Gulf of Mannar, Southeast Coast of India*B Muthu RAMAN**, *J Jerald WILSON*RESEARCH FELLOW,3/1392,UNIVERSITY FIELD LAB,MIDDLE
STREET ,PUDHUMADAM-623524,TAMILNADU,INDIA
muthu_mku@yahoo.com

The present work is to estimate the genotoxic potential of polluted water upon symbiotic algal partner present in coral tissues (*Galaxea* sp.) Coral samples were collected from polluted area and also from a non-contaminated reference site. From the coral polyps, the symbiotic algal cells were aseptically removed. DNA damage as a measure of DNA integrity in the Algal cells was measured using the comet assay. The results were compared to assess the genotoxic potential of the polluted seawater. **Keywords:** *Comet assay, Genotoxicity, Zooxanthellae, DNA damage, Gulf of Mannar** **Author for correspondence. Email Id:** muthu_mku@yahoo.com

Light Acclimation of a Scleractinian Coral, *Porites* sp. and its Zooxanthellae

*Takanori SATOH**, *Eriko NORMAL*, *Akio MURAKAMI*, *Atsushi SUZUKI*,
Hodaka KAWAHATA, *Tamano OMATA*, *Tadashi MARUYAMA*
413-10 Tsui, Inami, Wakayama Japan
keec173@snet.ne.jp

In order to understand mechanism underlying acclimation of scleractinian corals to various light environments, we studied effect of light intensity on zooxanthellae density and chlorophyll content of a massive coral, *Porites* sp. reared under controlled light and temperature conditions. Stocked colonies of *Porites* sp. with approximately 5 cm in diameter were nursed over several months in an outdoor aquarium under natural light. Five colonies were transferred to each tank that was continuously supplied with filtrated and temperature-controlled natural seawater (25 °C). Light was provided with a metal halide lamp (150W) and its intensity was maintained at 100, 300, 500 or 700 $\mu\text{mol photon m}^{-2} \text{s}^{-1}$ with 12h light - 12 h dark cycle. Colonies were cultured for several months with continuous monitoring of seawater temperature, salinity and colony condition. Although coral bleaching occurred in some colonies at 700 $\mu\text{mol photon m}^{-2} \text{s}^{-1}$ in a few days, they recovered a few weeks after the transfer to 100 $\mu\text{mol photon m}^{-2} \text{s}^{-1}$. Zooxanthellae density, size and morphology, chlorophyll concentration, and photosynthetic activity of the colony were measured. Chlorophyll content was higher in a zooxanthella cell at lower light intensity. We will discuss about mechanisms underlying acclimatization of *Porites* sp. to light conditions on the basis of photosynthetic pigments and photosynthetic activity of zooxanthellae.

Mechanism of Zooxanthellae Expulsion by Corals: Exposure to High Temperature in Darkness Induces Expulsion of Zooxanthellae by Coral Hosts

*Ryota SUWA**, *Atsushi SUZUKI*, *Michio HIDAKA*
University of the Ryukyus, Nishihara, Okinawa 903-0213, Japan
k028315@eve.u-ryukyu.ac.jp

The mechanism of coral bleaching has been intensely studied for the last decade. However, the mechanism of zooxanthellae expulsion by stressed corals is not well understood. To find stress conditions that induce algal expulsion by corals, we put isolated polyps of *Galaxea fascicularis* in 50 ml plastic tubes filled with filtered seawater and treated them with various stress conditions. We found that pre-exposure of isolated polyps to high temperature in darkness for 3 h increased algal expulsion by the coral during the subsequent recovery period (9 h) under normal light (100 $\mu\text{mol m}^{-2} \text{s}^{-1}$). This is consistent with the idea that high temperature decreases the threshold for photoinhibition, probably through inhibitory action on Calvin cycle, and makes algal symbionts susceptible to photodamage even under normal light condition. But the effects of the high temperature and darkness pretreatment varied depending on the light condition before the pretreatment. If corals were exposed to high temperature (34 °C) and medium light (100 $\mu\text{mol m}^{-2} \text{s}^{-1}$) for 3 h and then to high temperature in darkness overnight, the polyps became bleached expelling numerous zooxanthellae. Without the prior exposure to medium light, corals did not suffer bleaching. It is likely that pre-exposure to medium light at high temperature stimulates respiration in darkness causing O₂ depletion or leads to accumulation of toxic substances, which cannot be detoxified in darkness or under O₂ limitation. When fragments of *Pavona divaricata* pre-exposed to high light were treated with high temperature in darkness, SOD activity increased. This indicates that oxygen stress increased during the dark incubation and supports the latter possibility. Under high light, excess electrons are removed by the Mehler-Ascorbate-Peroxidase (MAP) cycle and photorespiration, where oxygen is consumed. We are now trying to investigate whether dysfunction of O₂-requiring electron scavenging systems plays some role in the expulsion of zooxanthellae in darkness.

Changes in the Concentration of Mycosporine-Glycine in Two Scleractinians in Response to Thermal Stress: Antioxidant Functioning and Protection

Irina YAKOVLEVA, *Ranjeet BHAGOOLI**
Vladivostok, 690041, Russia
yakovleva72@mail.ru

In vitro studies have confirmed an antioxidant role for the mycosporine-glycine (Myc-Gly), an oxo-carbonyl mycosporine-like amino acid (MAA). This study examined the *in vivo* composition of MAAs, changes in their concentrations and activity of antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT) in the host tissue and zooxanthellae of two scleractinian corals, *Platygyra ryukyensis* and *Stylophora pistillata*, in response to high temperature (33.5°C) exposure over 12 h. In *P. ryukyensis*, Myc-Gly contributed about 30% of the total MAA pool, whereas the major components of MAAs in *S. pistillata* were presented by oxidatively robust imino-MAAs. After 6 and 12 h exposures at 33.5°C, *S. pistillata* showed a significantly more pronounced decline in the photosynthetic efficiency (F_v/F_m) compared to *P. ryukyensis*. Significant declines only in the concentration of Myc-Gly were apparent in the animal tissue and zooxanthellae after 6 h exposure in both *S. pistillata* and *P. ryukyensis*. After 6 h exposure at 33.5°C, *S. pistillata* showed a significant increase in the activities of SOD and CAT while *P. ryukyensis* did not show any significant changes in the activity of these enzymes even after 12 h of stress treatment. Thus, *P. ryukyensis* appears to be less sensitive to oxidative stress compared to *S. pistillata*. This differential susceptibility of corals is consistent with the twenty-fold higher concentration of Myc-Gly in *P. ryukyensis* compared to *S. pistillata*. The lack of Myc-Gly and the increase in the activities of the antioxidant enzymes in *S. pistillata* after 6 h stress treatment suggest the latter has a secondary role in antioxidative protection. These findings confirm that Myc-Gly is functioning as a biological antioxidant in the animal tissue and zooxanthellae of scleractinian corals and demonstrate its importance in the survival of reef-building corals under thermal stress.

Analysis of Actin cDNAs in a Zooxanthellate Scleractinian Coral and *Symbiodinium* spp.

*Minoru YORINOBU**, *Isao FUKUDA*, *Shuzo IMAGAWA*, *Kenji IWAO*,
Kiyotaka TAKISHITA, *Tadashi MARUYAMA*, *Toshiki WATANABE*
1-15-1 Minamidai, Nakano, Tokyo 165-8639 Japan
yorinobu@ori.u-tokyo.ac.jp

Actin is a component of the cytoskeleton in eukaryotes, and its expression is generally constitutive and ubiquitous. Thus, actin mRNAs are commonly used as 'standards' in gene expression studies. We identified actin sequences in a scleractinian coral and *Symbiodinium* spp. with the purpose of using them as expression standards. Complementary DNA sequences encoding actin were amplified using reverse transcription-polymerase chain reaction (RT-PCR) with RNA isolated from asymbiotic planular larvae and symbiotic adult of the scleractinian coral *Galaxea fascicularis*. Thus, two actin cDNAs named *LGfact* (larval) and *AGfact* (adult) were identified. Expression of *LGfact* was observed both in larvae and adults, strongly suggesting that it is in the host genome. Its high sequence similarities (96-97% at the amino acid level) to cytoskeletal actins in animals argue for this suggestion. On the other hand, the *AGfact* expression was detected in adults, but not in larvae. It exhibited higher levels of sequence similarity (96% at the amino acid level) to known actins in dinoflagellates (*Lingulodinium polyedrum*, and *Cryptecodinium cohnii*) than animal actins (87% or less). To address the possibility that *AGfact* is a zooxanthella actin, it was compared to sequences obtained by similar PCR using RNA templates from two *Symbiodinium* strains (CS-156 and PLTS-1). Multiple actin (or actin-like) sequences were identified in both strains, and one of the sequences from CS-156 (clade F, derived from the scleractinian coral *Montipora verrucosa*) was highly similar to *AGfact* (99.7% at the amino acid level), although none of the sequences in PLTS-1 (clade A, from the giant clam *Tridacna squamosa*) exhibited high similarity (87% or less). The similarity to a clade F sequence may suggest that *AGfact* is derived from *Symbiodinium* sp..

Telomerase Activity in *Madracis mirabilis* and *Madracis decactis* and their Associated Zooxanthellae

*Sandra ZIELKE**, Richard OWEN, Henry TRAPIDO-ROSENTHAL, Andrea BODNAR

17 Biological Lane, Ferry Reach GE-01, Bermuda

szielke@bbsr.edu

Telomeres, the repetitive sequences of DNA and associated proteins that cap the ends of eukaryotic chromosomes, play an essential role in maintaining chromosome stability. Due to the inability of the DNA replication machinery to completely replicate the ends of linear DNA molecules, telomeres shorten during cell division. The mechanism used by most cells to maintain chromosome integrity and thus retain full proliferative potential is the expression of telomerase. Telomerase is a ribonucleoprotein which can synthesize telomeric DNA and is usually found in dividing cells which require a high replicative potential but not in post-mitotic, or senescent cells. Using the TRAP (telomeric repeat amplification protocol) assay, telomerase activity was detected in nuclear extracts prepared from 2 species of coral, *Madracis mirabilis* and *Madracis decactis*. Telomerase activity was also detected in the endosymbiotic zooxanthellae isolated from these species. Telomerase expression in coral may confer longevity and reproductive plasticity to these organisms, which form the foundation of one of the oceans most diverse and productive ecosystems

Coral Genus *Montastraea* in Chinchorro Bank Reef, Mexico: Spatial Prediction of its Distribution Pattern

Gilberto ACOSTA-GONZALEZ, Nestor MEMBRILLO-VENEGAS, Rodrigo GARZA-PEREZ, J. Ernesto ARIAS-GONZALEZ*

Antigua Carretera a Progreso, km 6. AP 73, Cordemex, Merida, Yucatan. CP 97310 United Mexican States

gacosta@mda.cinvestav.mx

The scleractinian corals species of the *Montastraea* Genus, have a paramount importance in the Caribbean coral reefs as they are considered the main reef building species. Their distribution and abundance along the reefs are very ample. The present study was aimed to perform the spatial prediction of the distribution patterns of this important Genus for the Chinchorro Bank Biosphere Reserve (CBBR). This plain/atoll type reef is part of the Mesoamerican Barrier Reef System (MBRS) and is one of the most important in the Caribbean by its size (40.7 km long and 18 km wide) and diversity. The reef was characterized from 235 sampling stations (video-transect method -50m long x 0.6m wide-) We estimated geomorphologic characteristics and different biotic variables from point identification (520 along the transect) of benthic organisms, grouped into Morph-Structural Groups (MSGs) and Broad-Functional Groups (BFGs). All the information was integrated in a GIS, along with satellite images (LANDSAT 7 ETM+) and a Digital Bathymetric Model (DBM). From the recorded data, a hierarchical classification procedure was performed and we obtained 11 different classes (habitats). Generalized Regression Analysis and Spatial Prediction (GRASP) methodology was used to create predicted distribution maps (GIS layers) of the different features and components of the reef, and a second modeling run produced a new map of the predicted spatial distribution pattern of the Genus *Montastraea*. This kind of application of modern predictive tools allows the creation of maps of ecological and economically important resources. Giving this way, a valuable tool for the definition of priority areas for conservation and marine protected areas (MPAs) creation.

Zonation of Coral Assemblages in the Ryukyu Islands (Southern Japan): The Importance of Land-Ocean Gradients and Reef Habitats

Mehdi ADJEROUD*

Universite de Perpignan, avenue Paul Alduy, 66860 Perpignan France, Metropolitan

adjeroud@univ-perp.fr

Coral reef communities often exhibit strong spatial structure, but the factors that influence their spatial arrangement are generally poorly understood. This study sought to examine the spatial structure of coral assemblages in the Ryukyu Archipelago, southern Japan, where relatively few studies have been conducted on this topic. A total of 21 stations were surveyed on the major reef habitats of 3 different islands: Aka, Ishigaki and Sesoko. On each island, 7 stations were disposed across the fringing reef (4 on the reef flat, and 3 on the outer slope, at 5, 10 and 15 m depth). Despite being small reefs, the total species richness of corals at the 3 islands was high (147 species). A marked spatial variability in the species richness, mean abundance, as well as diversity indices (Shannon, Pielou J) was found among stations. For each island, canonical correspondence analyses showed a clear and significant difference between assemblages of the reef flat and those of the reef slope, both in term of species composition (~19.1% of species restricted to the reef flat, ~52.8% species restricted to the reef slope, and ~28.1% of ubiquitous species), species richness, abundance, and diversity indices. A marked gradient was found across the reef flat, with an increase of species richness and abundance from the shore. Highest values of species richness, abundance and diversity indices were found on the reef slope, at 5 or 10 m depth. Within each reef habitat, a less pronounced variation was also found between islands. These results were compared with those previously obtained on other reefs in the Central Pacific, where species composition, diversity, geomorphology and perturbation history are different.

Monitoring the Coral Reef of Grande Comoro in the Time and Space

Said M AHAMADA*

Itsoundzou B.P. 1545 Moroni Comoros Republic of Madagascar

aide@snpt.km

The South western Indian Ocean Coral Reef Monitoring Network has developed methods for monitoring the coral reef of the region by adapting the Global coral reef monitoring network protocols to the regional context. Simultaneously vulnerability mapping methods of the Coastal area have been developed to contribute to the integrated coastal zone management of the member countries. The Association for Development and Environment as National focal point of this network has been carrying out the coral reef monitoring in the time since 1998. In 2003, the European Union provided funding to develop a vulnerability map of the Grand Comoro Island. These two approaches are complementary and provide better tools for the sustainable management of the marine resources. The coral reef monitoring methods are based on conducting transects, quadrats and fish accounts on fixed stations once a year. The vulnerability mapping is based on interpretation of aerial pictures, ground truthing and GIS data structuring and displaying integrating ecological sensitivity and risk factors. The combination of both approaches arises the general trends of unequal coral recovery in the different areas of the Island after the 1998/1999 bleaching event. It also makes obvious the reasons of the coral status considering the geomorphology, communities and human activities of each area. Resilience ability has been observed in the southern coast than in the north. This is explained by the intensity of the human pressures and the structure of the reef. According to the sensitivity and vulnerability of each sectors conservation actions are suggested for several zones of the Islands.

Adaptive Variation in Colony Geometry and Optimal Light Climates for Corals: A Predictive Model for Foliose Morphologies

Kenneth ANTHONY, Mia HOOGENBOOM*, Sean CONNOLLY

Townsville, Q4811 Australia

Kenneth.Anthony@jcu.edu.au

Light is a key resource for primary producers, but can also have damaging effects at high intensities. The ability of photosynthetic organisms to adjust their internal light climate is thus of great adaptive significance. Here, we test the hypothesis that phenotypic plasticity of the geometry of coral colonies is a mechanism for optimizing internal colony irradiances across a wide range of ambient light regimes. Using plating (folioseous) morphologies as a case study, we develop a light-distribution model based on a set of geometric parameters and then compare the internal irradiance distributions against the predicted physiological optimum, approximated by the sub-saturation parameter (E_k) of the photosynthesis-irradiance curve. Analyses of colony geometries along a depth gradient showed that two key parameters, plate angle and plate spacing, varied adaptively with depth. On the reef flat and crest, central plates had vertical orientation and were spaced 2-5 cm apart, whereas on the foot of the slope, plates had lower angles and were widely spaced. Despite more than 3-fold differences in ambient light regimes between the deep and shallow habitats, light distributions within coral colonies differed only marginally due to differences in colony geometry. Importantly, the modes of the internal light distributions for all morphologies or depths were within the dynamic range of the predicted physiological optimum.

Spatial and Temporal Variation in Small Coral Colony Abundance in Relation to Two Bleaching Events in Okinawa, Japan

*Chiaki BENA**

Senbaru 1, Nishihara, Okinawa, 903-0213 Japan

k018557@eve.u-ryukyu.ac.jp

The supply of coral larvae and their survival after settlement are two of the most important processes influencing the maintenance and recovery of coral communities following coral bleaching events. Small coral colonies, less than 3 cm in diameter, were censused at 4 depths (0-1, 3-4, 6-7 and 9-10 m) at 2 sites over a 5 year period (1998-2003) on western Okinawa, Japan. In 1998, the El-Niño Southern Oscillation thermal anomaly caused most *Acropora*, *Montipora* and Pocilloporid colonies to die on reefs < 4 m; for these colonies the extent of mortality was independent of colony size, while *Porites*, Faviid and Others small coral colonies did not decline right after the bleaching event. There was high recruitment of *Acropora* colonies at one site from 1999-2000, followed by a reduction due to a 2001 thermal anomaly, while the site nearby received few recruits. On the other hand, small colonies that inhabited depths > 6 m, mainly *Porites*, Faviid and Others, decreased in the summer of 2001, because of substrate dislodgement caused by Typhoon 21. Small colonies were censused at 11 localities (4 sites on both western and eastern Okinawa, and 3 sites on the outer islands west of Okinawa) and at 2 depths (3-4 and 9-10 m) in 2001. *Acropora* and Pocilloporid colonies were most prevalent on the southern and northern most localities, especially where currents are normally strong. These results indicate that thermal and solar stress to corals on Okinawan reefs varies in accordance with colony size, coral species, and depth, but that amelioration, in terms of reducing thermal stress through mixing, and further damage, in terms of structural reef dislodgement, is also related to the timing and intensity of the overpass of typhoons.

Fragility and Resilience of *Psammocora* Reefs in Costa Rica, Tropical Eastern Pacific

*M Bernadette BEZY**, Carlos JIMENEZ, Jorge CORTES, Alvaro SEGURA, Juan Jose ALVARADO, Alberto LEON

CIMAR, Ciudad de Investigacion, Universidad de Costa Rica, 2060 San Jose, Costa Rica

b_bezy@hotmail.com

Psammocora stellata and *Psammocora superficialis* are common scleractinian coral species in the tropical eastern Pacific; however, reefs constructed solely of these species have rarely been reported in the region. In Central America there are only three known reefs constructed almost entirely of *P. stellata* and *P. superficialis*. In the present study we describe two such reefs. Penca Reef, located in the upwelling region of Gulf of Papagayo has been severely impacted by recent ENSO events and is currently under seige by *Caulerpa sertularioides* algae. Curu Reef, located in the non-upwelling area of the Gulf of Nicoya was recently discovered (2002) and is described for the first time in the present study. We analyzed these reefs over two time scales; historic (sediment cores), and present (continued monitoring). Prior to the recent invasion of *C. sertularioides*, Penca Reef covered an area of 0.3 ha, was comprised of three of species (*P. superficialis*, *P. stellata*, and *Pocillopora damicornis*), and had 42.8 ± 20.8% live coral cover. By comparison, the Curu Reef, which is comprised of two species (*P. stellata* and *P. superficialis*) is 0.24 ha, and has 44.6 ± 10.1% live coral cover. The growth rate of *P. stellata* at Penca Reef is 9.5 ± 1.8 mm/yr., whereas *P. stellata* in Curu grow 13.13 ± 0.1 mm/yr. Sediment cores of the Curu Reef show a *Pocillopora*-dominated reef sandwiched between the present and a historic *Psammocora*-reef, possibly indicating a long-term resilience of such *Psammocora*-dominated reefs. The Penca Reef sits atop a similar pattern of interchanging *Psammocora*- and *Pocillopora*- dominated reefs. The recent decline in live coral cover due to ENSO and *C. sertularioides* infestations in conjunction with core samples showing layers of *Psammocora* interrupted by a *Pocillopora* reef demonstrate the short-term fragility and long-term resilience of such *Psammocora* reefs.

Significance of Sensor Characteristics in Scaling Benthic Carbon Metabolism with Remote Sensing

*John BROCK**, Kimberly YATES, Robert HALLEY, Ilsa KUFFNER

600 4th Street South United States of America

jbrock@usgs.gov

Models of the organic carbon metabolism of coral reef ecosystems, parameterized by process measurements and scaled up spatially using remote sensing, have the potential to address pressing research questions that are central to devising valid coral reef management strategies. This interdisciplinary approach to understanding reef biogeochemical dynamics allows investigations that integrate across time and space, thereby enabling prediction of coral reef change. Forecasting holistic ecosystem function within various environmental forcing scenarios has substantial promise to aid the mitigation of future disturbance. Moreover, management of coral reefs at the ecosystem level may be the only meaningful approach towards the preservation of coral reefs. Net community production (NCP), or its diurnal integral, excess production (E), is a measure of reef community metabolism that describes the holistic trophic state of coral reef ecosystems or their functional components. Excess production was estimated for a 0.5 square kilometer lagoonal patch reef site on the continental shelf within northern Florida reef tract by integrating benthic chamber measurements of organic carbon metabolism with benthic class maps derived from passive remote sensing. Model sensitivity to the choice of imagery used was tested by repeating the analysis using benthic class maps based first on AISA airborne hyperspectral sensing, and second on lower resolution IKONOS and ASTER satellite multispectral images. Further, the model estimation of E was stratified by depth through the use of detailed submarine topography provided by a NASA EAARL airborne lidar survey. Modeled export production and daily net calcification for the study area, and the total primary production, respiration, and calcification estimated for each benthic habitat varied significantly with sensor characteristics. Binning the model results by depth revealed that differences in estimated E between analyses using the AISA airborne hyperspectral sensor and the coarser satellite sensors was largely a function of water depth.

Coral Communities and Sedimentation in Inner Reefs of the Abrolhos Bank, Brazil

*Clovis B CASTRO**, Barbara SEGAL, Emiliano N CALDERON, Fabio NEGRAO

Quinta da Boa Vista, s/n, Rio de Janeiro, RJ, 20940-040 Federative Republic of Brazil

cbcastro@pobox.com

The relationship of coral community and sedimentation in Brazilian coral reefs is still poorly understood. It was investigated at the inner reefs of the Abrolhos Bank through coral and zoanthid cover, coral recruitment, monthly sediment deposition, sediment carbonate composition, and wind influence on sedimentation. Sediment deposition rates varied among sites, with a strong seasonal influence, especially related to winds. Some recorded rates were among the highest recorded in the coral reef literature. The main structuring organism of the cnidarian community is *Palythoa caribaeorum*. There was a variation among sites in relation to the commonest coral species, suggesting that local factors and/or stochastic events may be structuring these communities. Such features may be variable from one reef to another, and even among sites of the same reef. Communities subjected to this kind of influence tend to present mosaic distribution, without geographic patterns or a marked zonation, as the communities here studied. Scleractinian distribution and abundance could not be explained by differences in recruitment, nor by a lack of larval supply. There was higher milleporid settlement on sites with high *Millepora nitida* cover, which suggests local recruitment. Coral (scleractinians and milleporids) cover was negatively correlated with zoanthid cover. Coral and zoanthid covers were not correlated with peak or average sediment deposition or composition. However, the frequent dominance of *Palythoa caribaeorum* in areas with high sediment deposition suggests sedimentation may have an indirect effect in the structure of coral communities in the Abrolhos inner reefs.

Distribution of Sea Cucumbers in Reefs of Thailand and Effect of their Declining Populations

*Suchana CHAVANICH**, *Voranop VIYAKARN*

Department of Marine Science, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand
csuchana@sc.chula.ac.th

Sea cucumbers are considered to be one of the most conspicuous species in the coral communities. At present, populations of sea cucumbers in Thailand have been declined due to overfishing. They are harvested and then sold on Asian markets as food and medical properties. Pressure on the sea cucumber resources is likely to increase in the future in many countries including Thailand. The purpose of this study was to determine the possible effect of the declining of sea cucumbers on reef communities. The distribution of sea cucumbers and their habitats were investigated. In addition, individuals of sea cucumbers were collected for the stomach content analysis. Sediment samples and sea cucumber feces were also collected from their habitat and then analyzed for chlorophyll a concentration and bacteria counts. The results showed that overall the densities of sea cucumbers in several islands were low, and most were found in the sand areas. Gut contents were composed of sand and molluscan shells. When analyzed for the chlorophyll a concentrations, the results showed that there were differences on the concentrations of chlorophyll a between sediment, gut, and feces samples. The decline of sea cucumber populations may have negatively effect on the reef communities as it may increase the density of microalgae in the ecosystem.

Patterns of Reef Community Structure at the Northern Meso American Barrier Reef System

*Ernesto A CHAVEZ**, *Jose Manuel BORGES-SOUZA*

Av. IPN s/n, Col. Santa Rita, Playa El Conchalito, La Paz Baja California Sur, 23070 United Mexican States
echavez@ipn.mx

Structure of reef benthic community was analyzed at six reefs of the northern Meso-American Barrier Reef System, in order to explore the possible existence of patterns induced by the main environmental driving forces and to define an ecological baseline aiming to help in the planning of management actions for their protection. Three windward reefs and three leeward reefs were examined with the hypothesis that wind-driven waves nor light intensity would impose significant changes in reef structure over depth and reef exposure. Samplings were carried on by means of photographic transects and these were grouped by reef exposition and depth levels. Sponges are dominant over leeward reefs, whilst stony corals are dominant at windward reefs. Results of diversity spectrum, principal components, and cluster analysis, show that despite the basic similarity of community is maintained, significant changes in community structure are evidenced through substitution of dominant elements in different reef strata and exposure of reefs to the most important driving forces. Clusters as well as principal components clearly allocate reefs by exposure to wave action and depth. At shallow depths, soft corals and species of *Acropora* display the best fit to light and wave action. At deeper levels, sponges and fragile forms become dominant. Environmental stability as occurs in deeper zones of leeward reefs allows higher species diversity and a better structured community.

Corals and Coral Reefs in a Seasonal Upwelling Area in the Eastern Pacific (Costa Rica)

*Jorge CORTES**, *Carlos JIMENEZ*

CIMAR, Ciudad de la Investigacion, Universidad de Costa Rica, San Pedro, San Jose 2060, Costa Rica
jcortes@cariari.ucr.ac.cr

Cold waters are considered a limiting factor for coral growth and coral reef development. In some areas in the tropics, seasonal upwelling of cold waters creates, during part of the year, conditions considered as not conducive to reef growth. In the Mesoamerican region there are three areas of seasonal upwelling (between December and April-May): the Isthmus of Tehuantepec (Mexico), the Gulf of Papagayo (southern Nicaragua-northern Costa Rica), and the Bay of Panama (Panama). Corals and coral reefs have been studied in the northern section of the Pacific coast of Costa Rica. In this region temperatures as low as 12°C have been recorded at 15 m and 20°C on the surface. The coral species are the same as in non-upwelling areas but the importance of some species as reef-builders change. Growth rates of most species are higher than the same species anywhere else in the eastern Pacific. On one hand, it seems that the upwelling recorded at Papagayo is not limiting coral growth, in fact it is being enhanced, or the development of reef structures; but on the other hand, extreme low temperatures, as experienced during the Little Ice Age, can kill the corals. In Costa Rica, as in other regions of the eastern Pacific, a more important cause of coral death is warm waters as witness in recent years during El Niño-Southern Oscillation events.

Long-term Monitoring of Coral Reefs Subject to Sediment Stress in Papua New Guinea

Adrian J FLYNN, *Sandra ROTMANN**

124 Camberwell Road, Hawthorn East, 3123, Victoria, Australia
adrian.flynn@enesar.com.au

Fringing coral reefs in the Lihir Group of islands in Papua New Guinea, were monitored from 1994 to 2002 using video and photographic transects to record relative cover of major benthic life-forms. From 2001 to 2003, the thickness of living tissue of *Porites* spp. corals was also measured. The environmental impact assessment for the Lihir Gold Project, a mining operation on the east coast of Lihir Island, predicted that turbidity and, to a lesser extent, sedimentation in the nearshore environment would stress the coral reefs close to the mine and that impacts would range from 'severe' to 'transitional' to 'minor' (as operationally defined) and would decrease with increasing distance from the mine. Video transect monitoring data indicated spatial and temporal variation in the relative cover of major benthic life-forms, but delineation of the site classified as the 'severe' impact zone from 'control' sites. Reefs in the 'severe' impact zone were characterised by a decrease in the relative cover of live hard corals and an increase in the relative cover of algae. Monitoring of *Porites* spp. showed living tissue thickness to be inversely proportional to proximity to a source of sediment input, whether the mine or a natural source. The data indicate that, in terms of damage to corals at Lihir Island, there may be only two biologically relevant zones: 'impact' and 'no impact' as live coral cover at sites in the 'transitional' and 'minor impact' zones was often not significantly different from the control sites. Live corals were still observed at sites in the 'severe' impact zone suggesting that the a priori definition of predicted impacts to corals in this zone was conservative. The relatively new technique of *Porites* spp. tissue thickness measurement may provide a cost-effective and accurate method of monitoring the effects of sediment impacts to corals reefs.

Self-sustaining Resilience of Hermatypic Coral Communities Following Disturbance at the Reef Flat of Urasoko Bay, Ishigaki Island, Southern Japan

*Yoshimi FUJIOKA**, *Hideo OHBA*, *Takuro SHIBUNO*, *Yoshitake TAKADA*, *Kazumasa HASHIMOTO*, *Atsushi SUZUKI*, *Kaiho TOTTORI*
1-1 Ohwashi, Tsukuba, Ibaraki 305-8686 Japan
fujioka@affrc.go.jp

A monitoring survey was conducted to compare recovery patterns in community structure of hermatypic corals. Twelve 1-m² permanent quadrates were established under three different environmental conditions at the reef flat of Urasoko Bay, Ishigaki Island, southern Japan. After hermatypic corals were artificially stripped away from the surface of the substratum, all recruited coral colonies were monitored during eight years from 1995 to 2003. New settlement of hermatypic corals was observed in 1995, and the percent cover, as well as the number of species and colonies of corals increased gradually during the three-year period until 1998. The dominant coral was *Acropora* at the middle and outer reef flat, and *Porites* at the inner reef flat near the shore. There was a close relationship between the number of newly recruited young colonies and the percent cover of *Acropora* or *Porites* in the last year. Corals drastically decreased in number and in coverage as a result of the 1998 bleaching episodes, in which most *Acropora* species underwent catastrophic damage from high temperature; consequently, rich coral communities disappeared from the middle and outer reef flats. However, bleaching damage was not severe at the inner reef flat where *Porites* predominantly inhabited. After bleaching, coral communities recovered quickly especially at the outer reef flat where environmental conditions are suitable for growing corals. In the summer of 2002, hermatypic corals were somewhat decreased because of physical disturbances and sedimentation of coral fragments caused by the strong waves brought about by a typhoon. Hermatypic corals maintained a typical non-equilibrium community, the structure of which was determined by the kind and the degree of natural disturbances. However, coral communities have an innate ability to recover following disturbances. The present results have revealed the remarkable self-sustaining resilience of corals under favorable environmental conditions.

First Regional Assessment of Coral Reef Health in the Western Atlantic

Robert N GINSBURG, *Philip A KRAMER*, *Amit L HAZRA*, *Judith C LANG**
4600 Rickenbacker Causeway, Miami, Florida 33149 United States of America
rginsburg@rsmas.miami.edu

Clearly coral reefs in many areas of the western Atlantic are in decline. What is not clear is the spatial extent and severity of the declines. To produce answers to these concerns, the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program was designed to assess the health of coral reefs throughout the region by examining communities of reef-building corals, fishes, and algae in shallow and intermediate-depth habitats. It is the first ever initiative examining the regional health of coral reefs using trained experts rather than volunteers. The assembled data constitute an essential baseline against which to evaluate future changes by repeat assessments. The AGRRA surveys are based on three guiding principles: multiple indicators are required at each reef to evaluate the interrelated communities of corals, algae, and fishes; surveys must be done rapidly so that many reefs can be assessed; numerous reefs must be surveyed within each area or country to permit comparisons of reef ecosystem health at multiple spatial scales. Data collected since 1997 from over 720 sites in 17 nations is being summarized and will be presented with examples of how the results can be used to establish a classification of comparative reef health. Initial remaining tasks are to complete the regional assessment throughout the western Atlantic and compile results in a searchable database.

Destruction of Corals and Other Animals by Coral Spawn Slicks at Bills Bay, Ningaloo Marine Park, Western Australia: 1989 to 2002

*Timothy L GRUBBA**, *Chris SIMPSON*, *Jennie CARY*
47 Henry Street, Fremantle, Western Australia, 6160 Australia
tingm@calm.wa.gov.au

Annual mass coral spawning has been identified as a significant natural disturbance, which has been a major factor in shaping the reefs around Bills Bay, Ningaloo Marine Park, Western Australia. There have been three records (1978, 1989 and 2002) during the past 25 years of coral spawning events in the vicinity of Bills Bay resulting in the mass mortality of corals and other reef biota. During these events coral spawn did not disperse but formed concentrated coral spawn slicks. The observed mortality is a result of hypoxia (oxygen depletion) created initially by the respiratory demand of the coral spawn and maintained by the biological oxygen demand of the decomposing spawn slicks and dead animals. Long-term monitoring sites established in Bills Bay in 1989 and re-surveyed in 1994 and 2000 documented the impacts and recovery from these events. The 1989 surveys indicated an initial decline in average live coral cover from 42.9% to 9.4% with 70 - 100% coral mortality at some sites. The 2000 survey indicated average live coral cover increased to 27.4 % however recovery was patchy with some sites showing little signs of recovery. Initial reports on the 2002 mass mortality event indicate 30 - 80% coral mortality at some sites. In addition it is estimated that millions of fish and invertebrates died during the 1989 and 2002 events. Monitoring data indicates that recovery of corals in Bills Bay is patchy and in general slow and in the absence of further events is likely to be measured on the scale of decades and not years. It is hypothesised that coral recovery between events is affected by poor coral recruitment and recruit survival due to anthropogenic stress and prevailing site conditions including substrate stability and water circulation patterns.

Reef-framework Modification by Epi- and Endobionts in the Mexican Caribbean

*Leanne J HEPBURN**, *Christopher PERRY*, *Paul BLANCHON*
19 Moulin Terrace, Cardonald, Glasgow, G52 3JZ United Kingdom of Great Britain and Northern Ireland
l.hepburn@mmu.ac.uk

Coral reef accretion primarily involves the growth (and sometimes the destruction) of corals. Also important, however, are subordinate processes such as secondary encrustation and bioerosion which have been shown to enhance biomass and influence rates and styles of reef accretion. Despite this, little is known about the colonization rates or distribution patterns of the epi- and endobionts responsible for such processes. To address this deficiency we analyzed the taxonomic diversity and distribution of epi- and endobionts across a reef transect at Puerto Morelos, northeast Yucatan Peninsula. For endobionts we collected cobble-sized rubble from all environments whereas for epibionts we constructed artificial micro-habitats creating cryptic and exposed environments using settlement tiles and exposed them for periods of 12 and 24 months. Results of rubble analyses show that sponges are the dominant bioeroding species in all reef zones (removing 14-25% by volume) although species abundances are variable. Of secondary importance in the back reef are polychaetes (removing 4% by volume). Boring bivalves are relatively significant contributors to bioerosion in the reef front (removing 6% by volume). Analyses of the artificial microhabitats after 12 months exposure indicate that epibionts exhibit a clear zonation of species and morphological growth forms in response to differences in light intensity, water turbulence and reef-zonation. With the exception of the reef crest which is dominated by coralline algae (29% cover), exposed surfaces in all other reef zones are dominated by fleshy-algal assemblages. In cryptic environments too, the crest is dominated by crustose corallines (27% cover), whereas other zones are dominated by serpulids (27-40% cover) and foraminiferas (13-15% cover).

Spatio-temporal Variability of the Colonization of Uvea Island (Wallis and Futuna) by Coral Fish Species

Matthieu JUNCKER*, Laurent WANTIEZ

Matthieu Juncker, Service de l'Environnement, PB 294 Mata'Utu, 98600 Uvea. Territoire de Wallis et Futuna
juncker@univ-nc.nc

The study of the colonization of coral fish was carried out in September 2002, December 2002, March 2003 and June 2003 on the barrier reef of Uvea Island (Wallis and Futuna, Western Pacific), in three sites which are more than 10 km apart. Altogether, 45,127 young fishes were collected whose bodies height is more than 5 mm. They belong to 131 taxa. On one hand, the most represented taxa (recorded number >100) are found in all the nets whatever their direction. On the other hand, the taxa which are not very abundant (recorded number ranging from 6 to 99 individuals) and the rare ones (recorded number <=5 individuals) are not dispatched up in a homogeneous way. These observations make it possible to put forth the assumption that the paths of abundant taxa can be several dozens of kilometres long whereas not very abundant taxa and rare ones may only form aggregates whose size cannot exceed 10 km.

Ecological Role of a Zoanthid, *Palythoa caesia* on Coral Reefs in the Gulf of Thailand

Napalai JUNTARUK, Thamasak YEEMIN*

Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240 Kingdom of Thailand
thamasakyeemin@hotmail.com

Palythoa caesia is a common benthic animal in Thai waters, especially in the Inner Gulf of Thailand. It can play a major role on several aspects of reef ecology such as sedimentation and competition. Ecological studies on *Palythoa caesia* (Anthozoa : Zoanthidea) in turbid environment at Khang Khao Island, Chonburi Province were carried out during June 2000 - February 2002. *P. caesia* obviously played a major role as a dominant competitor with sessile reef organisms. It grew over other sessile reef invertebrates because of its rapid growth rate and propagation by both sexual and asexual reproductions. *P. caesia* assimilated sediment on colony surface and in its mesoglea. The present study concentrated on growth rate, mortality rate, change of coverage, competitive and sediment assimilated abilities of *P. caesia*. The results clearly showed that mean growth rate was 1.45 cm./month. Mean mortality rate was 25.08% per year. Change of coverage during June 2000 - February 2002 was 0.41% per year, *P. caesia* was a hermaphrodite. Average of amounts of sediment on *P. caesia* colony surface in deep stations was 3,442.85±2,173.60 mg./m.² while that of shallow stations was 2,931.81±2,787.49 mg./m.². Average of assimilated sediment in deep stations was 15,881.60±5,837.43 mg./m.² but that of shallow stations was 14,564.62±6,777.38 mg./m.². Average of amounts of sediment found in mesoglea was 71.85% of tissue dry weight. Mean sedimentation rates in the field measured by using sediment traps with 1.5 cm. and 5 cm. in diameters in deep stations were 57.55±126.11 and 20.21 ± 22.82 mg./cm.²/day, respectively, while those in shallow stations were 100.09±134.40 and 17.90±19.97 mg./cm.²/day, respectively. Sedimentation rates measured by using sediment plates were also examined and showed very low figures compared to sediment traps. Most colony of *P. caesia* grew on a massive coral, *Porites lutea* and certain sponges.

Miocene to Pliocene Reef Coral Assemblages of the Northern Dominican Republic

James S KLAUS*, Ann F BUDD, Donald F MCNEILL

1301 West Green St., Urbana, Illinois United States of America
jklaus@uiuc.edu

Assemblages of reef corals from the Late Miocene to early Late Pliocene of the Northern Dominican Republic were statistically analyzed to document patterns of change during the period of high generic and species origination leading up to the Late Pliocene Caribbean-wide episode of accelerated faunal turnover. The sections analyzed were part of a thick sedimentary wedge (as much or more than 1000 m thick) that prograded north forming a thin shelf and slope along a narrow eastward-opening trough located north of the rapidly uplifting Cordillera Central. Exposures are located along five rivers of the Cibao Valley: the Rio Gurabo, Rio Cana, Rio Mao, Rio Amina and Rio Yaque del Norte. Stratigraphic variations in coral occurrences were determined from over 2,900 coral samples collected by haphazardly extracting well-preserved material from the surface of the outcrop. Sampling therefore was roughly representative of species composition, but not of abundance. Analysis of occurrence data was performed using average linkage clustering, nonmetric multidimensional scaling and Jaccard similarity coefficients. At the coarsest level assemblages can be categorized as either grassflat communities (>35% free-living taxa) or mixed-shape communities (<29% free-living taxa). Grassflat and mixed-shape communities are stratigraphically scattered throughout the section, reflecting variations in facies rather than the evolution of communities. To more accurately characterize the mixed shape coral communities in three areas of exceptional reef development, twenty-six 40 m point intercept transects were additionally collected. This data allows characterization of pre-turnover coral reef zonation patterns and provides insights into the ecological role of several dominant pre-turnover taxa.

Another Apparent Shift in the Structural Diversity of Reefs, Little Cayman, Cayman Islands

Carrie MANFRINO*, Vania COELHO, Soranno ALEXANDER

1000 Morris Ave. Union, NJ 07083 United States of America
manfrino@reefresearch.org

Changes in the structure and diversity of the reefs of Little Cayman (LC) were documented from 1999 to 2002, 2003. By comparison with earlier reports, major changes in community structure included the shallow framework reef previously built by *Acropora palmata* and *A. cervicornis* becoming uncommon by 1999. Little Cayman is the least developed island (with only 150 residents) of the Caymans and though it had high average coral cover, the reefs also had overall high percent of diseased coral (24.4% at one site) in 1999. Of the 18 original sites surveyed around LC we re-surveyed 8 fore-reef sites for this study using the AGRRA protocol. The recent mortality impacting the massive coral species in 1999 continued to be due largely to white plague syndromes in 2002/2003 suggesting that disease stresses may have become a chronic condition of these reefs. The dominant *Montastraea annularis* species complex had the highest incidence of disease in both studies, averaging 17% for *M. annularis* and *M. faveolata*. Total mortality (per colony) of *M. annularis* increased from an average of 35.7% in 1999 to 48.5% by 2002/2003. Species richness increased at five of eight sites and declined at one site. Previously less important species, *Porites astreoides* and *Agaricia sp.*, are becoming increasingly abundant at the study sites as massive corals decline. Our data suggests a trend toward another major community change in stony coral on a relatively short time scale. Successions similar to these are identified in the shallow modern lagoons as well as in the sea-level driven successions of juxtaposed Pleistocene outcrops around the island.

Damselfish Territories and Bioeroders: Are They a Threat to the Structural Integrity and Long-term Persistence of a Reef?

*Sarah A MCTEE**

2340 St. Louis Dr., Honolulu, Hawaii United States of America
mctee@hawaii.edu

Within the national park on Ofu, American Samoa, *Stegastes nigricans* and *Stegastes albifasciatus* have established, and effectively defend, algal "gardens" within various expanses of *Acropora donei*. The ongoing presence of algae in this area led to the concern that damselfish territories may negatively affect the long-term persistence of Ofu's reef. Consequently, this study was designed to determine if damselfish territories, by facilitating the establishment of a community of invertebrate bioeroders, significantly affect the structural integrity of the national park's reef. *Acropora donei* within and outside of *Stegastes* territories was examined for relative amounts of bioerosion, as well as overall abundance and taxonomic composition of invertebrate bioeroders. Bioeroders were more than twice as abundant in *A. donei* located inside *Stegastes* territories than outside. The majority of bioeroders were comprised of organisms from the phyla Annelida and phyla Sipunculida. Despite the greater abundance of bioeroders within territories, the amount of bioerosion was not significantly different from *A. donei* collected outside of territories. Assuming that the center is the oldest portion of a *Stegastes* territory, it was hypothesized that there would be more bioerosion in center than at the edges of territories. Surprisingly, the number of bioeroding invertebrates and relative amount of bioerosion in the centers of territories was not significantly greater than that of the edges. Although the presence of *Stegastes* algal gardens increase the number of invertebrate bioeroders the coral substrate is exposed to, damselfish territories do not appear to significantly alter the structure or stability of the reef system in American Samoa.

Spatial Variations of Coral Reef Fish Communities of the Archipelago Cayos Cochinos, Honduras

*Alicia C. MEDINA-HERNANDEZ**, *J Ernesto ARIAS-GONZALEZ*

A.P. 73 Cordemex. CP 97310 Merida, Yucatan, Mexico
alicamedina@hotmail.com, mhac@mnda.cinvestav.mx

The Cayos Cochinos Archipelago is located in Honduras and is one of the most important reefs in the South-eastern part of the Mesoamerican Barrier System (MBRS), with an area 460 sq.km. Its importance relies in being an important fishing site as well as a Marine Protect Area (MPA). An ecological study was carried out in order to explore the relationships between species composition, spatial components and environmental variables using partial canonical ordination. Reef fish community structure was characterized using the visual census technique for coral reef fishes. These surveys were conducted at 30 stations, each one comprising eight replicates 50 x 2m belt transects, along the entire MPA. Main ecological descriptors were assessed: density, richness, abundance, diversity and size structure along biomass and trophic structure analysis. The stations were classified according to their habitat characteristics in patch reef, bank reef and fringing reef and the benthic communities were benthic characterized by the video-transect method using morph-structural groups (MSGs) of stony coral, octocorals, hydrocorals and marine plants. The fish communities structure was dominated by families Pomacentridae (47%) and Labridae (31%). High densities of the labridae *Clepticus parrae* and the pomacentridae *Stegastes partitus* were recorded. The total richness species of the coral reef fishes was very high in the protected zones located away from the coast, in the north part of the Archipelago. The spatial variation of the fish communities was related with the environmental variables (water depth, coral abundance and coral richness of all the morphologic groups).

The Maintenance Mechanism of a High-latitude Scleractinian Coral Assemblage in Amakusa Islands, Southwestern Japan

*Yoko NOZAWA**, *Mutsunori TOKESHI*, *Satoshi NOJIMA*

2231 Tomioka Reihoku-chou, Amakusa-gun, Kumamoto-ken, Japan
yokon@amb1-ku.jp

To facilitate the understanding of maintenance mechanisms of high-latitude coral communities, a scleractinian coral assemblage was closely monitored for three years in Amakusa Islands, southwestern Japan (32 °N). Every visible-sized colony (ca. > 1cm in diameter) in a total area of 100 m² was monitored by taking close-up digital photographs every year. The relative size, species, and location of each colony were recorded. Data were mainly analysed on 1) the assemblage structure, 2) the demographic structure of each dominant or minor species, and 3) the growth rates and mortalities of different size-classes of each dominant species. Estimated maintenance mechanism will be discussed in comparison with those for lower-latitude scleractinian coral assemblages.

Subtropical Marine Vegetation under the Influence of Rivers at Miyara Bay in Ishigaki-jima Island, Ryukyus (Southern Japan)

*Hideo OHBA**, *Takuro SHIBUNO*, *Yoshitake TAKADA*, *Atsushi SUZUKI*, *Masayuki NAGAO*, *Kaiho TOTTORI*, *N MORIMOTO*, *Yoshimi FUJIOKA*

4-5-7 Konan, Minato-ku, Tokyo 108-8477 Japan
ohba@s.kaiyodai.ac.jp

Recently, coral reefs in Ryukyus have been gradually destroyed from pollution by excess sediment, high temperature, predation by *Acanthaster planci* and other factors. This ecological investigation was conducted to evaluate the influence of rivers on the coral reef organisms at Miyara Bay in Ishigaki-jima Island, Ryukyus on September of 2002. Miyara Bay has been subjected to the strongest influence of the river, especially pollution by excess sediment and human sewage in Ishigaki-jima Island. A total of 91 survey points was set up at intervals of 0.1 minutes each latitude and longitude in Miyara Bay. The survey area extended from beach to outer reef slope (up to 7 m of depth) and reef channel (up to 29 m of depth). Species richness and abundance of hermatypic corals, marine plants and fishes were examined in the 4 m x 10 m belt transect put at each survey point. Environmental factors (temperature, salinity, nutrients, turbidity, sediment, substratum and tidal current) were simultaneously measured. Multivariate analyses were carried out to analyze the similarity of community structure and the influence of environment on reef organisms by using presence-absence data. We present the results of the marine plants in the present poster. Four distribution patterns of marine plants were recognized: (1) Taxa appearing on the inshore-side, (2) Taxa appearing from the offshore-side moat to the outer reef, (3) Taxa mainly appearing on the eastern reef, (4) Taxa mainly appearing on the western reef. As the results of multivariate analyses, Miyara Bay was categorized into five regions: (A) Inshore-side moat of sandy and muddy bottom, (B) Reef channels of sandy and muddy bottom, (C) Eastern moat, (D) Mid-moat and reef crest of western reef, (E) Offshore-side moat, outer reef flat and reef slope. The correlation between marine vegetation and some environmental factors was discussed.

Impacts of Benthic Marine Cyanobacteria on Coral Reefs: Ecology and Toxicity

*Valerie J PAUL**

701 Seaway Drive, Fort Pierce, FL 34949 United States of America
paul@sms.si.edu

Benthic cyanobacteria are increasingly abundant in coral reef habitats in the tropical Pacific, Florida and the Caribbean, sometimes forming extensive mats that can overgrow a variety of tropical organisms. Although rapid increases in the abundance of benthic cyanobacteria may be caused by the same factors that influence other algal blooms, the effects of eutrophication and reduced herbivory on cyanobacterial populations are not well understood. Many cyanobacteria can fix nitrogen, which may reduce their dependence on nitrogen availability. Cyanobacteria produce many different nitrogenous secondary metabolites, and some of these deter feeding by generalist herbivores such as fishes and sea urchins. Most organic extracts tested deterred feeding by generalist herbivores such as fishes and sea urchins but stimulated feeding by the sea hare *Stylocheilus striatus*, a more specialized consumer of cyanobacteria. The production of deterrent secondary metabolites by many benthic cyanobacteria provides protection from grazing by generalist herbivores and can facilitate the growth and persistence of cyanobacteria in herbivore-intense coral reef habitats.

Recruitment Processes and Maintenance of Scleractinian Coral Populations around Moorea (French Polynesia): The Link between Recruits, Juveniles, and Adults

Lucie PENIN, Mehdi ADJEROUD*

Universite de Perpignan, avenue Paul Alduy, 66860 Perpignan France, Metropolitan
penin@univ-perp.fr

Relationships among 3 stages of the life cycle of scleractinian corals were studied around Moorea Island, in order to improve our understanding of population maintenance and recruitment processes. Abundance and composition of recruits (< 3 months of age), juveniles (1-5 cm in diameter; ~1-4 years of age), and adults were determined at 9 stations disposed on the outer reef slope (3 sites: Vaipahu, Tiahura, and Haapiti; 3 depths: 6, 12, and 20 m). There was a strong variation among sites and depths in the abundance and composition of recruits, juveniles, and adults. At the station scale (~100 m²), no correlation was found between the abundance of recruits and juveniles, nor between recruits and adults (all families/genera pooled). In contrast, we found a positive and significant correlation between abundance of juveniles and adults, except for *Pocillopora* and *Porites*. Moreover, juvenile and adult assemblages showed marked similarities in term of relative abundance of the different genera, whereas recruits differed strongly. Relationships among recruits, juveniles and adults varied among the 3 dominant families (Pocilloporidae, Acroporidae and Poritidae), indicating the importance of life history traits in recruitment and maintenance processes. At the site scale (~10000 m²), stronger relationships were observed between recruits, juveniles and adults. Our results suggest that, at the station scale, early post-settlement processes are major factors influencing the variation in abundance and composition of adult assemblages, whereas at a larger spatial scale, recruitment-regulation processes may play a significant role.

Baseline Assessments of Coral Reefs in the Marshals Islands: A Comparison of Community Composition among Four Atolls

Silvia A PINCA, Maria BEGER, Berry MULLER, Emma REEVES, Melba WHITE*

P.O. Box 1258, Majuro Republic of the Marshall Islands
milviapin@yahoo.com

The Republic of the Marshall Islands (RMI) in the northwest equatorial Pacific hosts some of the most intact reefs in the western Pacific. The pristine atoll reefs can still be preserved following a precautionary approach. However, some of the reefs of RMI are highly endangered by the threats currently imposed on global coral reef ecosystems; i.e. fast growing populations and climate change, especially in the most highly populated atolls. RMI has been showing interest to conservation issues in the past few years and has recently committed to take steps on education and conservation, acting specifically on the activation of conservation sites. In order to assist governments in identifying priority sites for setting up marine protected areas, resources assessments and research projects have been undertaken by the College of the Marshall Islands and collaborators between 2001 and 2003. Results on abundance of commercial target fish families and coral cover and composition are presented here in order to compare health, production and community structure of reefs of the northern atolls of Bikini and Rongelap, central atoll of Likiep and southern atoll of Mili. The atolls of Rongelap and Likiep showed to be in extreme pristine conditions. Mili, in the Southeast, showed higher impact from human presence, while Bikini has a particular coral composition that distinguishes it from the others. Data on community composition were analyzed using grouping techniques, where fish and corals were used as descriptors. The results from each atoll showed high similarity among sites with high topographic proximity and similar orientation to the main current patterns, suggesting an influence of current transport and wave stress on community composition. I.e., ocean leeward sites showed the highest coral cover, while lagoon windward sites had the lowest. Differences among the four atolls were also analyzed showing a variation between South and North atolls.

Brain Coral Recruitment and Population Structure at San Andres Island, Colombia, Western Caribbean

Valeria PIZARRO, Sven ZEA*

School of Biology, Ridley building, University of Newcastle, Newcastle upon Tyne, Tyne & Wear, NE1 7RU, UK United Kingdom of Great Britain and Northern Ireland
Valeria.Pizarro@ncl.ac.uk

As a first attempt to describe the population dynamics of brain corals at San Andres Island, Colombia, recruitment and adult size distribution of three species (*Colpophyllia natans*, *Diploria strigosa* and *D. labyrinthiformis*) were examined for nine months at three locations. These locations were characterised by different hydrodynamic regimes. Smaller colonies were most abundant in the populations of *Diploria* spp., and conversely the larger colonies were more frequent in the population of *C. natans*. A significant difference in colony size between locations was only found for *D. strigosa* ($K-S = 2.46$; $p < 0.05$). Colony partial mortality and disease frequency varied significantly between locations for *C. natans* ($W = 416$; $p < 0.05$) and *D. strigosa* ($W = 74$; $p < 0.05$), but did not vary significantly for *D. labyrinthiformis* ($W = 644$; $p > 0.05$). As expected, higher partial mortality occurred in smaller colonies in all three species. A total of 184 brain coral recruits were recorded in this study. The highest recruitment rates were in June and July (0.0146 recruits cm⁻²). Recruit survivorship decreased with time, and the highest survivorship was found in the location characterized by lowest water flow and greatest depth (63.3 % of the recruits survive after 9 months). These results suggest similar preferences for physical environmental conditions for *C. natans* and *D. labyrinthiformis*. These species seem to be adapted to calmer and deeper water, unlike *D. strigosa*, which apparently prefers shallower depths and higher water flows. Brain coral recruitment data analysis suggests high self-seeding rates at San Andres Island, and the results suggest that environmental conditions are currently not detrimental to these brain coral populations. But as reef degradation continues, coral populations will decline if coastal management programmes are not implemented.

Effects of Monsoon Exposure and Impact of the 1998 Bleaching Event on the Benthic Community Structure of Tubbataha Reef National Marine Park: A Basis for Reef Management

*Marlowe SABATER**, *Micaela LEDESMA*, *Marivel DYGICO*

3 Wescom Road, San Pedro, Puerto Princesa City 5300, Palawan, Philippines
msabater@tubbataha.org

The coral reef, being a dynamic ecosystem, undergoes series of changes brought about by differences in environmental factors and disturbances at various spatial and temporal scales. Understanding these changes is important in improving the management strategies of the Tubbataha Reef National Marine Park, an atoll reef system along the Cagayan Ridge found at the center of Sulu Sea, Philippines. Results of the annual reef monitoring surveys were used in the annual review of its management plan. Video transect surveys were conducted at 7 representative sites in the Tubbataha Reef from 1997 to 2002 to monitor the reef condition and determine its benthic community structure. A 150 meter transect was laid on the reef parallel to the reef crest following the 5 and 10-meter isobath. The data were analyzed using multivariate techniques. The multivariate analysis showed significant differences in the percentage cover of various lifeforms between sites and between years. Spatial variations in benthic community structure were due to the exposure to the northeast and southwest monsoons. Corals with robust lifeforms were found in the northeast monsoon-exposed sites (high-energy environment) while branching corals were found in the southwest monsoon-exposed sites (low-energy environment). The community structure also changed as a result of the massive bleaching event that occurred in July 1998. The change in community structure resulted to shifts in the cluster relationships between sites. Four out of seven sites showed a continuous decline in reef condition and were considered as vulnerable sites, one of which did not show any sign of recovery from the bleaching event. Three sites, however, showed some degree of resilience. This study showed sections of the reefs which are vulnerable and which are resilient to perturbations. This information enables park management to focus on recovery measures in vulnerable sites and preservation measures in resilient sites.

Coral Communities Structure and Sedimentation at Different Distances from the Coast in the Abrolhos Bank, Brazil

*Barbara SEGAL**, *Clovis B CASTRO*

Quinta da Boa Vista, Sao Cristovao, Rio de Janeiro, 20940-040 Federative Republic of Brazil
bsegal@pobox.com

Sedimentation has previously been considered an important source of impact in coral reefs. We compared 3 sites at the Abrolhos Bank, Brazil, regarding sedimentation rates, carbonate sediment composition, coral cover, and colony size for the commonest local coral species (*Mussismilia braziliensis*, *Siderastrea stellata*, and *Favia gravida*). Sites are located at different distances from mainland: Pedra de Leste (14 km), Pontas Sul (26 km), and Parcel dos Abrolhos (58 km). Sedimentation was higher in winter ($p < 0.05$), but no difference among sites was noted. Sites differed in sediment type ($P < 0.05$), with Parcel dos Abrolhos showing near 90% of carbonate in sediment composition, Pontas Sul near 65%, and Pedra de Leste only near 50%. Coral cover was higher farther from mainland ($p < 0.01$), where zoanthid cover was smaller. Differences in colony sizes were found only for *M. braziliensis*, with smaller colonies occurring at Pedra de Leste ($p < 0.05$). It is suggested that terrigenous sediment distribution, associated with turbidity, may be the main factors controlling reef development at the Abrolhos Reefs.

Siliciclastic-Carbonate Mixed Sediments from the River Mouth of the Urauchi-Gawa to Coral Reefs in the Northern Part of Iriomote Island, Okinawa Prefecture

*Keiko TANAKA**, *Naoko HOSHINO*, *Kohei ABE*, *Shiro HASEGAWA*, *Hiroki MATSUDA*

805Toukann ooe kyasuteeru, Ooe1-5-12, Kumamoto city, Kumamoto Japan
kei@es.sci.kumamoto-u.ac.jp

Iriomote-jima Island is situated in the Yaeyama Islands, South Ryukyus, and is the second biggest island in Okinawa Prefecture. The island, covered with subtropical vegetation, is occupied mostly by the Miocene siliciclastic Yaeyama Group and is fringed by the Pleistocene reefal limestones and modern coral reefs. The study area located in the northern part of the island is an area from the river mouth of the Urauchi-gawa River to coral reefs off the Yoshino Beach. The river flows into a small embayment separated from open marine by Unarizaki Cape. A variety of sedimentary environments, such as mangrove swamp, beach, inner bay, outer bay and coral reefs, extends in this area. This study aims 1) to describe characteristics features and distribution of the siliciclastic-carbonate mixed sediments, and 2) to clarify critical factors controlling the distribution. To accomplish the above purpose, the following analyses were carried out; observation of sea-bottom sediments and reef organisms, *in situ* measurements of salinity, and analyses of grain size and total carbonate contents (TCC). Also examined were major bio-constituents, especially larger foraminifers, from 61 sea-bottom samples. The sediments in the study area are divided into six sedimentary facies: 1) Terrigenous Fine Sand Facies, 2) Terrigenous Fine Sand with Bioclastic Gravelly Sand Facies, 3) Terrigenous Fine Sand with *Operculina* Facies, 4) Near Reef *Baculogypsina-Calcarina* Gravelly Sand Facies, 5) Near Reef *Baculogypsina* Gravelly Sand Facies, and 6) Reef Facies. The terrigenous sediments are distributed mainly in the eastern part of the embayment along Tsukigahama Beach. On the other hand, the calcareous sediments with TCC of >80% extend in the northwestern and southern parts. The boundary between the sediments is sharp. The distribution is considered to be affected strongly by a counterclockwise current and a trapping of terrigenous sediments by seagrass in the embayment.

Reefs of the Mascarenes - Changes in Space and Time

*John TURNER**, *Rebecca KLAUS*, *Emily HARDMAN*

School of Ocean Sciences, Marine Science Laboratories, University of Wales, Bangor, Menai Bridge Anglesey Gwynedd, Wales, UK LL59 5EN United Kingdom of Great Britain and Northern Ireland
J.turner@bangor.ac.uk

Sustainable management and conservation of coral reef resources require an understanding of the dynamics of reef ecosystems at appropriate scales and times. Changes to the reefs of the Mascarenes have been significant in recent times (last 20 years), but past changes almost certainly had greater impact, and there is evidence that coral communities have adapted to particular environmental factors at different locations. The reefs of St Brandon, Mauritius, Rodrigues and Reunion are of different age, structure and development. The islands were not colonised by Man until relatively late (late 1500s), and it may be assumed that modern reefs were pristine until this time, having adapted to cyclones and higher sea levels. Early observations of reefs, lagoons and islands reported in ships' logs, diaries and literature, and data on population and deforestation from colonial times provide evidence of environmental degradation over 400 years, and are critically evaluated. The more recent accelerated development (exceptionally fast in Mauritius over two decades, and lower in other Mascarenes) has further resulted in degradation of water quality and reef biotopes, due mainly to sedimentation, eutrophication, overfishing and climate change. Data from remote sensing and biotope surveys is compared between 1979 and 2003. Within biotopes, coral reefs change due to natural and anthropogenic threats acting at scales varying from localised impact due to development projects, spatial re-arrangement with diversification by cyclones, and major phase shifts resulting from coral bleaching. At the cellular level, algal symbiont populations harboured by corals show change, and the timing of large scale perturbations acting at particular stages in coral and algal symbiont life-histories have important effects on reef recovery. Knowledge of these ecological processes acting at different scales in time and space allows better prediction of impacts and assists in the protection of vulnerable coral reefs.

Comparison of Benthic Communities in Coral Reefs at Tiaoshi in Nanwan Bay, Southern Taiwan

Bing-Je WU*, Lee-Shing FANG, Kwang-Tsao SHAO, Tung-Yung FAN
2 Houwan Road, Checheng, Pingtung 944 Taiwan
tyfan@nmmmba.gov.tw

Coral community at Tiaoshi in Nanwan Bay, southern Taiwan was originally dominated by branching *Acropora* corals which formed many monopolized patches. However, the community has been changed apparently on a local scale (2 km). Some of the *Acropora* patches were completely replaced by the solitary sea anemone *Condylactis nanwannensis* followed typhoon events that occurred in 1994. However, sea anemones in several of these anemone-monopolized patches decreased in 2002 and 2003. To understand the change of these benthic communities, three sites of *Acropora*-dominated, anemone-dominated and coral recovery at depths of 6 to 10 m were selected and monitored by permanent transects. Each site included three replicate patches. Branching *Acropora* dominated site had 65.4% mean cover of hard corals with 57.2% of branching *Acropora*. At the anemone dominated site, the mean cover of the anemone was 24.5%, followed by 10.6% macroalgae and 4.3% hard corals. At the coral recovery site, the mean cover of the hard corals, macroalgae and anemone was 20.2, 16.7 and 1.1%, respectively. It is interesting that the most abundant scleractinian coral recolonized was *Montipora stellata* (9.6%) while branching *Acropora* was only 2.6% at the coral recovery site.

Occurrence of Anaerobic Photosynthetic Bacteria in Nongeniculate Coralline Algae and Massive Corals

Seitaro S YAMAZAKI*, Takashi NAKAMURA, Hideo YAMASAKI
Okinawa 903-0213, Japan
montastrea@hotmail.com

Reef-building corals have evolved for adapting to low nutritional environments by acquiring carbon and nitrogen assimilation capabilities through the establishment of endosymbiosis with dinoflagellates. In nitrogen assimilation, the primary form of nitrogen compound should be either nitrate (NO_3^-) or ammonium ions (NH_4^+) but not nitrogen gas (N_2). In a long-term cultivation in aquarium, we observed that corals grew normally for more than five months without supplemental nitrogen compounds (NO_3^- , NH_4^+ or organic materials). This preliminary observation led us to investigate the possibility for the presence of N_2 -fixing activities in a closed aquarium. It is known that gaseous nitrogen (N_2) is fixed to ammonia by specific bacteria (N_2 -fixing bacteria) through the activity of the enzyme nitrogenase. Because the enzyme activity is extremely labile in the presence of molecular oxygen, N_2 -fixation process requires anoxic environment. In this study we examined the occurrence of N_2 -fixing bacteria in anoxic space in reef-building corals and nongeniculate coralline algae. Photosynthetic pigments were extracted with appropriate solvents from nongeniculate coralline algae and corals. The identification of the photosynthetic pigments was carried out with spectral analysis and thin layer chromatography (TLC). TLC showed that nongeniculate coralline algae with benthic space included two major chlorophyll components whose *Rf* values agreed to those of the plant *Trifolium repens*. There was another band of chlorophyll whose *Rf* value corresponded to that of green sulfur bacteria. Spectral analysis revealed that these chlorophylls were chlorophyll *a*, *b* and bacteriochlorophyll *c*. We conclude that green sulfur bacteria, along with chlorophyta or with prochlorophyta, exist in thin anoxic space and may fix N_2 to produce N-forms available for other organisms.

The Replacement of Branching *Acropora* Coral Community by Solitary Sea Anemone in Southern Taiwan

Bing-Je WU*, Lee-Shing FANG, Kwang-Tsao SHAO, Tung-Yung FAN
2 Houwan Road, Checheng, Pingtung 944 Taiwan
tyfan@nmmmba.gov.tw

The benthic community in the Inlet of the Nuclear Power Plant in southern Taiwan was originally dominated by branching *Acropora* corals which formed monopolized patches. However, the community had been markedly changed on a local scale (1 km). Much area of the *Acropora* patches was completely replaced by the solitary sea anemone *Mesactinia ganesis* with unknown reason. The sea anemone has formed dense aggregation on the surface of dead *Acropora* coral skeleton. Three areas were monitored by permanent transects at depths from 1 to 5 m. The mean cover of the sea anemone *M. ganesis* was 43.0%, followed by 12.4% hard corals and 4.1% macroalgae. This suggests that the sea anemone *M. ganesis* is an aggressive competitor for space in interspecific interactions with *Acropora* corals in southern Taiwan.

Identification of Shallow-water, Coral Reef Sub-environments Based on Foraminiferal Death Assemblages: An Example from Ishigaki Island, Okinawa, Japan

*Kazuhiko FUJITA**

Senbaru 1, Nishihara, Okinawa 903-0213 Japan
fujitaka@sci.u-ryukyu.ac.jp

In order to determine the degree to which shallow-water, reef sub-environments could be distinguished from each other based on foraminiferal data, modern foraminiferal death assemblages (0.5-2 mm size-fraction) have been examined in 21 surface sediment samples from a variety of coral reef sub-environments (three replicates by seven sample sites), off the north coast of Ishigaki Island (Okinawa, Japan). The sample sites comprise four sub-environments on reef flat (beach, seagrass beds, shallow lagoon, and reef crest) and three depths on fore-reef slopes (6, 18, and 30 m). Relative abundances of foraminiferal tests in reef sediments are higher on reef crest (>50%) than other sites. Fragments of the discoid foraminiferan *Soritidae* are more common in back-reef sediments, while those of the red, encrusting foraminiferan *Homotrema* are more common in fore-reef sediments. The taxonomic composition of foraminiferal death assemblages exhibits a striking contrast between reef flat and fore-reef sediments. Reef flat foraminiferal assemblages are characterized by the dominance of the *Calcarinidae*, while fore-reef foraminiferal assemblages are characterized by the presence of various dominant species (>3% of foraminiferal assemblages at any site). Diversity indices [Species richness (S), Shannon-Wiener diversity index (H), and Fisher's diversity index (λ)] are higher on the fore-reef than reef flat. Multivariate analyses (Q-mode cluster analysis and non-metric multidimensional scaling ordination) of foraminiferal death assemblages based on the Bray-Curtis dissimilarity matrix clearly delineate the following five reef sub-environments: beach, back-reef, reef crest, shallower fore-reef, and deeper fore-reef. Combined these foraminiferal data would be useful for paleoenvironmental interpretations of the Quaternary reef deposits in the Western Pacific, particularly for the identification of fringing reef growth patterns during Holocene sea-level fluctuations.

The Middle Pleistocene Reef-complex Limestone in Maeda-misaki Area, Okinawa-jima, the Ryukyu Islands, Japan

*Atsuko MURAOKA**, *Yasufumi IRYU*, *Kei ODAWARA*, *Tsutomu YAMADA*, *Tokiyuki SATO*

Aobayama, Sendai 980-8578 Japan
netarou@dges.tohoku.ac.jp

The Pleistocene Ryukyu Group, consisting mainly of reef-complex deposits, is exposed in Maeda-misaki (Cape Maeda) area, central Okinawa-jima, the Ryukyu Islands, southwestern Japan. Although many stratigraphic and sedimentologic investigations have been conducted for some 50 years on the reef-complex deposits in Yomitan area which is adjacent to Maeda-misaki area, there are few references on the Group in the latter. The Upper Cenozoic sequence, unconformably overlying phyllite of the pre-Tertiary Nago Formation, comprises the Ryukyu Group and Holocene beach and alluvial deposits. The Group consists of the Sobe Formation unconformably overlain by younger limestones. The Sobe Formation constitutes the main body of the Group, exceeding 35 m in thickness, and is exposed at elevations up to 90 m. It is divisible into five units (Units 1 to 5 in ascending order), each consisting of proximal coral limestone and distal rhodolith, *Cycloclipeus-Operculina*, and detrital limestones. The Yontan Limestone proposed by Flint et al. (1959) is equivalent to Unit 4. This unit rests unconformably on the lower ones at elevations of >20 m, contrasting well with its conformable relationships with Unit 3 below the elevation. The younger limestones are found at 3 sites on the coast. They include coral and detrital limestones, each of which is less than 4 m in thickness. The stratigraphic relationship between the detrital and coral limestones remains unknown due to their limited occurrences. Calcareous nanofossil biostratigraphy indicates the lower part of the Sobe Formation ranges in age from 0.41 to 0.85 Ma, implying that extensive coral reef formation started at -0.9 Ma in Okinawa-jima. This is roughly synchronous with the Mid-Pleistocene Climate Transition (MPT) at which marine oxygen isotopes increased in amplitude and frequency.

From Mud Sea to Coral Sea - Changes in Marine Environment in Southern Okinawa-jima in Early Pleistocene Time

*Kei ODAWARA**, *Yasufumi IRYU*

Aobayama, Sendai, Miyagi Prefecture, 980-8578 Japan
odawara@dges.tohoku.ac.jp

Upper Cenozoic sequence in southern Okinawa-jima consists of Pliocene siltstone (Shimajiri Group), Plio-Pleistocene bioclastic sandstone/limestone (Chinen Formation), and Pleistocene reef-complex deposits (Ryukyu Group). The stratigraphic succession indicates that marine environment in southern Okinawa-jima in early Pleistocene time. One prevailing scenario of reef initiation in the Ryukyus is that coral reef commenced to form in middle Pleistocene time immediately after the Kuroshio Current flew into the Okinawa Trough. This is based on an outdated theory that the Ryukyu Group is middle to upper Pleistocene in age and that it unconformably overlies the Shimajiri Group. We have conducted sedimentologic and biostratigraphic investigations on the Upper Cenozoic sequence in southern Okinawa-jima. Although the Chinen Formation unconformably overlies the Shimajiri Group, no calcareous nanofossil biozones are lacking in some places such as Urizun section. The upper part of the Chinen Formation is earliest Pleistocene in age (1.45-1.65 Ma). The lowest member of the Ryukyu Group ("Reddish Limestone") dates back to 1.21-1.45 Ma. Examinations of drilled cores have shown that the Reddish Limestone extends on southern Okinawa-jima. These indicate that changes in marine environment from mud sea to coral sea were rapid (< 0.5 million years) in southern Okinawa-jima. DNA analysis of a poisonous snake (*Trimeresurus flaviridis*) indicates that the Central Ryukyus have been isolated for the last 5 million years. Molecular biological data shows that snakes and frogs in the Central Ryukyus resemble those in central part of the mainland China. These, combined with the fact that coral reefs formed in the early Pleistocene time in Okinawa-jima, implies that the China-Okinawa Land Bridge did not exist for the past 5 my and that the Kuroshio Current flew into the Okinawa Trough in least early Pleistocene time.

Strontium Isotope Stratigraphy of Funafuti Atoll: Implications for Coral Reef Growth, Erosion and Sea-level Change

*Shigeru OHDE**, *Mervyn GREAVES*, *Harry ELDERFIELD*

1 Senbaru, Nishihara, Okinawa Japan
sohde@sci.u-ryukyu.ac.jp

Over a century after the 1896-98 Royal Society Coral Reef Expedition to Funafuti Atoll in the Pacific Ocean, the 340 m long drill core collected on the expedition has been dated, providing a two million year record of environmental change. The original purpose of the expedition was to carry out the experiment outlined by Charles Darwin in order to interpret the origin and history of atoll formation. But drilling did not reach the base of the atoll. Darwin's theory of 1842 that atolls form by growth of reefs to the sea surface on subsiding ocean floor was not therefore testable and it was left to U. S. drilling of Eniwetok and Bikini atolls in the 1950s (linked to the nuclear explosion experiments) to prove Darwin correct. Samples from the half of the Funafuti core preserved at the Natural History Museum have been dated. From radio carbon dating, the top 26.4 m of the core records the history of sea-level rise since 8000 years ago. High-precision Sr isotopic data made it possible to establish a chronology for the past two million years, dating a previously undatable core, and provides records of the history preserved in the atoll carbonates of the tropical Pacific. During the past 1.5 million years, more than 150 m of reef-lagoonal calcite (calcium carbonate) was deposited through the interplay between glacial/interglacial sea-level changes and subsidence of the Pacific tectonic plate. Sections of dolomite (Ca-Mg carbonate mineral) in the lower part of the core were formed through alteration of the reef between 1 and 2 million years ago, possibly by interaction with percolating seawater.

Mid-Quaternary Sea-level Fluctuations and Reef Development in Shallow-water Carbonates, Northwestern Pacific: Examples from Pleistocene Ryukyu Group

*Saburo SAKAI**, *Natsume SAGAWA*

2-15 natsushima-cho, Yokosuka, Kanagawa Japan

saburo@soc.shimane-u.ac.jp

Shallow-water carbonates (SWC) are one of the best recorders of sea-level changes, because they contain fossils from which both geochronology and paleobathymetry can be determined. Developing a chronology for Early to mid-Quaternary SWC, however, has been problematic because they are beyond the limits of U-series dating, and diagenetic alteration has precluded the use of marine oxygen isotope stratigraphy for the determination of chronology. Three new developments allow us to return to the study of relative sea-level change in the Early to mid-Quaternary: (1) the discovery of original oxygen and carbon isotope signals of planktic foraminifers preserved in diagenetically altered SWC [Sakai & Kano, 2001], which allows accurate correlation with the marine oxygen isotope stratigraphy, (2) sedimentological and biotic/faunal proxies such as coral assemblages have been developed as high-resolution paleobathymetric indicators [e.g., Sagawa et al, 2001], (3) the use of negative $\delta^{13}C$ excursions in early diagenetic carbonates as indicators of episodic subaerial exposure, which is often difficult to recognize based on descriptive sedimentology [e.g., Allan and Mathhews, 1982; Sakai, 2003]. Here we present a more detailed relative sea-level curve during the Early to mid-Quaternary than any previously available. This work is based on the Pleistocene "Ryukyu Group" SWC and the three methods described above. The relative sea-level curve we analyzed is characterized by high-frequency and low-amplitude cycles for Phase 1 (~1.5-1 Ma: Pre-Mid Pleistocene Revolution (MPR)), transition to lower-frequency and greater-amplitude cycles during Phase 2 (~1-0.8 Ma: MPR), and low-frequency and high-amplitude cycles for Phase 3 (~0.8 Ma: Post-MPR). In addition, both sea-surface temperature and carbonate accumulation rates increased from Phase 1 to Phase 3, which suggests that warming at about 0.8 Ma and change to high-amplitude sea-level fluctuation may have been important for the widespread expansion and development of reef-complexes at this time.

Interstadial Coral Reef Terraces and Relative Sea-level Changes during Marine Oxygen Isotope Stages 3-4, Kikai Island, Central Ryukyus, Japan

*Keiichi SASAKI**, *Akio OMURA*, *Kazuo MURAKAMI*, *Natsume SAGAWA*, *Toru NAKAMORI*

10 Sue-machi, Kanazawa, 920-1392 Japan

sasaki1@kanazawa-gu.ac.jp

Coral reef terraces are one of the best recorders of relative sea-level changes during the last glacial cycle. Thus far, knowledge of detailed sea-level record based on coral reef terraces during the marine oxygen isotope stage (OIS) 3 has been limited to studies of the Huon Peninsula, Papua New Guinea. Lithostratigraphic investigation and high-precision $^{230}Th/^{234}U$ dating demonstrated an offlapping sequence of five coral reef complexes, ages of which are ~66 ka, ~64 ka, ~62 ka, ~55 ka, and ~52 ka, in the northern part of Kikai Island, central Ryukyus of Japan. We obtained 18 reliable $^{230}Th/^{234}U$ ages after evaluation of closed system behaviour of mineralogical and U and Th isotopic compositions. They range from 74.9 ± 0.9 to 51.3 ± 0.6 ka ($\pm 1\sigma$). Interstadial reefs of Kikai are characterized by the give-up type of growth pattern in contrast to the typical catch-up reefs forming marine terraces. Detailed examination of the coral assemblages provided evidence for deepening-upward sequences just beneath the terraces. These reefs recorded three hemicycles from transgression to highstand at ~52, ~62, and ~66 ka. Although large uncertainty is included in timing of the ~66 ka peak, correlations between these highstands and the eustatic record reconstructed from the Huon reef terraces indicate that eustatic rises caused drowning of these reefs. The minimum rates of eustatic rises at ~52 and ~62 ka are estimated to be 2.1 and 1.5 m/kyr, respectively. Consequently, the give-up reefs constructed poorly developed and irregular shaped marine terraces in this island. Further, three peaks at ~52, ~62, and ~66 ka can be correlated with the interstadials 14, 18 and 19 of the GISP 2 oxygen isotope record. This consistency implies the eustatic sea level responding to the millennial-scale climate changes even during the glacial period of OIS 4.

Pleistocene Reef Development on Ie-jima, the Ryukyu Islands, Southwestern Japan

*Tsutatu TAKEUCHI**, *Yasufumi IRYU*, *Tsutomu YAMADA*, *Kei ODAWARA*

Aobayama, Sendai 980-8578 Japan

finale@dges.tohoku.ac.jp

The Pleistocene Ryukyu Group composed of reef-complex deposits crops out on Ie-jima, off Motobu Peninsula, the Ryukyu Islands, southwestern Japan. Sedimentologic investigations were conducted on the carbonates from boreholes drilled to construct an underground dam. The Group comprises lower, middle and upper parts, the every part being unconformable to each other. The lower part is composed exclusively of thin (< 5 m thick), altered coral limestone that is similar in lithology and stratigraphic position to the "Reddish Limestone" reported from southern Okinawa-jima. The middle part (< 80 m) constitutes the main body of the Group on this island, consisting of 3 units. The lowest unit is composed of marine conglomerate (< 30m) that grades upward into detrital limestone containing abundant larger foraminifera (*Operculina*). In some cases, terrestrial conglomerate occurs at the base. The other units commence with shallower coral limestone overlain by deeper rhodolith and detrital limestones, clearly displaying a deepening-upward stratigraphic succession. The upper part is thin (< 20 m thick) and composed of two units. The lower unit begins with coral limestone that grades upward into detrital limestone rich in coral rubble. The upper unit consists of coral limestone. Geologic ages of the Ryukyu Group in this island have not been well constrained because calcareous nannofossils are poorly preserved. It is evident from the stratigraphic succession and configuration of lithofacies that the reef grew in response to at least six repeated cycles of sea-level change with amplitude of up to 50 m during the deposition of the Ryukyu Group in Ie-jima.

Paleo Sea-level History of the Pleistocene Ryukyu Limestone of Yomitan Area Okinawa, Japan: Integrated Hermatypic Coral, Larger Foraminiferal and Microfacies Data

*Melaku TESFAYE**, *Kazuhiko FUJITA*, *Kaoru SUGIHARA*, *Kouchi NAGAI*, *Satoshi YAMAMOTO*

Marine and Environmental Science, Graduate school of Engineering and Science, University of the Ryukyus, Nishihara, Okinawa, 903-0129, Japan

melakutesfaye@yahoo.com

Thick successions of the Pleistocene Ryukyu limestone exposed in the Naghama, Chuo and Morioka quarries of Yomitan area, central Okinawa, Japan have been examined. Detailed sedimentological studies of these exposures have revealed six stratigraphic units each bounded by exposure surfaces of considerable lateral extent, which can be traced for long distance. Paleodepositional environments of these units have been assessed based on community types of hermatypic corals and taxonomic composition of larger foraminifera as well as fluctuation patterns of microfacies belts. Paleodepth estimates of these analyses have been compared with published accounts of present-day depth distributions of hermatypic coral communities and larger foraminifera in the adjacent area of Okinawa. Finally, a paleo sea-level curve has been constructed from the integrated estimates, and then compared with the oxygen isotope records from deep-sea foraminifera using available calcareous nannofossil age data as a control. The result shows that the stratigraphic pattern records an imprint of sea level changes during the glacial and interglacial periods in marked contrast.

Quaternary Sea-level Rise and Reef Backstepping in Southeast Florida*Brian K WALKER**, *Richard E DODGE*, *Bernhard RIEGL*, *Kenneth BANKS*

8000 North Ocean Drive, Dania Beach, FL 33004-3078 United States of America

walkerb@nova.edu

Bathymetric and subbottom surveys off the southeast coast of Florida have clarified the presence of three Holocene reefs containing *A. palmata* frameworks in shallow water (7m, 12m, and 16m depth). Two deeper structures (40m and 85m depth) have been identified, which may be reefs as well. Three-dimensional surfaces and profiles were derived from multibeam SONAR and LADS bathymetric survey data to map the topography. Chirp subbottom profiles were also collected along several transects, which indicated the deeper structures are frequently covered by a sand veneer. Coring of the shallower reefs confirms the subbottom profile results nearshore. Recently published Caribbean Holocene sea level data compared to the reef bathymetry (and thickness when available) suggests that the 85m structure (5th reef) was at or near the sea surface at the onset of meltwater pulse (MWP) 1A, starting about 14.5 ka. Subbottom data do not show reef structure. The base of the next deepest structure, the 40m 4th reef, coincides with the end of MWP 1B, approximately 11 ka. From this point until recent, the slowing of sea level rise has apparently allowed the nearshore reefs to backstep onto newly submerged shorelines. The 3rd reef morphology and internal composition illustrates a classical reef structure, with a spur and groove formation and *A. palmata* crest and framework. The data also suggest that concurrent to 3rd reef growth, there was a nearshore fringing reef, the present day 2nd reef. Today, the shallow reefs are covered by a high-density octocoral and sponge community interspersed by low-density and low-coverage scleractinian corals (without live *A. palmata*). The timing of initiation, switch-off, and backstepping in the shallow and deeper reefs as well as their composition merits further investigation.

Pleistocene Reefal Deposits in Tarama-jima Island, Southern Ryukyus, Southwest Japan*Shigeaki YAMADA**, *Hiroki MATSUDA*, *Akio OMURA*

Kakuma-machi, Kanazawa Japan

yamadas@kenroku.kanazawa-u.ac.jp

Tarama-jima Island is wholly covered with the Pleistocene reefal deposits composed of the following six sedimentary facies; Coral (Co), Coral-Bioclasic (CB), Rhodolith (Rh), Large foraminiferal (LF), Halimeda (type A, Ha, and B, Hb) and Bioclasic (Bc) limestone facies. The deposits are divided into three units, TR-Unit 1, 2 and Dune Unit, which correspond to a sedimentary sequence related to glacioeustatic sea-level changes. TR-Unit 1 consists of Rh, LF and Hb limestone facies, indicating that the unit was deposited on an insular shelf with Halimeda mound at 50 to 150m deep. TR-Unit 2 consists mainly of Co, CB, Bc and Ha limestone facies, associated with three fossil coral assemblages of *Acropora hyacinthus*, *A. palifera* and mixed. The sedimentary facies and fossil coral assemblages suggest that the deposition of the unit was on reef flat to upper reef slope at 0 to 5m deep. TR-Dune Unit is composed of aeolian carbonate sediments. A depositional age of TR-Unit 2 correlates to Oxygen isotope stage (MIS) 4 to 5a, 5c, 6 and 7 by U-series dating of coral skeletons from the unit. From the above line, it is concluded that the depositional environment of the reefal deposits in Tarama-jima Island drastically changed from an insular shelf deeper than 50m deep to coral reefs shallower than 5m deep before MIS 7 by tectonic uplifting. During the deposition of TR-Unit 2, the environment favorable to coral reef development was repeatedly formed with glacioeustatic sea-level changes under the stable tectonic condition. As a result, the reef complex composed of several coral reefs at different MIS stages was developed. After MIS 5c, the uplifting started again with the uplifting rate of ca. 0.28m/ka.

Early Pleistocene Reef Complex Deposits on Motobu Peninsula, Okinawa-jima - Its Significance of the Initiation of Coral Reefs in the Ryukyus*Kazuyuki YAMAMOTO**, *Yasufumi IRYU*, *Tokiyuki SATO*, *Hiroshi NAKAGAWA*

Abayama, Sendai 980-8578 Japan

kazu@dges.tohoku.ac.jp

Before 1990's, it had been considered that reef growths started in middle Pleistocene time in the Ryukyus. However, coral reef deposits older than 1 Ma were found from some islands in the early half of 1990's, which showed that the reef formation in the Ryukyus might date back to early Pleistocene time. We investigated reef-complex deposits and their related siliciclastic sediments on Motobu Peninsula, northern Okinawa-jima. The Ryukyu Group comprises the Kourijima Formation and younger limestones in this area. The Kourijima Formation, resting on the pre-Tertiary basement rocks, is divided into three units, each consisting of proximal coral limestone and distal rhodolith, detrital, and *Cycloclypeus-Operculina* limestones. The limestones pass laterally into siliciclastic and calcareous sediments on the neck of the peninsula. These sediments are divided into the Guga and Nakoshi Formations. The Guga Formation consists of fluvial conglomerate with intercalated beds of marine siltstone. The Nakoshi Formation conformably overlies the Guga Formation and is composed of calcareous siltstone/sandstone. Calcareous nannofossil biostratigraphy indicates that the upper part of the Guga Formation were deposited in early Pleistocene time and that the lowest part of the Kourijima Formation and the Nakoshi Formation are coeval, ranging in age from 1.45-1.65 Ma. This is the oldest of all the ages known from the Ryukyu Group. In early Pleistocene time, coral reefs formed and the coeval siliciclastic and calcareous sediments accumulated on Motobu Peninsula. In contrast, sedimentation was prevailed by calcareous muds/sands in central-southern Okinawa-jima that is presumed to have been in shelf edge to shelf slope environment at that time. This suggests rapid tectonic uplifts of central-southern Okinawa-jima relative to the northern part in late Pliocene to early Pleistocene time. The reef-complex deposits on Motobu Peninsula provide important information on initiation and development of coral reefs as well as tectonic history in the Ryukyus.

A Six-year Continuous Record of Sea Surface Salinity and Seawater Isotopic Composition at Ishigaki Island, Southwest of Japan

Osamu ABE*, Seizen AGATA

Hydrospheric Atmospheric Research Center, Nagoya University, 464-8601, Nagoya, Japan

oabe@ihas.nagoya-u.ac.jp

Salinity is one of the most important parameters for the oceanographic investigations. Combined with another parameters, such as water temperature, it is possible to evaluate horizontal and vertical mixing of water masses, heat and water fluxes between ocean and atmosphere, freshwater inputs from land, etc., using Sea Surface Salinity (SSS). On the other hand, Isotopic composition of seawater (D/H and O-18/O-16) is considered as a promising approach to evaluate these processes quantitatively, based on the particular isotopic composition of each water masses and isotope fractionation during kinetic and equilibrium transfer processes. In general, both ratios of D/H and O-18/O-16 correlate positively with SSS because most of freshwater have a lower isotopic composition than that of seawater. D/H and O-18/O-16 show almost similar characteristic in seawater except for evaporation process. During evaporation, oxygen isotope is more fractionated relative to hydrogen isotope; therefore, quantitative estimation of evaporation process at sea surface can be derived using difference in fractionation between oxygen and hydrogen isotopes. Seawater sampling was conducted at every 10-day interval since December 1997 to date at Ishigaki Harbor, located on south of Ishigaki Island. Both SSS and isotopic composition indicates low values in summer and high values in winter during the observation period due to more rain in the former while evaporation is high in the latter season.

Can Fossil *Porites* Be Utilised for Reconstruction of Climate during Marine Isotope Stage 9 (Mis 9), Henderson Island, SE Pacific?

Bridget F AYLING*, Malcolm T MCCULLOCH

Research School of Earth Sciences, The Australian National University, ACT 0200, Australia

Bridget.Ayling@anu.edu.au

The carbonate skeleton of fossil corals has the ability to provide a high resolution archive of modern and past climate. Numerous studies have reconstructed modern and Holocene climatic conditions using corals from a variety of tropical locations. However few studies exist that extend high resolution climate data further into the past, particularly into previous interglacial periods. Reasons for this fall predominantly into two categories : (a) lack of suitable fossil coral to work on due to limited existence of paleoreefs older than MIS 5e, and (b) post mortem effects of diagenesis on coral, resulting in degradation of primary skeletal geochemistry. Henderson Island is an emergent limestone island, uplifted ~30m due to lithospheric flexure associated with the emplacement of Pitcairn Island 200km distant at 800kyr BP. In this study, we attempt to reconstruct climate during MIS 9, utilizing fossil *Porites* coral from Henderson Island, (dated by U-series as 304-326 kyr BP). These fossil corals appear remarkably well preserved for their age, and together with chronological studies, their potential for paleo-proxy work was examined. Established coral geochemical proxies including Sr/Ca, U/Ca and ^{18}O (temperature and salinity), Ba/Ca (upwelling signals) and residual ^{18}O (salinity) enable constraints to be placed on MIS 9 climate. Preliminary results from XRD, petrographic thin sections and scanning electron microscopy (SEM) indicate diagenesis has certainly occurred, predominantly in the form of dissolution, aragonite-aragonite neomorphism and precipitation of syntaxial inorganic aragonite, but calcite diagenesis is not significant at this site. As such, traditional bulk sampling techniques which can potentially incorporate both primary and secondary inorganic aragonite may not be appropriate in this instance. A new method of retrieving climate information from these partially altered fossil corals is being investigated, using a combination of SEM and high resolution LA-ICPMS to avoid areas affected by diagenesis. Results using this approach will be reported.

A 52-Year Record of Mg/Ca and Sr/Ca Ratios in a Modern *Porites* Coral from Con Dao Island, Vietnam

Phong X DANG, Takehiro MITSUGUCHI*, Hiroyuki KITAGAWA, Tetsuo UCHIDA, Yasuyuki SHIBATA

18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam

aal53740@nyc.odn.ne.jp

We measured Mg/Ca and Sr/Ca ratios in a coral skeletal core (*Porites* sp.: 68 cm in length) collected in May 2000 from Con Dao Island, Vietnam, ~90 km distant from the mouth of the Mekong River. UV luminescence photography and X-radiography of the skeletal core revealed 53 annual growth bands from 2000 back to 1948 with an average skeletal extension rate of ~11 mm/year. The annual nature of the skeletal growth bands was confirmed by radiocarbon analyses showing an abrupt increase of $\Delta^{14}\text{C}$ around 1955 that is due to atmospheric nuclear tests. Along the skeletal growth axis, 627 subsamples were manually picked out with a special needle at 1-mm increments, corresponding to a temporal resolution of ~5 weeks. An aliquot (~1 mg) of each subsample was reserved for ^{18}O and ^{13}C analyses. The remaining aliquot (~2.5 mg) was treated with 99.5% ethanol and 0.004 mol/L HNO_3 dissolved in 0.5 mol/L HNO_3 , and measured for Mg, Ca, and Sr by inductively coupled plasma atomic emission spectrometry (ICP-AES). Results showed seasonal variations of the Mg/Ca and Sr/Ca ratios throughout the 52 years of skeletal growth. The Mg/Ca and Sr/Ca variations seem to be partially incompatible with the variation of sea-surface temperature observed in Con Dao Island, implying that environmental factors associated with the Mekong River discharge (e.g., suspended matter, salinity) and/or metabolic effects may also influence the Mg/Ca and Sr/Ca ratios.

Seasonal Variations of Middle Eastern Climate during the Holocene Documented in Fossil Red Sea Corals

Thomas FELIS*, Henning KUHNERT, Saber AL-ROUSAN, Juergen PAETZOLD

Klagenfurter Str., 28359 Bremen Federal Republic of Germany

tfelis@allgeo.uni-bremen.de

Recent studies from the northernmost Red Sea have shown that annually banded corals from this subtropical site (28-29 degrees North) can provide proxy records of atmospheric variability over the extratropics of the Northern Hemisphere. In a more regional context, these records based on *Porites* corals provide information about the influence of climate phenomena such as the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) on Middle Eastern climate. Here we present new coral records obtained from about 20 fossil *Porites* colonies collected near the northern end of the Gulf of Aqaba. The coral records are based on oxygen isotopes, Sr/Ca, and U/Ca and have a bimonthly resolution. The time windows provided by individual fossil coral colonies have a length of a few to several decades, and provide information about changes in the seasonal cycle of temperature and hydrologic balance for the period between about 6000 to 2000 years ago. The influence of changes in the AO/NAO on changes in the seasonal cycle in the Middle East during the mid to late Holocene will be discussed.

Historical Climate Variation in Belize (Central America) as Recorded in Scleractinian Coral Skeletons

*Eberhard GISCHLER**

Senckenberganlage 32, 60054 Frankfurt am Main Federal Republic of Germany
gischler@em.uni-frankfurt.de

Three cores from *Montastraea faveolata* and one core from *Siderastrea siderea* from the Belize reef complex were analyzed with regard to sclerochronology (skeletal extension rates) and stable isotope geochemistry ($\delta^{18}O$ and $\delta^{13}C$). The cores cover the time span from 1815 to 2000. Time series were compared with historical climate data available such as sea surface temperatures (GISST 2.3b), cloud cover (GHCN), and precipitation (COADS). Skeletal extension rates measured in the cores average 8.5-14 mm/year in *M. faveolata* and 8 mm/year in *S. siderea*. No systematic correlations between extension rates and historical climate data were detected. Annual variation in oxygen isotopes is 0.6-0.8‰ and accounts for monthly averages of sea surface water temperature fluctuations of 3-4°C. In the cores from the Belize shelf and barrier reef negative correlations of $\delta^{18}O$ with the GISST 2.3b data were observed. Time series analyses of the oxygen isotope data revealed a decadal periodicity, which may be attributed to the influence of the Atlantic SST dipole variation. Carbon isotopes of the Belize shelf and barrier reef also exhibit negative correlations with the GISST data. It may be speculated that warmer years were characterized by higher cloud cover leading to reduced photosynthesis rates in the corals. Indeed, there is a negative correlation between $\delta^{13}C$ and historic cloud cover data. Carbon isotopes in the Belize shelf and barrier reef cores also exhibit general trends towards lighter values in time indicating the uptake of fossil fuel CO_2 in the coral skeletons. A proxy data time series from a core from the restricted Turneffe Atoll lagoon differs from those of the Belize shelf and barrier reef cores, and there are no systematic correlations with historical climate and proxy data. This is probably a consequence of the strong influence of local environmental factors, which obliterate broader scale environmental parameters.

Coral X-Radiograph Densitometry System (Coral Xds): Measuring Coral Growth and Analyzing Relationships with Skeletal Chemistry

Kevin P. HELMLE, Kevin E. KOHLER, Richard E. DODGE, Peter K. SWART, C. Mark EAKIN*

8000 N Ocean Drive, Dania, Florida 33004 United States of America
kevinh@nsu.nova.edu

The information content included within the skeletons of reef-building corals is potentially prolific, but much continues to remain cryptic. Proxy records from skeletal chemistry are fundamentally related to skeletal accretion and therefore are more completely interpreted in conjunction with coral growth data. Skeletal density data is an underutilized resource that provides a continuous chronological record of coral growth and permits the determination of linear extension and calcification. CoralXDS is a program for measurement of linear extension and density from coral X-radiographs and for the determination of calcification for high-density, low-density, and annual bands. The program allows the input of isotopic or elemental data. These multiple chemical datasets can be delimited by their annual signals and matched to the annual peaks and valleys shown by the skeletal density bands. Vertical data stacking allows rapid visualization of where annual signals may be common or absent between datasets. This provides a method of cross-dating within a single coral core using multiple parameters. The absence of expected signals (either isotopic, elemental, or density) may be indicative of an event not well recorded by a certain parameter. Such a missing signal might otherwise go unnoticed; however, in comparison with multiple datasets, the absent signal may be found and indicate an event of biological importance (e.g., the influence of bleaching, disease, or other such stressors). CoralXDS is conducive for locating anomalies in isotopic, elemental, and density records thus helping to identify time relationships, correlations, and possible causations. This multi-proxy approach to sclerochronology will aid in developing more accurate coral chronologies and will help to identify relationships between skeletal-chemistry and density-band records.

Reconstruction of Water Mass Mixing Caused by the Mindanao Dome and El Niño in the Western Tropical Pacific Using Coral Skeletal Radiocarbon

Hiroko IJIMA, Hajime KAYANNE, Maki MORIMOTO, Osamu ABE, Hiroyuki MATSUZAKI*

7-3-1 Hongo, Tokyo, 113-0033, Japan
ijima@eps.s.u-tokyo.ac.jp

Coral skeletal radiocarbon ($\delta^{14}C$) records reflect surface seawater $\delta^{14}C$ and are useful for reconstructing the history of water mass mixing in the tropical oceans. In this study, we have reconstructed the annual and seasonal variations of surface and intermediate water mass mixing by using coral skeletal $\delta^{14}C$ records from the Palau Islands in the western tropical Pacific. The coral $\delta^{14}C$ records exhibited seasonal cycles with higher values during winter than those during summer to autumn. The vertical distribution of seawater $\delta^{14}C$ close to Palau indicated high $\delta^{14}C$ peak at 70-80m (WOCE, P9 cruise; 7°N, 137°E) derived from "subtropical mode water". Regional upwelling event called Mindanao Dome in northern winter, which is the cyclonic circulation composed of the North Equatorial Current, the Mindanao Current, and the North Equatorial Countercurrent between the Mindanao Island of the Philippines and Palau, was reported by Masumoto and Yamagata (1991). The formation of Mindanao Dome conveys the intermediate water with high $\delta^{14}C$ to the surface, which then might be recorded in the coral skeleton as the seasonal ^{14}C cycles. From the end of 1996 to 1999, during which period the 1997-98 El Niño occurred, the coral skeletal $\delta^{14}C$ decreased by 40 per mil, which exceeded over the magnitude of seasonal variation (20 per mil). During an El Niño event, the depth of thermocline (under sub-surface water) becomes thinner than usual in the western Pacific, and the mixing was activated between the surface water and the water under thermocline with low $\delta^{14}C$, which then made the surface $\delta^{14}C$ decrease. This study showed that coral skeletal $\delta^{14}C$ from Palau was recorded the upwelling event evidently with temporal resolution of seasonal to annual.

Time-series Monitoring of Stable Carbon Isotope Ratio of the Animal Tissues and the Skeletons in the Scleractinian Coral *Porites lutea*

Yohei MATSUI, Osamu ABE, Naohiro YOSHIDA*

G5-203, 4259 Nagatsuta, 226-8502, Yokohama, Japan
ymatsui@depe.titech.ac.jp

Stable carbon isotope ratio (C-13/C-12) of tissues and skeletons from identical coral colony had been monitored to investigate how C-13/C-12 of tissue changes in natural condition and how tissue signature relate to C-13/C-12 of skeletal calcium carbonate. Sampling was performed biweekly from July (summer) to November (winter) in 2002 at Ibaruma reef, Ishigaki Island, Japan. During summer to winter, C-13/C-12 of tissue showed positive correlation with light intensity, whereas negative correlation was found with rainfall and typhoon. C-13/C-12 of tissue, which were sampled in fine days, were correlated significantly with monthly average of light intensity prior to the sampling day ($r > 0.96$, $p < 0.01$). Skeletal growth rate was about 13 mm/y during monitoring period. C-13/C-12 of the skeleton was also best fitted with monthly average of light intensity prior to sampling ($r > 0.92$, $p < 0.01$). Though skeletal sample (0.25 mm) corresponds to growth of about 7 days only, however positive correlation with monthly average of light intensity could be due to monthly turnover of tissue carbon.

The Effect of Upwelling, Species and Depth on the Natural Variability of Cadmium in Three Species of Panamanian Corals

*Kathryn A MATTHEWS**, *Andrea G GROTTOLO*, *William F MCDONOUGH*, *James E PALARDY*

Hayden Hall/EES; 240 S. 33rd St; Philadelphia, PA 19104-6316
United States of America

kam2@sas.upenn.edu

The ratio of cadmium to calcium in coral skeleton ($\text{Coral}_{\text{Cd/Ca}}$) has been used as a qualitative tracer of oceanic upwelling. However, it is not well known if $\text{Coral}_{\text{Cd/Ca}}$ varies between species or across depth, and the extent to which this may affect the interpretation of $\text{Coral}_{\text{Cd/Ca}}$ proxy records. To test our null hypothesis of no variation in $\text{Coral}_{\text{Cd/Ca}}$ with species or depth, we measured the $\text{Coral}_{\text{Cd/Ca}}$ in three coral species commonly used in paleoclimate reconstruction (*Pavona clavus*, *Pavona gigantea* and *Porites lobata*) across two depths (1m and 6m) in the Gulf of Panama (Pacific) from January to July 2003, a period spanning both upwelling and nonupwelling intervals. Using a new analytical methodology, samples as small as 50 mg were measured using inductively coupled mass spectrometry for a suite of minor and trace elements. Preliminary data suggests a species-specific offset between *P. clavus* and *P. gigantea*. In addition, comparison with previously published $\text{Coral}_{\text{Cd/Ca}}$ data from the Galapagos shows that the $\text{Coral}_{\text{Cd/Ca}}$ range within species is similar, suggesting that $\text{Coral}_{\text{Cd/Ca}}$ calibrations would be applicable to all corals, irrespective of location, within a species. A comprehensive understanding of the natural variability in $\text{Coral}_{\text{Cd/Ca}}$ is a necessary step towards the development of this tracer as a quantitative upwelling proxy.

Early Mid-Holocene Sea-Surface Temperature in the Ryukyu Islands Reconstructed from Coral Mg/Ca and Sr/Ca Ratios

*Takehiro MITSUGUCHI**, *Eiji MATSUMOTO*, *Tetsuo UCHIDA*, *Peter J ISDALE*, *Toshio KAWANA*, *Hironobu KAN*

16-2 Onogawa Tsukuba Ibaraki 305-8506 Japan

aal53740@nyc.odn.ne.jp

We report Mg/Ca and Sr/Ca analyses for several coral skeletal samples (*Porites* spp.): one modern sample from the Great Barrier Reef (GBR), Australia and the others from the Ryukyus, Japan, including two fossil samples with calibrated ages of ~7270 cal BP and ~7670 cal BP. X-radiography for all these skeletal samples revealed annual growth bands with skeletal extension rates of 11-16 mm/year. Subsamples for the elemental analysis were manually picked out using a special needle along the skeletal growth axes at 1-mm increments, corresponding to temporal resolutions of 3-5 weeks. The subsamples were subjected to a series of chemical treatments, individually dissolved in 0.5 mol/L HNO_3 , and measured for Mg, Ca, and Sr using an inductively coupled plasma atomic emission spectrometer (ICP-AES). For all of the samples, the Mg/Ca and Sr/Ca ratios showed synchronous seasonal variations, indicating seasonal variations of sea surface temperature (SST). We calibrated a Mg/Ca-SST relationship and a Sr/Ca-SST relationship using the modern GBR sample and applied them to the results of the two fossil samples for SST reconstruction in the Ryukyus. For both of the fossil samples, Mg/Ca-derived SSTs are in excellent agreement with Sr/Ca-derived SSTs. In the early mid-Holocene (7.3-7.7 ka) in the Ryukyus, SST variation seems to have been almost the same as seen today.

Southwestern Pacific Sea Surface Temperature at 197 Ka Inferred from Oxygen Isotopic Composition of a Niue Coral

*Takashi MIWA**, *Tsutomu YAMADA*, *Yasufumi IRYU*, *Gustav PAULAY*

Aobayama, Sendai 980-8578, Japan

miwata@dges.tohoku.ac.jp

Oxygen isotopic composition of hermatypic coral is one of the fundamental tool for reconstructing past sea surface temperature in tropical and sub-tropical regions. In this study, we examined the isotopic composition of a fossil coral (*Porites* sp.) from Niue Island, southwestern Pacific in order to estimate past SST around the island. The fossil coral was collected at Limu, northeastern part of the island. Analyses of the coral skeleton using SEM and XRD confirmed that the skeleton had not been diagenetically altered. Uranium-series age of the coral was dated to 197 ± 3.5 ka. Isotopic composition of the coral was measured at an interval of 300 μm along two major growth trajectories that include 4- and 5-year increments, respectively. Skeletal materials of the two transects had formed roughly simultaneously. Skeletal extension rates along the transects averaged 7.0 mm/yr and 6.2 mm/yr. The $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values along the transects showed seasonal variations with $\delta^{18}\text{O}$ values of -3.88 ± 0.34 and -3.72 ± 0.32 permil, and $\delta^{13}\text{C}$ were -0.75 ± 0.45 and -0.60 ± 0.56 permil, respectively. The disagreement of $\delta^{18}\text{O}$ values between the two transects might arise from differences in degree of isotopic disequilibrium. Although relationships of coral $\delta^{18}\text{O}$, temperature at growth site and $\delta^{18}\text{O}$ of ambient seawater were reported in many studies, the equations proposed by Quinn et al. (1996, 1998) were thought to be most suitable for our case because the coral used in their study were collected in New Caledonia, southwestern Pacific. Annual mean SST in the Southwestern Pacific was estimated as 24.0-24.7 °C with annual amplitude of 3.6-4.0 °C at 197 ka, assuming seawater $\delta^{18}\text{O}$ to be 1.02 permil at that time. The reconstructed SST was about 1.9-2.6 °C cooler than the present with similar annual amplitude.

B/Ca, Sr/Ca, U/Ca and Mg/Ca Ratios of a Non-tropical Coral (*Cladocora caespitosa*) from the Northern Adriatic Sea (Mediterranean Sea) and their Relationship to Sea Surface Temperature

*Paolo MONTAGNA**, *Malcolm MCCULLOCH*, *Claudio MAZZOLI*, *Sergio SILENZI*

37 Corso Garibaldi, I-35137 Padova Italian Republic

paolo.montagna@unipd.it

Corals secrete calcareous skeletons with minor and trace elements contents being incorporated as a function of the physical and/or chemical parameters in the ambient seawater, modulated to varying extents by biologic factors. Trace element systematics in corals therefore have the potential to provide environmental records of sea surface temperature (SST), salinity (SSS), ocean chemistry, (e.g. ocean upwelling, and anthropogenic inputs). In smaller semi-enclosed basins such as the Mediterranean Sea, profound and complex changes are commonly observed. To assess the causes of these changes and their relationship to the broader scale global climate system, requires long-time series of parameters such as SST, which are not available from instrumental data. Here we report the calibration of a long lived non tropical coral (*Cladocora caespitosa*) (L.), collected in the Natural Marine Reserve of Miramare (Northern Adriatic Sea). High resolution analyses (weekly) of B, Sr, U and Mg have been obtained from a 4 cm long (~10 years growth) external coralline portion (wall region), using the laser ablation ICP-MS system at the ANU. Using this approach it is possible to discriminate structural induced heterogeneities arising from different morphological and compositional zones, such as calcification centres, needle-shape crystals and dissepiments. Geochemical ratios (Sr/Ca vs. B/Ca; Sr/Ca vs. Mg/Ca; Sr/Ca vs. U/Ca; U/Ca vs. Mg/Ca and B/Ca vs. Mg/Ca) generally exhibit a close relationship to the fortnightly in-situ measured SST data collected over the last 6 years. In particular, B/Ca shows an extraordinary high degree of correlation ($r^2 = 0.84$, $n = 111$) with SST. Furthermore the range of concentrations is larger than those typically recorded in tropical corals, consistent with the large seasonal variation in SST of the Adriatic. Our study thus demonstrates the feasibility of using high-resolution geochemical records from the non-tropical coral *C. caespitosa* for the high fidelity reconstruction of SST records.

Changes of Radiocarbon Concentration in Surface Seawater Recorded in Corals from Ryukyu Islands, Subtropical Northwestern Pacific

*Maki MORIMOTO**, *Hiroyuki KITAGAWA*, *Osamu ABE*, *Yasuyuki SHIBATA*, *Hajime KAYANNE*

Nagoya 464-8601, Japan
morimoto@ihas.nagoya-u.ac.jp

Past changes of radiocarbon concentration of dissolved inorganic carbon (DIC) in tropical and subtropical ocean can be reconstructed by coral annual bands. Radiocarbon concentration in surface ocean is influenced by vertical and horizontal mixing between different water masses, when each of them has a particular radiocarbon concentration, and CO₂ exchange between atmosphere and ocean on various temporal and spatial scales. For example, time-series analysis of the radiocarbon concentration from modern long-lived corals can reveal the evidence for anthropogenic CO₂ emission from fossil fuels (Suess Effect) and nuclear bomb tests in the middle of twentieth century. In this study, past radiocarbon concentration changes in subtropical Northwestern Pacific were reconstructed from corals collected at Yonaguni Island and Kikai Island, both located on Ryukyu Islands, in the southwest of Japan. Yonaguni Island is the southwesternmost Island in Japan and faced to Kuroshio Current that originates from the North Equatorial Current. A modern coral (*Porites* sp.), which has 60-year annual bands, was collected 1km offshore and at a depth of 17 m, so that radiocarbon variation in the coral skeleton can be regarded as that of ocean DIC, free from any local environmental effects. Kikai Island is located on the northern part of Ryukyu Islands and has poorly developed modern reefs. A modern coral (*Porites* sp.) collected offshore has 8-year annual bands. Radiocarbon results from a Kikai coral show seasonal cycles superimposed on a secular annual decreasing trend of 3.8 per mil since 1991 to 1998.

Kinetic and Metabolic Isotope Effects in the Northernmost Living Coral in Amakusa, Japan

*Tamano OMATA**, *Atsushi SUZUKI*, *Hodaka KAWAHATA*, *Satoshi NOJIMA*, *Akiko HATA*

2-15 Natsushima, Yokosuka, 237-0061, Japan
omatat@jamstec.go.jp

Geochemical analysis of coral skeletons provides valuable information on past oceanographic conditions such as seawater temperature, biological activity, etc. The relationship between carbon and oxygen isotopes is controlled by the intensities of the kinetic isotope effect accompanied by calcification speed and metabolic effects such as that of photosynthesis. In fast-growing corals, ¹³C and ¹⁸O show anti-phase fluctuations. On the other hand, in slow-growing corals, these isotopes fluctuate in phase. We investigated the stable carbon and oxygen isotopes along the growth axis in *Porites* skeletons that lived in the northernmost range of coral occurrence in Amakusa, Japan (130° 01.6'E, 32° 11.8'N). ¹³C and ¹⁸O fluctuations were in phase in 1969, 1970, 1971, 1985, and 1987, which means that this coral were in poor health in those years. The in-phase relationship of carbon and oxygen isotope fluctuation means that ¹³C and ¹⁸O fluctuations due to the kinetic isotope effect were relatively dominant because ¹³C fluctuation due to the metabolic effect was weaker than in healthy coral. This is supported by X-ray photographs that show growth disturbances in the beginning of 1969 and in the summer of 1987. Growth increments in those years varied from 3.2 mm to 4.8 mm. Because the average of growth increment is 5.8 mm and 3.2 mm was the least growth increment in this coral, this also implies poor health. The in-phase relationship of ¹³C and ¹⁸O from 1969 to 1971 may imply that the coral experienced an event that disturbed growth and they remained in poor condition for 3 years. It implies that the ¹³C and ¹⁸O, growth increments, and growth disturbance are linking each other.

Paleoclimate Records from Fossil Corals Recovered from Drowned Reefs around the Main Hawaiian Islands

*Andrew J ROTHWELL**, *A Christina RAVELO*, *Jody WEBSTER*, *David CLAGUE*, *Donald POTTS*

1156 High Street, Santa Cruz, CA 95064 United States of America
rothwellaj@yahoo.com

The geochemical measurements of fossil corals from past periods provide the opportunity to evaluate whether the amplitude and frequency of seasonal and interannual climate variability depend on mean background climate conditions. The ROV *Tiburón* was used to collect fossil *Porites* corals from the drowned reef terraces preserved on the flanks of the main Hawaiian Islands. These corals grew during past periods when mean global climate was different than today. We selected three fossil corals, from terraces on the east side of Kohala, Hawaii, that probably drowned during deglaciations ~250-450 ka. We also selected one fossil coral sample from the terraces surrounding the shield volcano on Niihau that drowned as long as 5 Ma. X-ray diffraction and petrographic analyses confirmed the corals are composed of >98% aragonite. Corals were micro-sampled at 0.4- 0.5 mm intervals along major growth axes, and ~10 samples per annual growth band were analyzed for carbon and oxygen isotopes. Preliminary data from the Kohala samples give average ¹⁸O values that are 1.3‰ higher than a modern *Porites* collected at Kealekaku Bay, Hawaii, probably reflecting a combination of lower temperature and larger ice volume during past glacial periods. There is clear cyclicity in both ¹³C and ¹⁸O. The ¹³C cycles are correlated with annual density banding, and may represent seasonal variations in environmental conditions such as cloud cover, water turbidity, or upwelling. ¹⁸O cycles show similar periodicity, but move in and out of phase with the density bands, suggesting that a seasonal temperature cycle is obscured by an effect of local hydrology on the isotope record. We will extend these preliminary results to include a sea-surface temperature record using Sr/Ca ratios, and dating (²³⁰Th/²³⁴U) of the corals, allowing further interpretation of the ¹³C and ¹⁸O data.

Variability of Skeletal Oxygen and Carbon Isotopes of Cultured *Porites* Corals

*Atsushi SUZUKI**, *Hodaka KAWAHATA*, *Kohei HIBINO*

AIST No. 7 Tsukuba Central, Higashi, Tsukuba, Japan
a.suzuki@aist.go.jp

Skeletal oxygen isotope ratio of *Porites* corals is most frequently used as a proxy for seawater temperature and salinity for paleoclimate reconstruction in tropical and subtropical oceans. However, field calibration of the proxy signal often faces difficulties due to co-variation of water temperature and salinity, which controls oxygen isotope composition of water, in the natural condition. We conducted tank experiments for growing coral colonies under controlled environments. Tanks were supplied with thermostated Pacific surface seawater at five temperature settings between 21°C and 29°C. Colonies were grown under light intensity of approximately 250 μmol/m²/sec with a 12:12 photoperiod. All colonies were cultured for 4 months with continuous monitoring of water temperature, salinity and oxygen isotope compositions of water. Metabolic rates including photosynthesis, respiration and calcification were measured on selected colonies using pH-alkalinity technique towards the end of the experiment. All skeletal samples were microsampled vertically from the top of colonies along major growth axes. Stain line of Alizarin Red at the beginning of the incubation confirmed the skeletal growth during the tank experiment. Skeletal oxygen isotope ratios of newly deposited skeleton remains almost constant along the growth axes of each colony, except for bleached colonies in the 29°C tank. Although the obtained slope of the relationship between skeletal oxygen isotope ratios and temperature is close to previous estimate (approximately 0.2 permil / °C), the oxygen isotope ratios displays a high variability among colonies. No significant correlation was found between skeletal carbon isotope ratios and metabolic parameters including day-time photosynthesis and respiration rates and P/R ratio.

High-resolution SST and Light Intensity Records from Modern Tridacnid Shell

*Tsutomu YAMADA**, *Sachi HENMI*

Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan
yamada@dges.tohoku.ac.jp

Tridacnid shells are useful in paleoceanographic studies because their large shell and fast growth rate allow detailed sampling of shell carbonates and because their fine growth bands in the shells provide us with accurate chronology. In this study, we examined growth bands and carbon and oxygen isotopic profile of one specimen of *Hippopus hippopus* cultured in Yoshihara Reef, Ishigaki-jima. Environmental variables such as water temperature, salinity, photon density flux, and isotopic composition of seawater were measured at the collected site. The shell, collected in summer of 1996, was cut along its growth axis. Width of fine growth bands in the inner layer of the shell was measured using thin sections and chemically-etched slabs. The isotopic composition was measured at intervals of 20 μm . The number of fine growth bands within an annual increment determined by oxygen isotopes reached ~ 360 , indicating that the fine bands were daily products. The fine band width averaged 45 and 20 μm in summer and winter, respectively. Precise comparison of oxygen isotopic profiles/daily growth rates with the environmental variables revealed that they were controlled mainly by water temperature and light intensity, respectively.

Synthetic Organic Chemicals, Microorganisms, African and Asian Dust, and Coral Reefs

Virginia H. GARRISON*, R Scott CARR, William F FOREMAN, Dale W GRIFFIN, Christina A KELLOGG, Michael S MAJEWSKI, Eugene A SHINN, Garriet W SMITH
600 Fourth Street South, St. Petersburg, Florida 33701 United States of America
ginger_garrison@usgs.gov

Hundreds of millions of tons of African dust are transported annually from the Sahara and Sahel to the Caribbean and southeastern U.S.. A similar dust system in Asia carries dust from the Gobi and Takla Makan deserts across Korea, Japan, and the northern Pacific to the Hawaiian Islands, the western U.S., and as far eastward as Europe. Although these global atmospheric systems have been transporting fine soil particles for hundreds of thousands of years, the quantities of dust vary annually as a result of global climate, local meteorology, geomorphology of source areas, and human activities. We suggest that the quality of the dust has changed as a result of the burning of biomass and waste, and use of antibiotics, pharmaceuticals, and pesticides in dust source regions. A series of pilot projects were initiated to test our hypothesis that Sahelian dust air masses transport viable microorganisms and synthetic organic chemicals thousands of kilometers to the Americas and that these chemical and microbial contaminants are adversely affecting coral reefs and human health. Recently, we have identified synthetic organic chemicals and hundreds of species of microorganisms, including known pathogens, in dust event air samples from the Caribbean and Mali (West Africa). Preliminary ecotoxicology tests indicate African dust is toxic to some marine organisms. Findings from these exploratory studies are opening new avenues of research that require the involvement of multiple disciplines and approaches.

An Investigation of the Antimicrobial Properties of the Eggs of Eleven Species of Scleractinian Corals

Christopher P. MARQUIS*, Andrew H BAIRD, Rocky DE NYS, Christine CHUANG, Carola HOLMSTROM, Noriko KOZIUMI
BABS, University of NSW, Sydney, NSW, 2052 Australia
c.marquis@unsw.edu.au

Potential sources of mortality of marine invertebrate larvae are numerous including diseases caused by marine microorganisms. In our study, the extracts from the eggs of 11 coral species were evaluated for their ability to deter surface attachment and inhibit the growth of two marine tolerant laboratory strains of bacteria and ninety two bacterial strains isolated from seawater and the surface of coral colonies on the Great Barrier Reef (GBR). Extracts of the eggs of *Montipora digitata* inhibited the growth of the two laboratory marine bacteria, *Vibrio harveyi* and *Bacillus subtilis*, and a single bacterial isolate from the mucus of the coral *Favia pallida* in disc diffusion and liquid culture assays. No other microbial strains (n = 91) from the reef environment were inhibited by *M. digitata* extracts. No activity was found in the egg extracts of the remaining 10 coral species and none of the extracts inhibited surface attachment of bacteria. The potential contribution of zooxanthellae found in the eggs of this coral species in the synthesis of the potent antimicrobials has also been evaluated.

Carotenoids Producing Marine Microorganisms in Coral Reef

Yasuhiro NISHIDA*, Hirokazu KANENO, Yasuji SUMIYA, Hideaki SAKAKI, Miyuki TSUSHIMA, Wataru MIKI, Sadayoshi MATSUMOTO, Akiyoshi SAWABE, Sadawo KOMEMUSHI
3327-204 Naka machi Nara city, Japan 631-8505 Japan
hplc@nifty.com

The surface of the sea and coral reef in subtropical regions is a severe environment for the growth of microorganisms, because active oxygen species are generated by intense irradiation with strong sunlight. The microorganisms then take photooxidative damages. From this point of view, we have focused on marine microorganisms in coral reef, especially those that produce carotenoids with antioxidative activity. The carotenoids are an important group of natural pigments that are widely distributed in living organisms. They can function as protective compounds against photooxidative damages. Since the communities of living organisms in coral reef have very diverse varieties, we have isolated the carotenoids producing microorganisms from the seawater of a coral reef region. As a result, the carotenoids that are rich in the diverse structures containing new carotenoid, neurosporaxanthin -D-glucopyranoside, have been isolated from marine microorganisms.

The Association of Virus-like Particles and Heterotrophic Bacteria with Scleractinian Corals from an Inshore and Outer Coral Reef Ecosystem

Nicole L. PATTEN*, Justin R SEYMOUR, David G BOURNE, James G MITCHELL
PO Box 2100, Adelaide, SA 5001, AUSTRALIA
patt0067@flinders.edu.au

Escalating reports of coral pathogens causing disease and bleaching in the last two decades, has research effort primarily focused on the identification of the infectious agent(s). Identifying potential infectious microbes requires knowledge of the natural microbial assemblage associated with healthy coral tissue. However, to date, there is little information regarding the diversity and distribution of bacterial populations and virtually no information regarding viral distributions associated with healthy and/or unhealthy corals. We report here, bacterial and virus like particle (VLP) distributions associated with corals from an inshore and outer coral reef using flow cytometric analysis. Mean concentrations overlying healthy *Acropora sp.* of $6.5 \times 10^5 \text{ ml}^{-1}$ and $1.3 \times 10^5 \text{ ml}^{-1}$ were observed for virus like particles (VLP) and bacterioplankton respectively with these concentrations varying significantly ($p < 0.05$) between 4 distinct water-types associated with the reef. Micro-scale spatial relationships between coral colonies and planktonic microbial communities were determined from profiles sampled in the 12 cm layer of water directly above the surface of coral colonies at the inner and outer reef. Across profiles, mean changes of 2- and 3.5-fold were observed for bacterioplankton and VLP communities respectively. Bacterial and VLP abundance exhibited increasing trends with proximity to coral colony surfaces. Significantly higher VLP abundance ($p < 0.05$) were found in the 4 cm closest to the coral surface. While VLP were correlated to bacteria in all profiles, the virus:bacteria ratio (VBR) were however, higher at the coral surface than for any of the other water-types associated with the reef. Micro-scale changes in bacterial and VLP concentrations may represent fundamental shifts and de-coupling in the composition of these microbial communities close to coral surfaces. The potential ecological importance of VLP within coral reef systems is subsequently discussed, with particular reference to VLP as possible vectors for the spread of disease in coral.

Exploring Pharmacologically Interesting Natural Products from the Coral Reefs of Jamaica

*Norman J QUINN**, Nadia-Deen FERGUSON, Deborah GOTCHFELD, Mark THAMANN, Jennifer Ibi STEPHENSON, Larry WALKER, Barbara L KOJIS
PO Box 35, Discovery Bay, St Ann Jamaica
norman_q@hotmail.com

Efforts to investigate novel pharmacological products from marine organisms, while working to conserve the biodiversity of coral reef habitats, have commenced in Jamaica. Open forum meetings with members of government, academia, fisherman and community organizations were conducted to learn of local concerns regarding coral reef exploitation. The potential for natural product pharmacological discoveries and their benefits to the community was explained. These meetings ensured that local interests were included in the search for biologically active compounds. Initial habitat surveys were conducted with the prior agreements with local stakeholders and requisite government permits. Natural products research and technology skills will be taught to University of the West Indies (UWI) graduate students in the coming years. Students are receiving training in coral reef monitoring techniques, marine organism taxonomy and marine chemical ecology. Work to develop a model of target population variability that provides biomedical researchers with sourcing strategies is in progress. This will help to limit overuse and subsequent damage to coral communities. Future efforts will evaluate marine natural products in a wide range of assays for anti-bacterial, anti-fungal, anti-viral, anti-protozoal and anti-cancer activities. If the compounds are successfully commercialized, they will provide the royalties and impetus for sustainable economic development strategies while recognizing the limits of exploitation of coral reef communities. The value of biodiversity as a raw material for pharmaceutical and biotechnology industries is only a portion of its value to society. Community awareness programs stressed the need to conserve habitats whether or not they yield economically valuable material at this time. This project is providing an opportunity to create scientific/ technological enrichment opportunities that work to strengthen sustainable development efforts in the Caribbean and provide socially valuable pharmaceutical products and biotechnologies.

The Giant Clam, *Hippopus hippopus*, Exposed to Polycyclic Aromatic Hydrocarbons (PAHs): A Laboratory Study in the Northern Philippines

*Eva M BLIDBERG**, *Michael TEDENGREN*

SE-106 91 Stockholm, Sweden

eva@ecology.su.se

Population growth in coastal regions contributes to the threat of coral reefs and reef associated marine organisms. Increased boat activities increase the release of PAHs to the water, which is a growing environmental problem. In this study, the giant clam, *Hippopus hippopus*, was exposed to the water soluble phase of petroleum in three doses, 0 mg PAH /L, 0.01 mg PAH /L and 10 mg PAH /L. The exposure time was 5 days and production- and respiration rates as well as clearance rate and absorption efficiency was measured. An Energy Balance Equation (EBE) where then calculated for each individual. Semi-permeable membrane devices (SPMDs) establish the PAH concentration in the exposure water and tissue samples were taken for analysis of PAH uptake and DNA-adducts. The results showed that the PAHs had little effect on the physiological parameters. Only clearance rate and absorption efficiency was negatively affected, indicating toxicity. This effect reduced the EBE value from 3.1 in control clams to 2.5 kJ/ individual*day for clams in 10 mg PAH /L. No DNA-adducts were found, probably due to short exposure time. The PAH uptake indicated that the clams had a high PAH load from the beginning since the PAH content were almost the same for all treatments, ~2000 per ng/g fat whereas the SPMDs had a 49% increase in PAHs for 49% in high dose treatment compared to control water. The results indicates that higher doses of PAH give negative effects after exposure and that the clams in this study are chronically exposed to PAHs in the supposedly clean habitat where they were collected. The engines used by the local fishermen and smaller ship are probably the main source of PAH contamination to the local environment.

Induction of Heat Shock Protein 70 in the Coral Reefs of the Persian Gulf Exposed to Natural Environmental Stressors

*Peyman EGHTEADILARAGHI**, *Abdolvahab MAGHSOUDLOU*

#9, Etemeazadeh St., Fatemi Ave, P.O.Box 14155-4781, Tehran, Iran

eghtesadi@inco.ac.ir, eghtesadi@ibb.ut.ac.ir

During the past two decades, coral reefs have experienced extensive degradation worldwide. Coral reef communities of the Persian Gulf has also suffered from a severe decline of populations in the last decade in this region which is subjected to natural and human-made environmental pressures. This area is a semi-enclosed marginal sea with harsh conditions for the marine organisms, especially coral reef communities with regard to salinity, temperature and extreme low tides. Coral bleaching and mortality have been associated with elevated seawater temperature and elevated air temperature during periods of aerial exposure. Also, widespread coral mortality and limits of distribution coral species in areas such as Florida, Panama and Hawaii have also been related to temperature stress. We have studied the application of the heat shock protein (HSP) expression in the coral reefs as a biomarker for environmental stress and forerunner of coral community destruction. In this way the activity of repairing enzymes has been determined and also the antibodies to cnidarian Hsp70, cnidarian Hsp60, and cnidarian Cu/Zn superoxide dismutase has been applied for HSP determination. Our results indicate that corals that experienced this environmental stress had higher HSP (chaperonin) levels and protein turnover activity.

The Behavior of Estrogen-like Compound Surrounding the Coral Reef

*Seiji IWASAKI**, *Kenji IWAO*, *Tetsuya KIMURA*, *Makiko SAKKA*, *Kazuo SAKKA*, *Kunio OHMIYA*, *Tomonari MATSUDA*, *Saburo MATSUI*

3690-1 Sakura, Yokkaichi, Mie Japan

iwasas00@pref.mie.jp

A very wide range of chemicals, both natural and manmade have now been found to be estrogenic activity. Concern has increasing about the wide usage and waste of estrogen-like compounds recently. The major origin of estrogen-like compound is fecal and urine wastewater, so that these compounds can found out even in the sparsely populated area. Although field data of estrogen-like compound is very limited, since we investigated the estrogen-like compound in seawater surrounding Akajima Island, in which is the representative coral reef in Japan. Estrogen-like compound was measured by yeast screen assay, using a human estrogen receptor gene recombinant yeast. The estrogen-like compound of seawater samples collected from 9 sites along the coast surround Akajima Island was examined. The highest concentrations of estrogenic substances of water was found in the estuary of Nakamata River (8.5 ng/l). The concentration was gradually decreased with approaching the offshore from the Mae-hama beach. Estrogen-like compound was either very low or undetectable at the site of 100m offshore from the shore. It was not detected at all in the east and north coast of Akajima Island. It was suggested that this decrease could be mainly a result of dilution. However, adsorption to the seabed and biodegradation also contributed to the decrease. Concentrations of other water pollution indexes were also investigated, and the behavior of some of them was similar to estrogen-like compound. It is assumed that the concentration of estrogen-like compound surround the Akajima sea area was below the levels considered to have no effect on the coral.

Effect of Sedimentation and Pollution in the Reefs of Tuticorin Coast of Gulf of Mannar, Southeast Coast of India

Venkatesh M, *Mathews G*, *Edward J K PATTERSON**

44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India

victormaandy2k@yahoo.co.in, jkpatti@sancharnet.in

Gulf of Mannar (GOM) is one of the four major coral reef areas in India. The southern part of GOM, the Tuticorin coast includes 4 coral Islands (Kariyachalli, Koswari, Villanguchalli and Vaan) and is the most environmentally stressed coastal areas in GOM due to destructive fishing, coral mining and pollution from the industries and the port. The present study was carried out around the Vaan Island, which is nearer to the port. Sedimentation traps were deployed in 3 sensitive areas and the trap contents were collected every month. The sedimentation rate for one year was recorded and is varying between 75 g and 375 g / month. The fine particles were more in all sites and the average visibility was only 2.2 m. *Turbinaria* sp. is most affected because, this species is cup shaped and sediments can easily accumulate inside the cup, leading to slow mortality. Scleractinian corals are considered as potential and useful indicator organism for environmental monitoring because their skeletons accumulate certain metals over hundreds of years. Heavy metal (Mercury, Lead, Cadmium and Copper) concentration was analyzed in the skeleton of 4 common scleractinian corals, *Favia pallida*, *Porites lutea*, *Symphyllia radians* and *Acropora nobilis* from the Tuticorin coast. The concentration of Mercury was < 1 ppm, whereas for Lead, Cadmium and Copper it was from < 4 to < 6 ppm, < 1 to 2 ppm and 2 to 10 ppm respectively. Though this level does not interfere with the growth and survival of corals at present, during the course of time, they may hinder with growth or cause mortality.

Monitoring Change in Coral Growth Rate by Changing Physical Environments

*Wilson R RAMIREZ**, Jack MORELOCK

P.O. Box 9017, Mayaguez, Puerto Rico 00681 Puerto Rico
geoseawil@aol.com

We set up an experiment to quantify the effects of sediment and nutrient stress on coral growth. Three reefs impacted by terrigenous sediment and/or nutrient influx, and one clean reef were selected on the shelf off Mayaguez, Puerto Rico. To quantify the effects on coral growth we transplanted corals from stressed environments into clean water and vice versa. Coral from the clean site were transplanted into the same site as controls. Alizarin Red-S was used to mark the coral skeleton at the time of transplant. Fourteen species of coral were transplanted. Bi-monthly monitoring was performed for two years and then coral pieces were harvested to measure growth rates before and after transplantation. From 49 coral colonies transplanted as controls, 2 died during the two years. From 139 coral colonies transplanted from the clean to the impacted sites, 20 colonies died during the next two years. The mortality on these was caused mostly by overgrowth of the coral by turf algae. *Siderastrea siderea*, *Montastrea cavernosa*, *Colpophyllia natans*, *Porites asteroides*, and *Porites porites* showed resistance. From 48 coral colonies transplanted from the stress to the clean site, 1 colony died. *Porites asteroides* and *Montastrea cavernosa* showed significant growth when moved from stress into a clean site. Control corals indicated that transplantation did not cause significant changes in the coral growth rate. Similar coral growth rates were measured between impacted vs. non-impacted areas before the transplantation in the same species. Most corals showed significant growth rate changes after transplantation to the different environments. Growth rate changes were quantified before and after transplantation. Sediment input, texture, and composition as well as temperature, and water turbidity were measured at each site. Trace elements and oxygen isotopes will be measured in the coral skeletons to establish relationships with water temperature.

Comparative Concentration of Heavy Metals in Different Feeding Types of Benthic Fauna from Coral Communities in the Gulf of Thailand

*Chaipichit SAENGHAI SUK**, Thamasak YEEMIN

Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok, Bangkok 10240 Kingdom of Thailand
sh_chaipichit@yahoo.com

Coastal ecosystems in the Gulf of Thailand are potentially impacted by anthropogenic disturbances and contaminant inputs, especially heavy metals. The present study investigates comparative concentration of heavy metals in different feeding strategies of common benthic animals, i.e., a stony coral (*Porites lutea*), a soft coral (*Cladiella tuberosa*), a zoanthid (*Palythoa caesia*), a sponge (*Petrosia* sp.) and a sea urchin (*Diadema setosum*) from two absolutely different impacted coral communities in the Gulf of Thailand. Khang Khao Island, located in the inner Gulf of Thailand, has high potential to receive heavy metal contamination from land-based activities whereas Tao Island, located approximately 70 km from the mainland, has very low possibility for heavy metal contamination. Colonies or individuals of these animals were collected from shallow and deep areas of the study sites during 1996-2003. We focused on accumulation of six heavy metals, namely, Pb, Fe, Cu, Zn, Cr and Cd which were determined by using an Atomic Absorption Spectrophotometer (AAS-Perkin Elmer). Concentrations of all the six studied heavy metals were significantly different between the benthic animals and the study sites. Concentrations of Zn were the highest in all studied animals. Clearly, these benthic animals can be used as bioindicators for assessing and monitoring heavy metal concentrations in coral communities in the Gulf of Thailand with different degrees of sensitivity. This study also provides important information concerning present situation in the Gulf of Thailand and can be used as background levels for future comparison of seawater quality.

The Effect of Inorganic Nutrient Levels on Macroalgal Abundance in the Caribbean

*Shauna N SLINGSBY**, John BRUNO, Larry CAHOON

PO Box 1462, Wrightsville Beach, NC 28480 United States of America
shaunans@yahoo.com

Coral reef community structure is driven by many variables, such as substrate, light, and nutrient availability as well as grazing rates and larval supply. Many Caribbean reefs have experienced macroalgal dominance due to overfishing and nutrient runoff. The reefs along Mexico's Yucatan Peninsula are relatively low in coral cover and high in macroalgal abundance. It is suspected that nutrient input from untreated sewage is one of the major driving factors of macroalgal dominance in this region, along with overfishing. The Yucatan is particularly susceptible to nutrient runoff due to its karst limestone floor, extensive underground river system, and the reef's proximity to shore. Conversely, Bonaire has low macroalgal abundance, high coral cover, and higher rates of herbivory. The goals of this study were to assess ambient nutrient concentrations and macroalgal abundance at two distinct locations in the Caribbean: 1) the Mesoamerican Barrier Reef System in Mexico and 2) Bonaire, Netherland Antilles. From 2002 to 2003, seawater column samples were collected and analyzed for NO_3^- , PO_4^{3-} , and NH_4^+ , and the percent cover and height of macroalgae were estimated in situ at 17 reef sites. Results indicate that both the percent cover and height of macroalgae were significantly correlated to Total Inorganic Nitrogen (TIN) across sites. Along the Yucatan coast of Mexico, macroalgal abundance may be driven, in part, by elevated levels of inorganic nitrogen since overfishing was not prevalent at all sites. In Bonaire, low ambient nutrient concentrations and high grazing rates are most likely responsible for higher coral cover and low macroalgal abundance. This study identified a nutrient signal between the abundance of macroalgae and elevated concentrations of inorganic nitrogen. These results could have serious impacts on coral reef growth and recovery, especially where herbivory is low and may not be able to keep up with macroalgal growth.

Fragmentation of Coastal Vegetation Communities and Density of Coastal Development Impacts on Scope and Severity of Nutrient Loading to Nearshore Reefs in the Bahamian Archipelago

*Kathleen M SULLIVAN SEALEY**, Vanessa L NERO, Kathleen L SEMON

1301 Memorial Drive, Rm 25, Cox Science Center, Coral Gables, Florida 33146 United States of America
ksealey@miami.edu

A landscape-scale study of the coastal ecology of the Bahamian archipelago has utilized both remote sensing and field measurements to produce spatial datasets of coastal nutrient loading. Models of land-sea nutrient flux were based on change in coastal vegetation, extent of human development and hurricane disturbance history to examine impacts of near shore patch reef habitats. These patch reefs were identified as important fisheries habitats, and having a high, but variable, coral cover and benthic diversity in the Bahamian archipelago. Initially, twelve patch reef stations were established off developed and undeveloped islands in the central Bahamas; environmental parameters were measured to examine seasonal, tidal and diurnal variability. Water quality changes did not support the model for eutrophication hot spots, and were not significantly different between developed and undeveloped sites for temperature, salinity, dissolved oxygen, chlorophyll-a, total nitrogen and total phosphorus. However turbidity measurements were significantly different between sites. In contrast, multivariate analysis of benthic species composition and abundance revealed macroalgae and sponges were most sensitive to coastal land use changes and levels of coastal development. In addition, stony corals showed higher diversity, lower coral cover and higher incidence of lesions on patch reefs adjacent to developed islands. Results were used to create a spatial dataset of islands ranking coastal segments of similar geomorphology as to degree of human impact, and examine near shore macroalgal composition as an indicator of coastal eutrophication. Sensitivity analysis is used to determine the ecological criteria for vegetation setback zones, and density of coastal settlements on small carbonate islands of the Bahamas.

Status of Bahrain Coral Reef

Jassim A ALQASSIR, Ibtisam A KHALAF*

p.o.box:20071, manama , bahrain

ibtisam_khalaf@hotmail.com

Bahrain coral reef undergoing an extreme environmental stresses, due to two factors, firstly, natural stresses such as wide fluctuations of temperature (18-37 dc), causing coral bleaching in 1996 and 1998 and high salinity (42-48 ppt) which limit the growth and diversity. secondly human stresses due to multi-factors such as dredging, reclamation,pollution, industrial activity, urbanization, tourism, cooling water discharges from desalination and power plants, oil exploitation , illegal fishing gears and destructive fishing.there are signs that recovery was commenced in coral reef after 1996 and 1998 bleaching, in heir abulthama (offshore coral reef) the dead coralis 20% only in 2003, whilefashat alahdom (inshore coral reef) is only 8%. the recovery may due to the summer upwelling, which moderate the temperature. fish population and diversity is also recorded in the above two reefs.coral reef management is going to take a serious measures towards marine protected areas as soon as possible in order to conserve and maintain the existing coral towards sustainable balances in spite of the limited economical waters which does not exceeds 200 sqkm.

Nucleotide Sequence of a Red-soil Responsive Gene from the Scleractinian Coral *Pocillopora damicornis*, and its Comparison with Hsp70

Kazumasa HASHIMOTO*, Takuro SHIBUNO, Osamu ABE, Yoshitake TAKADA

148-446 Fukai-Ohta, Ishigaki, Okinawa, 907-0451 Japan

hashimot@affrc.go.jp

Coral reefs have been rapidly deteriorating because of a variety of environmental and anthropogenic pressures, such as sedimentation, elevated sea-water temperature, crown-of-thorns starfish, and cyanide fishing. In Okinawa, red-soil sedimentation is a major factor contributing to coral reef degradation. We previously reported that the expression of the BiP (a member of Hsp70 family)-like gene was upregulated by suspended red-soil in the scleractinian coral *Pocillopora damicornis* (Hashimoto et al. 2003). In this report, we cloned a full length cDNA encoding putative BiP by RACE (rapid amplification of cDNA ends) from *P. damicornis*. The isolated full-length cDNA clone contained 5' and 3' nontranslated sequence and encoded a protein of 669 amino acids. The predicted amino acid sequence shared 78.2% identity with that of the BiP of the mollusca *Aplysia californica*. The carboxyl terminus of the BiP of *P. damicornis* ended with the sequence RDEL, the endoplasmic reticulum retention signal tetrapeptide. Based on the nucleotide sequence of the Hsp70 of the scleractinian coral *Stylophora pistillata* (Tom et al. 1999), a full length cDNA encoding putative Hsp70 was also cloned from *P. damicornis*. The open reading frame of this clone was 1953 bp long, and encoded a protein of 650 amino acids. The predicted amino acid sequence of this clone has high similarity to the Hsp70 of *S. pistillata* (89.8%), but low to the Bip of *P. damicornis* (58.5%).

Trace Elements in Coral Skeletons from the Western Pacific Ocean Determined by a New ICP-MS Method

Mayuri INOUE*, Masato NOHARA, Atsushi SUZUKI, Wyss W -S YIM,

Wahyoe S HANTORO, Ahser EDWARD, Hodaka KAWAHATA

Aramaki, Aoba, Sendai 980-8578, JAPAN

mayuri-inoue@aist.go.jp

Coral reefs are increasingly being threatened by various types of pollution originating from domestic, mining and industrial effluents. In order to evaluate the condition of marine waters and to estimate the degree of pollution, we analyzed the concentrations of 12 trace elements (V, Co, Mn, Cr, Ni, Cu, Zn, Sn, Ba, Pb, Cs and U) in coral skeletons from Indonesia, Hong Kong, Micronesia (Pohnpei Island) and Japan (Ishigaki Island). The coral specimens and/or cores were cut into slabs and subsamples corresponding to approximately five years of coral growth were milled, excluding the coral tissue layer. A new ICP-MS method was then used to determine the concentrations of trace elements after sample digestion with 2% HNO₃. In this method, a regression line was constructed from 10 different concentrations of a mixed standard solution containing the 12 trace elements. For reducing the matrix effects of Ca and instrumental drift, internal standards (Sc, In, Y and Ho) were added in 2% HNO₃. A mixed standard was determined after every five samples for checking the precision of the measurements. The accuracy of this procedure was also checked using a coral reference material (JCP-1) prepared by the Geological Survey of Japan. The concentrations of the trace elements were found to be comparable with known values of JCP-1 with the exception of Cr, Ni and Cs, indicating that the method adopted for the other elements is reliable. The corals studied were found to show variable concentrations of trace elements indicating differences in marine conditions and pollution degree.

Ecological Indicators of Stony Coral Health and Reef Condition for Skilled Volunteers

Judith C LANG*, Lisa A MONK, Seba B SHEAVLY, Loretta A LAWRENCE

125 Airstrip Lane, P.O. Box 539, Ophelia, VA, 22530 United States of America

jandl@rivnet.net

Resource managers and scientists cannot hope to monitor reef ecosystems with sufficient frequency to provide more than scattered early warning and diagnostic capabilities. In the Reef Condition (RECON) Monitoring Program, well-trained recreational divers collect data for carefully chosen western Atlantic coral reefs. Changes in the health of certain large (at least 25 cm diameter), massive stony corals and in the overall status of the surveyed habitats are tracked with relatively simple indicators: seawater color, wave height and horizontal visibility pertain to the relative effects of runoff versus exposure to waves; seawater temperature and vertical visibility are important correlates of mass bleaching which, if present, is also assessed. The size (documented by surface area) and percent partial mortality of massive stony corals integrate previous conditions for their growth while signs of disease, presence of corallivores, and other perturbations are relevant to recent mortality. The relative density of stony coral recruits on the dead surfaces of these corals, along with the relative abundance of crustose coralline algae versus other algal functional groups, are clues to the likely regeneration potential of the reef. The net direction of spatial competition between stony corals and macroalgae can be approximated from the percent cover of live stony corals versus that of macroalgae, the identities of the most common macroalgae, and the density of the long-spined sea urchin, *Diadema antillarum*. The relative abundance of damselfish bites on stony corals, and densities of spiny lobsters and queen conch in belt transects, reflect the intensity of localized fishing. Future activities will include efforts to integrate these parameters into more generalized indices of reef condition. Grant support provided to the Office of Pollution Prevention and Monitoring of The Ocean Conservancy by the U.S. Environmental Protection Agency-Office of Wetlands, Oceans & Watersheds/Oceans & Coastal Protection Division/Marine Pollution Control Branch.

Indices of Ecological Function for Assessing Coral Reef Health at the Level of the Assemblage

Thaddeus J T MURDOCH*, Richard B ARONSON, Stuan R SMITH, John C OGDEN

101 Bienville Blvd. Dauphin Island, Alabama
tmurdoch@disl.org

The functional ecology of reef assemblages must be assessed to determine whether reefs are being affected by disturbances prior to ecosystem collapse. The metrics traditionally used to measure the status of reefs do not provide such information. New ecological indices, derived from terrestrial ecology are as yet untested in marine habitats. Research into functional group approaches, the search for assembly rules and the development of null statistical models all provide parameters that may be integrated to develop simple numeric ratings of the ecological integrity of coral reefs and other marine habitats. We demonstrate how these novel indices may be calibrated, using reefs located over gradients of disturbance across the Florida reef tract and the Bermuda platform. We also test whether the calibrated indices are able to rate the condition of protected and unprotected reef sites in Florida, Bermuda and elsewhere in the Caribbean in a meaningful manner.

Soil Sedimentation Monitoring on Coral Reefs Using Convenient Measuring Method of Content of Suspended Particles in Sea Sediment

Tatsuo OMIJA*

2085 Ozato Ozato-son Okinawa Japan
oomijatt@pref.okinawa.jp

Since its administrative restoration to Japan in 1972, Okinawa has discharged a large amount of its soil into the surrounding ocean. As a result of this Okinawa beautiful and arguably necessary coral reefs are being irrevocably damaged. This is having dire effects on the nearby ecosystem. In 1985 a method of monitoring the soil run-off was developed and named SPSS (content of Suspended Particles in Sea Sediment) Convenient Measuring Method. It is now the accepted method of soil sedimentation monitoring in the Okinawa Prefecture. This method has several key advantages and these are fast measuring times, mobile and simple operation and no special equipment is required. All of the results obtained over the last twenty years have been compiled into a database and as of September 2003 there were about 4000 entries. Since its inception it has proved invaluable in providing information for various investigations into coral reef conservation and has also contributed to the improvement of the soil run-off problem in Okinawa. Several organizations regularly implement SPSS; namely educational establishments, the fishery commission, environmental groups and other administrative bodies. The SPSS method is as follows: 1. Sieve the sample to remove any shells, pebbles and other unwanted debris. 2. Place between 5-100ml of the sample into a bottle and add clean water so there is 500ml of solution. 3. Shake and stand for one minute. 4. Measure the transparency of the solution and perform the appropriate calculation. A result of around 30kgm⁻³ yields an acceptable result and the soil does not affect the coral whereas 50kgm⁻³ indicates there is red sediment present. In fact when such sediment is agitated the red deposits can clearly be seen. Once the content reaches approximately 400kgm⁻³ the sediment becomes extremely muddy and this is unacceptable for the welfare of the coral reefs.

Effects of Sediment Regime on Coral Transplant Growth in West Maui

Gregory A PINIAK*, Eric BROWN

USGS Pacific Science Center, 400 Natural Bridges Drive, United States of America
gpiniaak@usgs.gov

As part of an ongoing US Geological Survey project on sedimentation and Hawaiian coral reefs, this poster describes the preliminary results of a transplant experiment to test the growth rate of the lace coral *Pocillopora damicornis* under different sediment regimes. In August 2003, 24 replicate coral nubbins were transplanted from a single donor site to five recipient sites (2-3 m depth) along the central west Maui coast. Growth rate was measured seasonally via the buoyant weight technique, and sediment regime monitored using sediment traps. Preliminary results describe four coral growth responses: rapid growth and linear extension, slow growth of dense skeletal material, photoadaptation but little growth, or death via scour, algal smothering, or fish predation.

Metal Concentration in Annual Growth Bands of the Coral *Montastraea faveolata* Located at Two Venezuelan Reefs

Ruth RAMOS*, Elia GARCIA, Hector GUZMAN

Apdo. 89000. Caracas 1080-A. Venezuela
99-80849@usb.ve

Scleractinian corals have been used as indicators either for natural or anthropogenic disturbances. The metal content of coral is almost unknown for Venezuelan reefs. Four metals (Cr, Ba, V and Mg) were determined in five coral cores of *Montastraea faveolata*. The samples were collected from inshore coral reefs from two different localities in the East Central region of Venezuela: the National Park San Esteban and the Nature Reserve Cuare. Each coral core has annual growth bands indicating approximately 60 years of growth. The interrelation of available environmental data, as rainfall with concentrations of metals, was also analyzed. The annual growth bands were analyzed through X-radiography. Each sample was rigorously cleaned, with 0.15 N HNO₃ and ultrasonic bath before it was digested in a water bath at 100 °C with HNO₃ 40%. Each sample was analyzed by duplicate using an ICP-EA to determine the concentration of each metal. The samples were analyzed against synthetic standards. The calcium concentration was also measured in order to obtain the relation $\mu\text{mol metal/mol Ca}$. The metal concentrations presented differ significantly ($p < 0.05$) between localities. Positive and significant correlation ($p < 0.05$) were found between the concentrations of Mg and Ba, as well as V and Cr. The analyses showed no significant differences based on time. However, some relations between the amount of rainfall and metal concentrations during the same time period were observed. Higher concentrations of V and Cr found in different annual growth bands, suggest an effect of human activity in the coastal area.

A Simple Metabolic Monitoring Method for Coral Reefs Exposed to Nutrient Loading and Other Environmental Stresses

*Jacob SILVERMAN**, Boaz LAZAR, Jonatan EREZ

Faculty of Natural Sciences, Edmond Safra Campus, Givat-Ram, 91904 State of Israel

jacobs@vms.huji.ac.il

Community metabolism of coral reefs, which are exposed to increased nutrient levels, display decreasing calcification (G) and increasing ratio of gross production (P_g) to respiration (R). These changes are probably due to trophic phase shift from symbiont to macro-algal dominated productivity. Metabolic processes are combined to define an ecologically sensitive value termed Environmental Parameter (EP) expressed as $EP = G/(P_g/R)$. High EP represents healthy oligotrophic reefs, which calcify normally, while low EP represents stressed reefs, which are gradually covered by macro algae and their live coral cover is decreased. This parameter is obtained from community metabolism studies using the measurement of diurnal cycles in Dissolved Oxygen (DO) and Total alkalinity (A_T), as well as automatic logging of temperature, salinity and water depth. Changes in DO reflect the net community production during the daytime and respiration at night. Changes in A_T reflect the net community calcification. These measurements are difficult to carry out on a routine basis and therefore we propose an algorithm to reduce the metabolic monitoring to two daily measurements. The minimum and maximum daily values of DO, A_T and temperature (daybreak and late afternoon) in the lagoon of a given reef are used to calculate a Reduced Environmental Parameter (REP). Comparison of EP to REP on a reef which is naturally exposed to nutrient loading displays a remarkable similarity ($R^2 = 0.98$). Alternatively, measurements of A_T (which are more complicated) may be substituted with measurements of pH, representing a combination of both net production and calcification. Using DO, pH and temperature, which can be obtained with a portable instrument, allow a less accurate estimate of reef performance (PEP, pH-based EP). A comparison of PEP with EP is non-linear ($R^2 = 0.7$) but still provides highly informative metabolic monitoring on a day to day basis.

Spatial and Seasonal Patterns of Algal Community Structure on Key Largo, FL USA, Coral Reefs: Do Patterns Suggest that Nutrient Enrichment Is a Factor?

*Alina M SZMANT**, Benjamin M MASON

5600 Marvin K. Moss Lane, Wilmington NC 28409 USA

szmanta@uncw.edu

Florida Keys coral reefs are claimed to have high macroalgal cover caused by anthropogenic eutrophication. However, few data are available with which to justify such claims. High cover by crustose coralline algae (CCA) and short, grazed turfs is considered to be typical of coral reefs with good water quality and high grazing rates, while high macroalgal cover is often characteristic of poor water quality and/or reduced grazing. In this EPA-NCORE-funded study, 10 reefs were sampled spring, summer and winter from May 2000 to April 2002, for algal cover, biomass and elemental composition. Nutrient enrichment and herbivory reduction experiments were conducted at three reefs. Study reefs included offshore high relief, offshore relict, and nearshore patch reefs. Results show that algal cover was dominated by four algal functional groups: turf algae (30 to 50 %), CCA (15 to 30 %), and two fleshy algae: the calcified green *Halimeda* (5 to 15 %) and the brown *Dictyota* (ca. 25 %). Other algal species were present at minimal percentages. *Dictyota* dominated in terms of percent cover, but *Halimeda* dominated the biomass; both species are chemically defended against grazers. There was no seasonality on relict reefs (low percent cover and biomass year-round) nor for *Dictyota* (similar cover on all reefs, all times). There was strong seasonality for *Halimeda* on both high relief and patch reefs; both reef types had higher levels of algal biomass during the spring and summer seasons. N and P composition and N:P ratios of *Dictyota* and *Halimeda* were not significantly different by either season or reef-type, nor proximity to land sources of nutrients. Experimental results showed minimal effects of nutrient enrichment on algal biomass, but major effects of reduced grazing. Overall, results do not suggest eutrophication as a key factor affecting Key Largo algal communities.

Boom and Bust Fishing in Coral Reef Systems: A Sea Cucumber/Seahorse Example from the Central Philippines*Sian K MORGAN**, Hazel M PANES

2204 Main Mall, University of British Columbia, Vancouver, BC Canada V6T 1Z4 Canada

s.morgan@fisheries.ubc.ca

In heavily over-fished systems, such as those found in many parts of South-East Asia, artisanal fishers are exploiting coral reefs for income. Many of these small scale fisheries show boom and bust cycles that are rarely documented and lead to the serial depletion of reef species. This paper presents the rapid, successive rise and fall of two pristine stocks: the first a sub-benthic sea cucumber (presently unidentified), and the second a deep water seahorse (*Hippocampus spinosissimus*). Semi-structured (post hoc) interviews and direct monitoring were used to estimate harvested biomass, the number of individuals captured, and incentives to fish. Interviewees included fishers, buyers and boat owners, as the three strata of stakeholders in the fisheries. Results showed that the sea cucumber and seahorse populations were reduced by an order of magnitude over a period of 2 years and 5 months respectively. Participants knowingly over-harvested, convinced of the inevitability of depletion and determined to obtain their share of income in a tragedy of common access. We highlight the need to document serial depletions and that quantitative reconstruction may provide insight into boom and bust dynamics. These fisheries will need creative and flexible management approaches that are able to ride the rapid extraction of taxa with unknown and/or variable life history traits. The potential for allocation and stewardship-based options are discussed for the purposes of both sustainably harvesting coral reefs, while providing livelihoods for marginalized fishers.

A Conceptual Model Linking Reef Landscapes to the Behavior of Piscivores and the Functional Responses of Prey

*Peter JAUSTER**

1080 Shennecossett Rd., Groton, Connecticut 06340 United States of America
auster@uconn.edu

Attributes of reef landscapes vary at multiple spatial scales (e.g., roughness, slope angle). Predators have developed behavioral repertoires that vary based on landscape attributes and behavior of prey. Further, predator morphologies constrain behavior such that predators operate at particular, or across a range of, spatial scales. A conceptual model was developed to integrate these factors in a manner that allows observational studies to partition data by predator guild (based on behavioral strategy), landscape attributes, prey guild, and predator success. Observational and experimental studies of predator-induced mortality in fishes generally treat predation as a black box and do not attribute components of mortality to particular predators or predator strategies. In order to understand the recruitment patterns of fishes mediated by interactions with a diffuse piscivore guild, a reductionist approach seeking to understand how variations in the suite of predators influence mortality may provide important insights.

Ecosystem Science to Support Ecosystem-based Management of the US-Affiliated Pacific Islands

*Russell E BRAINARD**

1125B Ala Moana Boulevard, Honolulu, Hawaii, USA 96814 United States of America
rusty.brainard@noaa.gov

Marine resource management is undergoing a fundamental transformation from the management of individual stocks or species to ecosystem-based management. This transition has challenged policy makers, resource managers, and scientists as they struggle to define what ecosystem-based management is and how it might be implemented. As this process evolves in the U.S. Pacific Islands region, a multidisciplinary team of scientists sponsored by NOAA's Coral Reef Conservation Program and led by the Coral Reef Ecosystem Division of the Pacific Islands Fisheries Science Center has been collaborating with other Federal, State, and Territorial agencies, and nongovernmental organizations to initiate a long-term, comprehensive program to assess, monitor, and map the coral reef ecosystems of the region. Since 2000, this program has conducted baseline assessments and initiated multidisciplinary spatial and temporal monitoring of the major components of the coral reef ecosystems of the Northwestern Hawaiian Islands, the U.S. Pacific Remote Islands Areas (Howland, Baker, and Jarvis Islands and Johnston, Palmyra, and Kingman Atolls), American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. Monitoring efforts include rapid ecological assessments of the corals, other invertebrates, fish, and algae using multiple methods; spatial towed-diver surveys of benthic composition and the abundance and distribution of ecologically and economically important fish and macro-invertebrate taxa; mapping of shallow and deepwater benthic habitats using single and multibeam acoustic systems, towed cameras, and satellite imagery; bioacoustic surveys of water column biomass; and multi-platform oceanographic monitoring using shipboard surveys, moored instrument arrays, drifters, and satellite remote sensing. Integration of concurrent observations of the marine resources and their benthic and oceanographic habitats allows improved understanding of the spatial and temporal variability and complex biophysical linkages controlling these ecosystems. Long-term multidisciplinary monitoring across the major functional components of these ecosystems will provide resource managers the critical information needed to implement ecosystem-based management principle

Co-design of Knowledge Bases in Marine Biology: Application to Corals of the Mascarene Archipelago and to Fishes and Hydroids of Reunion Lagoon

*Noel CONRUYT**, David GROSSER, Yannick GEYNET, Gerard FAURE, Michel PICHON, Nicole GRAVIER-BONNET, Pascale CHABANET, Francois HALLOT, Alain SENTENI, Jacques LE RENARD, Sandrine TRICART, Mohammad SANTALLY, Dorothy COOSHNA

15, av. Rene Cassin, 97715 Saint-Denis, France French Southern Territories
conruyt@univ-reunion.fr

This paper describes an emergent collaborative e-research and e-learning project between knowledge experts (content producers) of French institutions and laboratories (Museum National Histoire Naturelle de Paris - MNHN, Ecole Pratique des Hautes Etudes de Perpignan - EPHE, Laboratoire Ecologie Marine de St-Denis - ECOMAR) and computer scientists - designers (editors) of the Universities of Reunion and Mauritius (Institut de Recherches en Mathematiques et Informatique Appliquees - IREMIA, Virtual Centre for Innovative Learning Technologies - VCILT). The objective is to make scientific research results on reefs biodiversity available to a wider audience, aiming to create awareness and contribution to a better protection of this environment. E-research is the Computer Support Collaborative Working task for helping systematists to better classify their specimen descriptions: it is operated through synchronous (videoconference) and asynchronous (Content Management System) streams. E-learning is the Computer Support Collaborative Learning process for helping non-specialists to better identify their observations of specimens: the high value content is accessed through a multimedia questionnaire on the Web, that is built upon decision tree discrimination and case based reasoning comparisons. Starting from applications on corals of the Mascarene Archipelago, then fishes and hydroids of Reunion Lagoon, we show how enhancement and dissemination of research results can be achieved by a combination of an upstream strategy based on IKBS (<http://ikbs.univ-reunion.fr>), a generic software for building knowledge bases on the internet in natural sciences, and a downstream one, based on a pedagogical approach borrowed from the DARWIN world (<http://darwin.cyberscol.qc.ca/>). The final outcome expected for the overall IKBS-DARWIN project is a transversal bilingual (French - English) research and educational portal for corals, fishes and hydroids modelling, description, classification and identification tasks. It will support online activities for enhancing several related domains at different levels of competency, from researchers and graduate students to undergraduate students, associations or communities of practice.

A Local Action Strategy for Coral Reef Fishery Management in Guam

*Trina LEBERER**

192 Dairy Road, Mangilao, Guam 96913, USA Guam
tleberer_1999@yahoo.com

In the past 18 years, Guam saw a decline of 70% in catch per unit effort for coral reef fish stocks based on inshore creel and participation surveys conducted by the Division of Aquatic & Wildlife Resources (DAWR). The many causes for this decline include: more efficient and non-selective gear types; the deterioration of coastal water quality and subsequent decline in health of coral reef habitat; fisheries that target the largest individuals; a shift from subsistence-based to relatively small-scale, commercial-based fishing; the cultural importance of and affinity for juvenile fisheries; human population increase; and an increase in fishing pressure due to economic recession and current levels of immigration. After nearly 15 years, seven public hearings, and thousands of public comments, DAWR established 5 marine preserves, in addition to other fishing regulations and statutory restrictions regarding species, size, number, and the limiting of certain gear types. A 3-year local action strategy for coral reef fishery management focusing on increasing the effectiveness of the 5 marine preserves was developed by DAWR and reviewed by fishermen, resource managers, and other stakeholders. The strategy addressed three main issues: lack of enforcement and prosecution, lack of public awareness and support, and the need to assess the effectiveness of the preserves in increasing reef fish stocks. Specific management actions proposed to address these issues include the purchase of vehicles, a vessel, and equipment for conservation officers, implementing a reserve officer program to expand enforcement coverage, hiring of a natural resource prosecutor, implementing a multi-media education and outreach campaign, and funding studies that focus on assessing fish biomass increases and spillover effects.

A Project for Preservation of the Sanctuary of Coral Reef in Okinawa, Cooperated with Volunteer Divers, Local Community, Local Government and Mass-communication

*Hajime NOJIMA**, *Shinji OMORI*
2-3-1, Kumoji, Naha, Okinawa Japan
nhajime@lime.ocn.ne.jp

Coral reefs in Okinawa have about 350 species of reef-building corals and are known as one of complex coral-reef ecosystem in the world. However, coral reefs in Okinawa have been severely damaged by coral bleaching event in 1998 and recent *Acanthaster*-attacks. Taking these critical conditions of coral reefs into account, the government of Okinawa Prefecture set the sanctuary of coral reef in Kerama Is. in 2003 for preserving corals remained. In 2002 before this setting, the local TV-company, RBC(Ryukyu Broadcasting Corporation), founded a network group named "THE GARDIAN FOR CORAL REEFS", cooperated with volunteer divers, local communities, local government and mass-communication. The volunteers of "THE GARDIAN FOR CORAL REEFS" carried out removing *Acanthaster* from the sanctuary and over 3,000 sea-stars in total removed by four-times activities. RBC has reported and broadcasted these activities in each time. RBC also calls local communities and private companies for donations and joining with the network group. "THE GARDIAN FOR CORAL REEFS" is intending the survey of *Acanthaster* in deeper areas using ROV (remote operating vehicle) owed the local coastguard in the next year. In the future, "THE GARDIAN FOR CORAL REEFS" is planning to remove *Acanthaster* also in Sekisei Lagoon and to monitor coral reefs in Okinawa.

The Impacts of Muroami Fishing on Coral Reef in Karimunjawa National Park, Indonesia

*Shinta T PARDEDE**, *Michael J MARNANE*, *Joni T WIBOWO*,
Yudi HERDIANA, *Rizya L ARDIWIJAYA*, *Ahmad MUKMININ*
Jl. Pangrango No.8, Bogor, West Java Republic of Indonesia
shintril@wcsip.org

Muroami is a fishing technique used to harvest reef fishes in Southeast Asia, whereby numerous divers drive fish into a large, set net. This study investigated the impacts of *muroami* on fish stocks and coral habitats within Karimunjawa National Park (KNP), Indonesia. The main objectives were to: i) quantify the proportion of fish removed from reefs by *muroami*, ii) quantify the amount of damage caused to corals by *muroami*, iii) determine the efficiency of *muroami* compared to other gear types, and iv) examine community perceptions of the use of *muroami* within KNP. Data were collected on fish biomass, the size of *muroami* fishing areas and the amount of coral damage caused by *muroami* divers using underwater surveys. Data on gear efficiencies were collected using surveys of fishers and their catches. Community perceptions of the use of *muroami* gears were examined through household surveys. Results suggested that *muroami* was five times more efficient than any other gear type. An average of 62 kg (\pm 13 SE) of fishes were removed per hectare of reef swept by *muroami*, which approximated to more than 40% of the standing biomass of fish stocks in a given area (147 kg \pm 11 SE). In addition, *muroami* was found to cause significant coral damage, averaging 58 cm² of broken coral per 1 m² of operational area. Household surveys showed that the majority of community members were in favor of reducing or banning *muroami* within KNP. This study suggested that *muroami* had a significant, detrimental impact on reef fish stocks and coral communities within KNP and that there was strong community support for gear regulation. The provision of this information to national park management and district government has been critical in a motion being passed to ban *muroami* within KNP.

Integrating Science Toward the Management of Coral Reefs: An Assessment of the First Four Years of the National Center for Caribbean Coral Reef Research's Interdisciplinary Study of the Florida Reefs

*Johanna POLSENBERG**, *John MCMANUS*
4600 Rickenbacker Causeway, Miami, FL 33135 USA
jpolsenberg@rsmas.miami.edu

The National Center for Caribbean Coral Reef Research (NCORE) was established in 1999 to foster interdisciplinary, process-oriented studies directed at answering fundamental questions regarding the function, health, and sustainability of coral reef ecosystems in the Americas. With an initial focus on the Florida reef tract, the center brings together scientific and management experts to identify critical scientific questions and approaches, develop research initiatives, facilitate acquisition of research funds and efforts, and communicate findings to relevant agencies and public interest groups. The initial research emphasis of NCORE was on the biogeochemical, trophodynamic, and hydrodynamic processes impacting the nutrient cycle of the Florida reef tract. The interdisciplinary and simultaneous study of these processes was designed to enable greater understanding of the causes of increased algal overgrowth on the reefs. Complementary activities were conducted at a regional scale to: estimate the status of the coral reefs and reef management; investigate the regional extents of problems affecting the reefs; uncover crucial information gaps; and develop a series of tools to assist managers in maximizing ecosystem resilience in the face of current and future stresses. We present here a report on the achievements of the project and an analysis of the process by which an interdisciplinary, multi-investigator project of this magnitude succeeds and struggles to accomplish such diverse yet shared goals.

Linking Coral Reef Conservation into Integrated Coastal Management

*Sapta PUTRA**
Jl. Empang Tiga No. 11 RT 03/10, Kalibata Timur, Jakarta 12740 Republic of Indonesia
sapta@cbn.net.id

Indonesia is the world largest archipelagic nation with more than 17,500 islands and an 81,000 kilometer (km) coastline rich in coral reefs. Coral reefs are extensive covering 25,695 km² equivalent to about 10% of the world coral reef area, with about 70 genera and 450 species of corals. The challenge facing Indonesia is how to manage these coral reef resources in a sustainable manner. Since 1998 Indonesia has implemented a 15 year Coral Reef Rehabilitation and Management Program (COREMAP). It is currently entering its fourth year. COREMAP is supported by both ADB and World Bank/GEF funds as well as Government of Indonesia and JFPR. It has three goals: (i) Ensure sustainable management of coral reef ecosystems; (ii) Strengthen capacity of communities and local institutions; (iii) Lower incidence of poverty. COREMAP seeks to gain support for these goals by demonstrating the direct quantifiable benefits to be gained from coral reef protection. This paper discusses how Indonesia is planning to transform management of twelve districts from an exploitation base to one of conservative, long-term sustainable management, while maximizing sustainable fishery benefits and conserving biodiversity. Program components of Coremap II include institutional strengthening at all levels, community based and collaborative management and public awareness and education. Important facets of the Program include enhanced community involvement in management; better law enforcement; reduction in destructive fishing practices; promotion of alternative income generation strategies; and the large scale adoption of Marine Protected Areas. Key words: Marine biodiversity, Co-management, Community Based Management, Marine Protected Areas, Sustainable Use, Maximized fisher benefit

Private Sector Investment in Marine Protected Areas - Experiences of the Chumbe Island Coral Park in Zanzibar/Tanzania*Sibylle RIEDMILLER**

P.O.Box 3203, Zanzibar/Tanzania

sibylle@chumbeisland.com

Chumbe Island Coral Park Ltd (CHICOP), established in 1991 and the first fully managed Marine Protected Area (MPA) in Tanzania, illustrates issues for a privately created and managed marine protected area in East Africa. Investment and fisheries legislation and the institutional environment of Zanzibar (Tanzania) made the park possible, but required higher investment than anticipated. Management costs are funded through ecotourism and much lower than donor-funded government-run park budgets. Particularly training and employment of local fishermen as park rangers by volunteers proved cost effective and facilitated direct partnership with local fishing communities. Contrary to expectations, international security concerns and travel warnings have not affected the income levels needed for cost effective on-site conservation management. Non-extractive and non-destructive use through genuine ecotourism adds economic value to coral reefs and creates incentives for effective and sustainable conservation. Like any monopoly, the government monopoly in conservation that is predominant in many parts of Africa, tolerates poor performance and management inefficiencies. In contrast, private sector cost control and income generation create better prospects for sustainability. Private nature reserves can play a decisive role in establishing and managing no take ecological marine reserves that support biodiversity and fisheries. Therefore, the private sector needs to be acknowledged and encouraged as a legitimate actor in conservation, not only as a source of funding. To encourage private investment in partnerships for conservation, a conducive investment climate, security of tenure and contractual security are essential. International insurance schemes for MPAs could help buffer risks of volatile tourism markets.

Sustainable Management of Gulf of Mannar, a Marine Biosphere Reserve in India*Naganathan V**

Wildlife Warden, Gulf of Mannar Marine National Park, 2/219 Madurai Rameswaram High Way, Ramanathapuram 623503, Tamilnadu, INDIA

nag_ifs@rediffmail.com

Gulf of Mannar is the first and the biggest (10,500 km²) Marine Biosphere Reserve in India as well as South and South East Asia. The first international coral reef symposium was held on the banks of this Biosphere Reserve at Mandapam. There are about 21 coral islands and all of them are under different stages of degradation due to human interference. About 45 fishing villages with a population of about 50,000 are dependent on this biosphere reserve. It harbours nearly 3600 marine organisms of which many are endangered, The sea cow Dugong dugon and the hemichordate *Ptychodera flauva* are notable among them. It has unique endemic biodiversity too. Introduction of modern trawling methods leading to over exploitation of resources is threatening many reef organisms to extinction in this region. Pearl industry and Chank industry which were flourishing well once have disappeared totally due to lack of sustainable utilization strategies and other organisms like Holothurians and sea horses are under severe threat. Mushrooming of hazardous industries along the coast, weed collection, lack of organization among fisherfolk, migration of traditional agriculturists to fisher-vocation and swindling of lion-share by middlemen have caused serious threat to this unique Biosphere. Sedimentation, Industrial Pollution and Erosion due to anthropogenic activities are the major problems resulted due to mining of corals and sand along the Reserve. By introduction of GEF-UNDP Project on "Conservation and Sustainable use of Gulf of Mannar biosphere Reserve's Coastal Biodiversity". The management of GOMBR has attempted to integrate efforts of Management with various stakeholders of GOMBR such as other Government organizations, NGOs, Local fisher folk, Technical Institutions, Research Institutions, Market force etc., with focus on Educating and Empowering local fishermen in sustainable management of GOMBR resources through awareness education and identification of feasible pragmatic alternative livelihood opportunities.

***Dendrogyra cylindrus* (Anthozoa: Scleractinea) in Providencia Island, Colombian Caribbean: Habitat Preference and Demography**

Andrea ACEVEDO, Alberto ACOSTA*

Cra. 7 No. 43 - 82 Ed. 53 Of. 106B, Bogota, Colombia
andrea_acevedo78@yahoo.com

Few studies have quantified the habitat preference and demography of species considered for potential restoration programs. Habitat preference and demography of *D. cylindrus* was evaluated in the Providencia Island reef complex to determine whether this species is rare and if it has made a useful contribution to restoration there. Through 24 belt transects (240,000 m² each) and 20 circular plots (2,800m² each), density, colony size, and area of partial mortality were quantified and compared in four different ways: leeward vs. windward, reef zones (fore reef, reef flat, patch reefs, and two barrier reefs), ecological units (soft corals, macroalgae, mixed corals, sand-coral rubble), and depth (<5, 5 to 12 and >12m). *D. cylindrus* was founded primarily in the leeward habitat, on the fore reef, in the ecological unit of soft corals, and at depths between 5 and 18m. Density was significantly higher on leeward (500 to 1500 col/km²) vs. windward (<150 col/km²) sites. Density was highest on the fore reef (655 col/km²). Colonies generally exhibited a low susceptibility to partial mortality (3.2% of total area) and disease. *Diadema antillarum* was the main bioeroder of *D. cylindrus* (73 of 283), fragmenting the colonies through grazing their bases, thereby increasing the coral distribution and density. Of the 283 colonies considered here, 75% were adults (>16cm high) and 25% were juveniles (mostly fragments). In conclusion, *D. cylindrus* is not a rare species in Providencia Island, exhibiting higher densities there than on other reefs in the Caribbean. It also requires specific habitat, hydrodynamic, depth characteristics and reef species association. The high density of columns produced by a colony, the high rate of fragment regeneration, the low susceptibility to partial mortality and disease, as well as the quantity of associated fauna make it a promising species for restoration.

Coral Diversity on Artificial Reef Structures (Pallet Balls) off Fahal Island, Sultanate of Oman

Musallam M AL JABRI*, Vanda M MENDONCA, Mohamed AL MUZAINI

MRMEWR, P. O. Box 323, Muscat 113, Oman
vmendonca@hotmail.com

In the Sultanate of Oman, major coral growth is restricted to four areas: Muscat area (Gulf of Oman, including the Dimaniyat Islands, Sawadi Area and Fahal Island); the straits, shallows and shores west of Masirah Island (Arabian Sea); and some isolated sheltered locations in Dhofar and the Al Hallaniyats (Arabian Sea). Threats to coral reefs include temperature-drops upwelling-related factors, especially turbidity; sediment characteristics, which may not enhance larval settlement of coral communities; strong currents; biotic relationships, in particular depletion of corals by predators, such as starfish *Acanthaster planci*, and diseases; and finally human disturbances. Therefore there is a need for rehabilitation of the coral reefs of Oman. Artificial reef structures have been deployed in the Muscat area, especially off Fahal Island, after observation of damage to the coral reef. In the present study (2001-2003), coral communities off Fahal Island were studied at two depth levels (4m and 16m) along two transects (Transect 1 with artificial reef structures - pallet balls, deployed in 1998; and Transect 2 with coral communities on natural substrate), totaling four sampled sites. Non-destructive video monitoring was carried out on 10 balls per depth level along Transect 1, and 10 quadrat areas per depth level along Transect 2. Of the total 31 coral species identified at the four sites, 16 were recorded on balls, and 25 on natural substrate. Either on pallet balls or on natural substrates, coral communities were more diverse at 16 m depth, although they were less dense than at shallower sites. On the other hand, 6 species that colonized the balls were not found on the surveyed natural substrate. Therefore, the deployment of artificial reef structures also provided more stable and additional substrate for corals species, especially incrusting corals.

Corals, Resorts and Reef Restoration in the Maldives

Abdul AZEEZ*

Vabbinfaru Island, North Male Atoll Republic of Maldives
a.azeez@banyantree.com

The coral reefs of the Maldives were severely damaged during the mass global coral bleaching in 1998. Since then, Banyan Tree Maldives, a 5 star resort based in North Male Atoll, has instigated a number of programs to research, conserve and restore some of the local coral reefs. Banyan Tree Maldives employs full time, Maldivian environment education officers to start, and oversee various programs that have three main aims: to educate diving/snorkeling tourists by actively involving them in conservation projects; to educate Maldivians (particularly local school children) about the marine environment; and to invite scientists to carry out research projects that have conservation and educational benefits. To facilitate this work, Banyan Tree Maldives is currently setting up a small marine laboratory that can be used for education and research. Examples of projects carried out so far include: construction of electric reefs, for reef restoration and education; construction of artificial reef structures to help prevent beach erosion, planting of coral fragments in an attempt to improve aesthetic value of the house reefs, and more recently, monitoring of the timing and extent of multi-species coral spawning events in the Maldives. Banyan Tree hopes to continue and expand these programs in the future. Potential projects include research in to coral bleaching (i.e. molecular and experimental work to look at bleaching tolerance), coral reef recovery processes and the effectiveness of reef rehabilitation and coral transplantation.

Isolated *Acropora* Coral Colonies as Critical Nursery Habitat for Fish, with Coral Transplantation as a Potential Means to Accelerate Fisheries Recovery within Coral Reef Management Areas

Austin BOWDEN-KERBY*

GPO Box 18006 Suva, Fiji Islands
bowdenkerby@connect.com.fj

The potential for coral transplantation as a coral reef fisheries resource management strategy was investigated, modeled on natural colony transport and colony establishment in calm backreef areas dominated by unstable rubble and sand where recruitment of coral larvae is inhibited. Such unstable substrata dominate on reefs impacted by destructive fishing, dredging, and coral harvesting, and thus the study is relevant to the restoration potential of such degraded reef areas. Transplantation experiments were carried out in southwestern Puerto Rico. *Acropora cervicornis* coral colonies were grown on reef flat to >25cm high and then transplanted at various distances from reefs on sand and seagrass, to test for differences in fish recruitment to the corals. Results indicate that coral colonies transplanted >30m from reefs harbor significantly more fish than colonies <13m from reefs, with considerable difference between species and initial recruit size in seagrass beds and sand flat sites. A natural process of hurricane-mediated patch reef formation in the sandy back reef was substantiated during the study as well, with hurricane transport of staghorn *Acropora* colonies up to 127m.

Community Based Reef Restoration Using Branching and Non Branching Corals in Tuticorin Coast of Gulf of Mannar, Southeast Coast of India

G MATHEWS, M VENKATESH, Edward J K PATTERSON*, Dan WILHELMSSON
44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India
coralmat@yahoo.co.in, jkpatti@sancharnet.in

The Gulf of Mannar (GOM), the first Marine Biosphere Reserve in India has an area of about 10,500 sq.km and includes 21 islands, surrounded by fringing and patchy reefs rising from the shallow sea floor. Tuticorin coast, the southern part of GOM is the most environmentally stressed area due to destructive fishing, coral mining and pollution from the industries along the coastal belt. Due to mining, at present the corals are distributed in small patches. Reef restoration by involving local community was initiated in two locations at Tuticorin coast, with the objectives to restore the damaged reef back as nearly as possible to its original conditions in biological diversity and to preserve the threatened / endangered coral species. The involvement of local community is cost effective and aids in conservation coupled with awareness creation. The branching (*Acropora intermedia*, *A. humilis*) and non-branching (*Porites lutea*, *Favia pallida*) corals were selected for restoration using low-tech methods. Concrete frames were deployed at different depths, to serve as platforms for the attachment of coral transplants. The frames (1m²) were placed to give an approximate area of 17 m length and 8 m width. The coral fragments were fixed to the substrate by nylon rope and then to the concrete frame. The survival was measured monthly in terms of the percentage number of living coral transplants. After 10 months, the average growth rates of branching coral fragments were > 4-5 cm and non branching coral fragments were > 0.8 cm and > 85 % of the transplants showed good survival. This method is cost effective, fast in the increase of biomass, and is possible to apply also at larger scales. However, suitable species and sites are the basic requirements for successful restoration of corals in the degraded areas.

Reef Restoration by Coral Transplant Techniques, in the Yucatan Shell, Mexico

Miguel A GARCIA*, Roberto IBARRA, Susana A PATINO
Boulevard Kukulcan Km 4.8 Z.H, Cancun, Quintana Roo, Mexico.
magarcia@conanp.gob.mx

During the hurricanes season the bad weather has forced the ships to find resguardo in the protected zone of the Mujeres bay and in some manoeuvrings some ships has crash with the coral reefs who is in there, making a great damage. The result has been different impacted areas. If we add all this damage, we have a 1,000.00 m² of coral damage, with different levels of affectation, since a break coral colony to the fracture of the all structure of the coral reef. The damage coral reefs is located in the National Marine Park of Cancun, Costa Occidental de Island Mujeres, Punta Cancun y Punta Nizuc, formed by some coral patches. The principal species register there are *Acropora cervicornis*, *Acorpora palmate* y *Porites astreoides*, with some massive coral growing of the Colpophyllia and Meandrina genus. After the impacts, a new project started, the goal was to make a restoration of the coral to reduced the negative effects of the ships accidents in the past two years. The principal action was focus to rescue and transplant the pieces of live coral produced by the crash. The restoration start when the coral pieces fragments was established to the firm stone and to the coral skeleton, using plastic bands, after this put some of cement, mixed sand and cement in a proportion 30 to 70. With the colonies and the big fragments, need a construction iron rod of 20 or 30 cm length beside the cement giving to the colony stability to stay firm in the soil. The survive percentage is about 70 to 80 % and this percentage increases or decreases depend the time who pass after the impact.

Coral Fragments, Cable Ties, and the Dynamic World of Shallow Caribbean Coral Reefs

Virginia H GARRISON*
600 Fourth Street South, St. Petersburg, Florida 33701 United States of America
ginger_garrison@usgs.gov

Storm produced fragments of *A. palmata*, *A. cervicornis* and *Porites porites* were collected from reefs in Virgin Islands National Park and transplanted to degraded reefs. Inert cable ties were used to attach coral fragments to dead coral substrate (usually *A. palmata*). Transplanted fragments and natural colonies of each of the three species were measured and photographed every six months during the four year study (1999 to 2003). Survival of natural and transplanted *A. cervicornis* and *P. porites* was very low. Approximately 20% of transplanted and 50% of natural colonies of *A. palmata* were alive and growing after 4 years. Damage from storm swells was the most common cause of mortality. Growth of both transplanted and natural colonies of *A. palmata* was similar, in that some colonies grew rapidly, while others sustained significant damage or grew little. Transplanted *A. palmata* tissue grew over the inert cable ties and cemented to the substrate within as little as a few months. This pilot project was successful in developing a low cost, low technology reef restoration technique using naturally-produced coral fragments.

Coral Reef Injuries and Relevant Case Studies: Tool for Restoration Management

Bruce D GRAHAM, Robert D MULCAHY*, Richard W CURRY
7897 SW Jack James Drive, Suite A, Stuart, Florida 34997 United States of America
bgraham@marine-resources.com

Coral reefs, recognized as significantly productive habitat, are experiencing severe degradation and the worst may be occurring in the Caribbean where coral cover has declined 80% in some areas. Causes of the degrading injuries are both natural and anthropogenic in origin and are attributable to small spatio-temporal factors such as ship groundings and relatively large-scale factors such as disease and climatic change. Restoration represents an important step in reducing the cumulative impact of coral reef injuries to preserve this unique habitat. The U.S. Department of the Interior National Park Service developed a program to identify and describe coral reef injuries to establish a developmental plane for understanding terminology used in connection with reef restoration management and to assist resource managers in defining restoration options based on injury type(s). A descriptive lexicon of coral reef injuries will additionally provide the baseline for the development of restoration alternatives required for National Environmental Policy Act compliance of proposed U.S. government actions. Coral reef injuries are broadly categorized as 1) surficial, involving damage to the biological (attached epibiota) and geological veneer of the reef, and 2) structural, involving destabilization of the reef structural integrity and characterized by major alterations of the reef topography. Case studies are presented that outline management approach to resource damage assessment and restoration and utilize field-tested options to treat both surficial and structural injuries. Identified injuries at a vessel grounding site offshore of Antigua dictated options for restoration/mitigation which were utilized in the habitat equivalency analysis to estimate compensation for lost services. Habitat restoration, following surficial and structural injuries from a grounding vessel in Biscayne National Park, included reattachment of corals at on-site reattachment locations and within two artificial structures.

Reef Restoration by Coral Larvae Seeding: An Experimental Study on Survivorship of Artificially Settled *Acropora* Polyps in the First Year

*Takeshi HAYASHIBARA**, *Kouki FUKUOKA*, *Motohiko SANO*, *Motoya TAMAKI*, *Hirofumi SHIMIZU*, *Megumi MINAGAWA*
148 Fukai-Ohta, Ishigaki, Okinawa Japan
hayat@fra.affrc.go.jp

The survivorship and growth of the *Acropora digitifera* polyps that settled on the unglazed tiles in the laboratory were examined for one year in Urasoko Bay, Ishigaki Island, Okinawa, Japan. In the course of field experiment, however, many natural settlers of *Acropora* spp. appeared on the tiles. They avoided settlement on upward surfaces those were exposed to strong light and tended to settle in the darker areas. The highest mortality of polyps for the first month was observed on the upward surfaces. Therefore, the reason that the planulae avoid upward surfaces in the settlement might be strong light is lethal for newly settled polyps. Higher mortality continued until the sixth month, which was attributed to grazing by herbivorous fishes on exposed surfaces and competition with other sessile organisms on the protected surfaces. After the sixth month, the survivorship was highest in the upward surfaces those were protected by the plastic mesh. These results suggest that an improvement in the artificial substrata would raise survival and growth during the early polyp stages.

Comparison of Coral Recruitment and Community Structure Development between Artificial Reefs and Natural Coral Rubble in Singapore

*Jani T ISA TANZIL**, *Tse Lynn LOH*, *Loke Ming CHOU*
Blk S3, 14 Science Dr 4, Singapore 117543 Republic of Singapore
sci00506@nus.edu.sg

This ongoing research compares naturally occurring coral rubble quadrats of same surface area as reef enhancement units (REUs) to evaluate the performance of REUs in coral recruitment and survival in highly degraded reefs with high coral rubble cover, as in Singapore. Five 1m² quadrats were randomly marked out on same reef and depth range as corresponding REUs (August 2003) at each of 2 sites chosen where; 1) REUs and quadrats were concurrently set up (Kusu), and 2) REUs established >1.5yrs (RL). Patterns of growth are studied over 1yr period, using monthly photo transects. Monthly recruitment, diversity, mortality and development are monitored. REUs at RL previously surveyed using modified Line Intercept Transect showed decrease in turf algae (TA) cover from 93.2% (2nd month) to 51.6% (22nd month), while coralline algae (CA) cover increased from 0.3% to 46.2%. Mean number of coral recruits increased from 0.86±1.57/m² (9th month) to 8.33±8.96/m² (22nd month). Photo-transect data from newly deployed REUs at Kusu seem to show similar early colonization pattern. TA cover decreased from 100% to 92.7% in 3 months, replaced by CA (0.9%) and ascidians (5.7%). However, pattern of growth on quadrats is still inconclusive, with percentage cover of different communities fluctuating within these 3 months. Observations from quadrat mappings show dynamic change in structure and location of rubble pieces. The case is similar at RL. While REUs at Kusu showed no recruits yet, 14 recruits (all *Pectinia* sp.) were recorded on quadrats in November (3rd month). At RL (24th month), equal number of new recruits (4 each) was counted on both substrates; mostly *Pectinia* sp. Results are expected in upcoming months, as instability of coral rubble foundation should lead to less coral recruitment and survival than on REUs, due to abrasive action and smothering from moving rubble pieces, in addition to higher sedimentation.

Enhancement of Production of Coral Larvae under Suitable Conditions of Temperature and Salinity and Technique for their Transplantation

*Kenji IWAO**
179 Aka, Zamami-son, Shimajiri-gun, Okinawa Japan
iwao@amsl.or.jp

Enhancement of reproduction of coral larvae during mass spawning events (sexual reproduction) and transplantation of the larvae have been attempted for restoration of damaged coral reefs. A series of laboratory experiments were conducted to determine the temperature and salinity conditions that control settlement and metamorphosis of planktonic planula larvae of the pocilloporid coral *Pocillopora damicornis*. In addition, the relationship between the angle of substratum and survival of coral seedlings was examined in the field. The coral larvae settled under wide ranges of temperature and salinity (18-32°C and 21-51psu). More than 90% of the larvae always settled under 22-30°C and 34-51psu conditions. Skeletal development, however, was smooth only under 26-30°C and 27-30psu. Survival rates of the seedlings on the unglazed tile were different according to the angle of the tiles. On the tiles set upward (horizontal orientation), the surface was covered with a mat-like structure of turf algae and sediments, and all seedlings were dead five months after the planting. Survival rate was also low on the tiles set outward (vertical orientation), as turf algae dominated on the surface. The survival rate was highest on the downward surface (horizontal orientation); however, many seedlings did not survive due to presence of colonial ascidians. A comparatively higher survival rate was observed on the inward surface (vertical orientation), although it was lower due to the occurrence of turf algae. The results indicated that downward and inward setting of the tiles were best for transplantation, although the occurrences of colonial ascidians and turf algae were not completely excluded.

Habitat Equivalency Analysis Software to Facilitate Calculation of Compensatory Restoration Following Natural Resource Injury

*Kevin E KOHLER**, *Richard E DODGE*
8000 North Ocean Drive, Dania Beach, Florida 33004 United States of America
kevin@nsu.nova.edu

Habitat Equivalency Analysis (HEA) is a means to determine the amount of restoration needed (following injury to natural resources) as compensation for the interim loss of resources from the time of injury until the resource service level reaches equilibrium. The amount of compensatory restoration to provide resources and services equivalent to those lost is such that the gains provided equal the losses from the injury. An injury to natural resources involves a time component during which the ecological services that the resources provide are lost. The HEA approach is particularly well suited for analysis of compensatory restoration because it can be used to quantify the loss and recovery of resources and includes this time factor. We have developed computer software that facilitates input of HEA assumptions and parameters and provides an efficient method of calculating the required compensatory action. The program allows input of the relevant parameters necessary for analysis: service loss parameters (injured area size; times of injury, initial recovery, and recovery equilibrium; post-injury level of services; maximum recovery level; recovery function shape; long-term service loss); service gain parameters (times of restoration beginning and equilibrium; restoration service baseline level; maximum compensatory service level; service gain function shape; long-term service gain); and general program parameters (relative value of lost and gained services, baseline level of lost and gained services, discount rate). Because HEA results are highly dependent upon assumptions, it is useful to examine sensitivity of results using a range of parameter values. The software facilitates this by offering an intuitive graphical interface that allows the user to modify input parameters and quickly alter the recovery shape functions. The ability to formulate many 'what-if' scenarios provides an efficient method of gauging the sensitivity of the required compensatory action scale to the analysis parameterization and time variability.

Application and Comparison of Video Survey Methods versus Field Count Method for the Purposes of Rapid Assessment of Coral Communities: Hillsboro Inlet (Florida) Accidental Damage Case

*Vladimir N KOSMYNIN**, Cheryl L MILLER, Michael K CALLAHAN

5050 W. Tennessee St., Bldg. B, Tallahassee, Florida, 32304 United States of America

vladimir.kosmynin@dep.state.fl.us

Abundance and cover (projective cover) by corals are common characteristics of coral reef bottom landscapes. Cover by corals and other groups of reef organisms is the major characteristic used for coral reef monitoring and assessment. Methods of rapid assessment provide characterization of the current status of reef communities or particular species within the community. Rapid assessment by using field counts in large areas requires considerable effort and a large amount of underwater time using SCUBA. Authors developed a method of rapid assessment using video surveys with subsequent processing of images and counts of scleractinian corals, octocorals, and sponges and their cover in damaged or other areas of interest. This method was applied in the areas damaged by cable drags during the dredging of Hillsboro Inlet, Florida. Along with the video survey, field counts of scleractinian corals, octocorals, and sponge *Xestospongia muta*, were made. Description of methodology and analysis of two sets of video surveys (45 cm and 100 cm above bottom) versus field counts are provided. It is demonstrated that data on abundance of scleractinian corals, octocorals, and sponges correlate well between the field count survey and the video survey conducted from 100 cm above bottom. Percent cover estimated from the two video surveys deviates considerably for octocorals and sponges, and less for scleractinian corals. Data on size class distribution correlates satisfactorily between the 100 cm above bottom video survey and the field count survey. Data on damages to *X. muta* and octocorals also correlates well between the field count survey and the 100 cm above bottom video survey. Statistical analysis of the data demonstrates that the less bottom time-consuming video survey yields data of comparable accuracy to the field count surveys.

Eco-friendly Technologies for Fishing Port Facilities Improvement in Okinawa

*Masamitsu NAKAIZUMI**, Mamoru KAMIZATO, Atsushi IKEDA, Seiyuu MIYASATO, Jun TANAKA, Hiroaki GAHARA, Hidekazu YAMAMOTO, Keiichi TAMURA

1-14-10, uchikanda chiyoda-ku, Tokyo, Japan

nakaizumi@jific.or.jp

Surrounded by tropical waters, Okinawa Prefecture has a large extension of coral reefs along its coastlines. Ample shallow water areas provided by coral reefs have supplied aquatic organisms with perfect grounds for spawning and breeding. With such precious roles of coral reefs in mind, along with the aim to improve the fundamental facilities for the fishing industry, it is critical to understand the characteristics of the natural environment and fishery resources in the seas surrounding a fishing port, and reform it to an eco-friendly fishing port, equipped with functions of creating and restoring the natural environment possibly lost in facilities improvement projects. Reviewing past examples of eco-friendly technologies, as well as findings from field surveys, we applied the results for improvement works of fishing port facilities in Okinawa. In regard to coral reservation and restoration technologies, for the project of constructing outskirt structures outside the reef such as breakwaters, it is advisable to employ the methods designed for protecting coral communities in the region directly affected by transplanting or relocating coral reefs, or the methods for expediting coral larvae settlement by providing uneven-surfaces on substrate. For the project of improving fishing port facilities inside the reef, methods designed for the dredging works of a waterway should be noted, which incorporate special consideration for coral damage inherent to the project. The field survey of the waterway in Tonoshiro Fishing Port showed that the slopes of waterway with gentle gradients attracted more abundant coral species. This indicates that adopting gently-inclined slopes in waterways is considered a feasible option for coral reestablishment.

A Study on Comprehensive Maintenance of Coral Reef Area

*Sayuko NINOMIYA**, Shunsuke KURAHASHI, Tsutomu IWASHITA, Takashi MASUMOTO, Yoshikatsu NAKANO

1-15, Nihonbashi 3-chome, Chuo-ku, Tokyo Japan

ninomiya@tc.kyuei.co.jp

Coral reef areas widely exist in shallow and lagoon, and in places, include sea-grass bed in moat, sargassum bed on the dead coral reef, and mangrove woods in estuary. They play an important role to form various types of biota. In Okinawan water, however, the coral reef areas, which maintain coastal abundant biota, are decreasing with increasing land and coastal developments. The authors have investigated maintenance techniques of coral and sea-grass for restoring coastal environment. This report shows the recent research results about rearing method of coral egg, preventing method from feeding disaster, stable transplant method of sea-grass, and the monitoring method as the comprehensive maintenance technique of coral reef areas.

Effects of Fixation, Season and Fragment Size on the Survival Rate and Spawning of Transplanted *Acropora formosa* and *Acropora hyacinthus*

*Nami OKUBO**, Hiroki TANIGUCHI, Makoto OMORI, Tatsuo MOTOKAWA

O-okayama, Meguro-ku, Tokyo, 152-8851 Japan

namiokubo@nifty.com

To establish successful methods of coral transplantation with high survival rate and reproductive ability, we examined effects of the posture of fixation and the season of transplantation using fragment in 3 sizes of *Acropora formosa* and one size of *A. hyacinthus*. In *A. formosa*, vertically-fixed and large transplants had higher survival rate. In *A. hyacinthus*, the vertical transplants adhered to the substrate faster than the horizontal ones and resulted in 100% survival rate, indicating this species is well suited to transplantation if the methods were thoughtfully chosen. Spring transplants showed 100% survival rate and the high proportion of spawning in both species. We found the transplants joined the coming mass spawning. The transplants thus contributed to the recovery of coral reefs not only through the survival of the transplants but also through producing offspring. The vertically-fixed and large transplants had higher proportion of spawning. The fragments, not only without oocytes but also with oocyte at transplantation, did not spawn when their fragment size was small or they were horizontally fixed. They seem to resorb or degenerate their oocyte. The conclusion we drew was as follows: the best posture of fixation is vertical; spring seems to be the best season for transplantation in Japan; use *A. formosa* of large size (20cm) if we expect both high survival rate and spawning at the coming mass spawning.

Culture of Hydrocoral *Millepora alcornis* in Aquarium

Marilia D M OLIVEIRA, Ruy K P KIKUCHI, Zelinda M A N LEO*

IGEO/UFBA, Rua Caetano Moura 123, Federacao Federative Republic of Brazil

mariliad@ufba.br

This study aims to show that it is possible to culture *Millepora alcornis* for using in restoration projects of impacted reef areas in Brazilian reefs, where this hydrocoral, one of the most important reef builders, was largely depleted. The effect of light in calcification of *Millepora alcornis* was evaluated and an optimum period of illumination for maximum skeletal growth was attained. *Millepora alcornis* colonies were collected at depths of 2m in Todos os Santos Bay, Eastern Brazil. The illumination system used was actinic blue (03) and white Coralife fluorescent light bulbs, and metal halide 150W HQI bulbs, both types controlled with timers. Three experiments were performed, with five weeks duration each one. Two groups (A and B) were constituted by *Millepora alcornis* fragments, 10cm high in average. Group A (environmental control) remained under 12hs light/12hs dark regime along all three experiments, while group B was exposed to three distinct light regimes (13hs light/11hs dark; 12hs light/12hs dark, and 11hs light/13hs dark). Calcification of each fragment was obtained once a week using buoyant weight technique. Data analysis shows that maximum growth of *Millepora alcornis* occurred under 13hs of illumination period. One hour change of photoperiod, relative to the intermediate situation, did not produce significant differences in calcification rate of fragments. Possibly, this reflects the existence of seasonal differences in calcification rates, since the change of 2hs in the photoperiod produced significant differences ($p < 0.01$) in the skeletal growth of *Millepora alcornis*. With the systems of illumination, water filtering and circulation used in these experiments, associated with the physic-chemical conditions of the water and the absence of nutritional supplement, *M. alcornis* fragments heavier than 7g did not show any sign of stress. It is suggested that the illumination periods greater than 12hs enhance the growth of *Millepora alcornis*.

Transplantation of Stag Horn Coral, *Acropora formosa* Using Low-tech Methods in Tuticorin Coast of Gulf of Mannar, Southeast Coast of India

Edward J K PATTERSON*, C CHELLARAM, E V MULEY

44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India

jkpatti@sancharnet.in

Gulf of Mannar (GOM), covering an area of approximately 10,500 sq km has 21 islands, possessing fringing and patchy type of reef. Tuticorin coast of GOM is one of the highly stressed areas due to various anthropogenic activities. The stag horn coral, *Acropora formosa* is one of the most affected species and so this study has been initiated first time in India to preserve the species and to increase their biomass in the degraded areas. Experiments were carried out in Tuticorin port area, where there is tiny percentage cover of *A. formosa*. The different size groups of *A. formosa* fragments were fixed on artificial substrates such as cement slabs and stones using nylon rope. They were deployed in the inter-tidal area and their survival and growth were monitored for a period of 10 months. The main transplantation work was done on the open sea floor using large ferro cement frames (1x1m) as substrates, and an area of 10 X 10 m was covered. The overall survivorship and growth rate were 84.5 % and 2.2 cm respectively. After 10 to 20 days of transplantation, the secondary basal disc was formed in maximum number of fragments. All the fragments were completely fused to the substrate after 4 weeks and among this, 85% fragments had also overgrown on the nylon rope while 15% had partially overgrown on the rope. The polyps start to form proto branches both horizontally and vertically from second month onwards. Another method was also employed in September 2003 using locally developed cost effective fish houses as substrate for coral transplantation.

Innovative Substrates for Spatial Control of Coral Larvae Settlement and Effective Management of Juveniles

Dirk PETERSEN*, Michael LATERVEER

P.O. Box 532, 3000 AM Rotterdam Kingdom of the Netherlands

d.petersen@rotterdamzoo.nl

We designed substrates for ex-situ coral larvae settlement with the aim (1) to attract and (2) to control settlement spatially to a maximum, (3) to provide easy handling, and (4) to have the possibility to separate polyps after settlement with a minimum risk of damaging them. Our first choice was a chessboard-like arrangement of two different types of tiles made from a mixture of clay and porcelain. The tiles were produced using a vacuum-press technique, which enabled us to create surface structures of an accuracy of ± 0.1 mm. To set the potential settlement surface of each tile to a minimum, only parts of the tiles were exposed to the larvae. This was a flat horizontal surface for the first type ($22.0 \times 22.0 \pm 1.0$ mm) and four times vertical surfaces for the second type ($17.0 \times 17.0 \times 25.0 \pm 1.0$ mm). The latter one had an elevated blunt-pyramide-like shape. All exposed surfaces were structured with several parallel grooves (width and depth 2.0 ± 0.1 mm). The arrangement of the tiles and their surface structure created a high spatial diversity on a small scale. We carried out settlement experiments using five reefbuilding coral species. Almost 100% of settled larvae were located in the grooves, which protected them from mechanical damages potentially caused by handling or algae grazing organisms. For settlement and outgrowth of juveniles the tiles were designed to be temporarily fixed in standard plastic grits, which are widely used in coral culture. The presented method offers the possibility to generate primary polyps on a semi-industrial scale for various purposes like coral nursery for reef restoration and aquarium stocking. The standard sizes and for example the ability to combine differently incubated tiles with each other in one experiment might offer new possibilities for research.

Recovery Potential and Role of Coral Fragments in Intensive Tourism Zone of Coral Communities at Krabi Province, the Andaman Sea

Rattika PETTONGMA*, Thamasak YEEMIN

Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok, Bangkok 10240 Kingdom of Thailand

prattika@yahoo.com

The present study was carried out in coral communities at Mu Koh Phi Phi, Krabi Province, in the Andaman Sea during 2002-2003. Seventeen genera of juvenile colonies were found on various types of natural substrates, such as dead coral colonies, rock and sandy bottoms. Dominant groups of juvenile corals were *Porites* spp., *Echinopora* spp. and *Fungia* spp. The averages of juvenile colony densities were 0.25, 0.20 and 0.16 colony/m², respectively. The highest density of corals recruits on the settlement plates was 242.73 colonies/m². The major components of coral spats on settlement plates were *Pocillopora* spp.(88.83%), *Acropora* spp.(1.12%), *Tubastraea* spp.(0.56%) and unidentified coral recruits (9.49%). Although the density of juvenile colonies on natural substrates was lower than that on the settlement plates but the diversity of juvenile colonies on natural substrates was higher. The present study clearly showed high potential of natural recovery of coral communities at Mu Koh Phi Phi. However appropriate management in the area, such as addition substrates for coral recruitment and control or decreased impacts that effect to growth rate of juvenile colony, may accelerate the natural recovery of coral communities. Mean of coral fragment densities was 1.39 pieces/m². Sizes of coral fragment were in a range of 2-24 cm in length with an average of 8.70 ± 0.55 cm. Dead coral fragments were 1.78%. Average partial mortality of survived coral fragments was 27.47%. The dominant coral fragments were *Porites nigrescens*, *Montipora aequituberculata* and *Acropora* spp. A lot of coral fragments derived from diving activities and strong wave action can be used as materials for coral reef restoration projects. The techniques and suitable methods for reattachment of coral fragments to natural and artificial substrates have been developed according to the experimental results.

Substrate Stabilization in a Marine Protected Area in the Central Philippines: A Novel Approach to Reef Rehabilitation

*Laurie J RAYMUNDO**, Aileen P MAYPA, Pablina L CADIZ, Edgardo D GOMEZ
Silliman University Marine Laboratory, Bantayan Beach, Dumaguete City
6200 Republic of the Philippines
lauriejr@dgt.mozcom.com

Rubble from destructive fishing is a persistent, intractable problem; coral recovery fails on unstable substrates and reef fish communities are depauperate and scarce. We developed a novel approach to stabilize rubble within a Marine Protected Area. Initial surveys revealed 31% hard coral cover, with 28% rubble persisting since mid-1980s. Diversity and biomass of commercially important fish were very low. We used plastic mesh and cemented rock piles to stabilize rubble in 2.5 x 5 m and 5 x 5 m replicate plots within a 2,420 m² rubble patch. Transplanted coral fragments were arranged to promote fusion, creating larger colonies faster. The rehabilitated area totaled 500 m²; 20% of the rubble patch. Remaining rubble served as a control against which to test changes in fish and invertebrate communities. This "biophysical" approach provided recruitment substrate and created habitat, while reducing the number of coral transplants taken from surrounding reef. Preliminary results show that mesh remained fixed during storms, though rock piles required additional cementing. One-month transplant survival was 91%, with *Porites*, *Hydnophora* and *Echinopora* surviving well, and Acroporids and Pocilloporids showing higher mortality. Fusion and basal growth attaching fragments to rocks were visible 3 mo post-transplantation. Recruits appeared 4 mo after plot deployment. Cluster analysis and multidimensional scaling ordination indicated three fish communities: 1) rubble, 2) rehabilitation plots and 3) healthy reef. While initial census showed a rehabilitation community identical to that of rubble, subsequent censusing suggests a shift in composition of rehabilitation plots toward that of healthy reef. Scarid biomass increased within plots. Changes in local government removed support for the MPA community management organization. Our involvement stimulated renewed vigilance and enthusiasm. Both enhancement of the biophysical environment, promoting natural recovery, and improved management contributed to the initial improvements we observed. Further monitoring will establish long-term effects of this approach.

Inhibition of the Settlement and Metamorphosis in Coral Planulae by Strong Light

*Go SUZUKI**, Takeshi HAYASHIBARA, Kenji IWAO, Motoya TAMAKI, Hirofumi SHIMIZU, Isao HAYASHI
Kitashitakawa-iwake-cho Sakyo-ku Kyoto-shi Kyoto, Japan 606-8502 Japan
gosuzu@kais.kyoto-u.ac.jp

We are now developing restoration techniques of *Acropora* (Scleractinia, Anthozoa) communities on a large scale by seeding planulae gained from their mass spawning events. In this project, it is suggested that coral planulae may avoid the place where the strong light strikes them in their settlement. To examine their settlement competency without refuges from light, we counted the number of settlers and measured the required time for settlement in a 20ml polystyrene cup under the three light intensity levels: strong light (500-700 μ mol m⁻²s⁻¹), weak light (150 μ mol m⁻²s⁻¹) and darkroom. Each cup was filled with filtered seawater, and contained 10 planulae and some pieces of crustose red algae (*Hydrolithon reinboldii*) that induce their settlement (Morse et al. 1996). Under the strong light condition, there were little settlers in the cups through the experiment period. Under the weak light condition, more than half of planulae settled in the wall or bottom of the cup. Under the darkroom condition, more than 70% planulae settled in the cup within 9 hours from beginning of the experiment. These results may suggest that strong light (more than 500 μ mol m⁻²s⁻¹) directly inhibits the settlement and metamorphosis of coral larvae. Moreover, many planulae that once exposed to strong light became to be unable to settle in, when we moved the cups alternately from strong light condition to darkroom. This fact supports the idea that the strong light does damage to the physiological function of settlement in coral planulae. The fruits of this study may contribute to establish the optimal timing of releasing acroporid coral planulae for the restoration of coral reefs.

The Nursery Production of Reef Building Coral

*Hiroki TANIGUCHI**
179 Aka, Zamami-son, Shimajiri-gun, Okinawa 901-3311 Japan
taniguchi@amsl.or.jp

A wide variety of naturally occurring and human-induced impacts continue to damage coral reefs worldwide. We developed a technique for coral nursery production during the annual mass spawning in which coral polyps can be raised in an artificial substrate and then placed in natural environment. The artificial substrate, 5cm x 5cm unglazed tiles, was soaked in the sea for the periods of 3 weeks, half-year and 1 year before the experiment. The coral larvae were raised in containers in the laboratory. The result of experiment showed that more coral settled on the substrates that soaked longer periods. Nearly 90% of the polyps received zooxantellae within 1-12 days. After 7 months the polyp colonies grew to about 10 mm in diameter. Less than 7 colonies remained on each substrate. Future improvement of the efficiency of the coral nursery will depend on elucidating the causes of death of polyps in the initial stage.

Coral Transplantation in Thailand: Assessment of Coral Growth, Fish, and Marine Invertebrate Communities

*Voranop VIYAKARN**, Suchana CHAVANICH
Department of Marine Science, Faculty of Science, Chulalongkorn University,
Bangkok 10330, Thailand
voranop@chula.ac.th

Coral reefs in Thailand play a crucial role in the fisheries and tourism industries, and therefore are of paramount importance for the economy of Thailand and the entire Southeast Asia. As a result, most anthropogenic degradation of corals in Thailand appears to be linked to these two economic activities. Regulations are established to protect the reefs; however, the reef conditions still do not improve and the recruitment is still rare. Therefore, one method recently used to increase the abundance of corals is coral fragment transplantation. Some areas particularly at islands around Sattahip, Chonburi Province, have been using the coral fragment transplantation technique to enhance the reefs in the area since 1995. However, they had not been monitored whether this technique is suitable for the area. In this study, we investigated the growth of the transplanted corals and determine the communities of fish and marine invertebrates in the transplanted areas. The results showed that the coral fragment transplantation is one of the important methods to increase the abundance of corals in these areas where are less recruitment of juvenile corals. In addition, the transplantation allows other marine invertebrates to colonize and utilize in the transplanted areas.

Mapping Reef Habitats and Ecological Richness of SE Mauritius, Using an Aerial Photograph Approach

*Mohammed Rezag BADAL**, Lionel BIGOT, Sarvanen CURPEN, Ushveen NUNDLALL, Umar DEENMAHOMED
St Jean Street, Quatre Bornes Republic of Mauritius
rezahmb@moi.intnet.mu

In September 2002, the Mauritius Oceanography Institute (MOI) undertook a research project with the funding of the Commission de l'Océan Indien (COI) to prepare a habitat map of the coastal zone. This study has the immediate aim of designing and developing a Geo-Spatial Information System that would allow the classification of the marine coastal environment using a relative richness index

In an effort to standardize and employ a reef terminology that would depict the ecological meaning of the various morphology, a classification scheme has been adapted from Battistini et al (1975) and Montaggioni & Faure (1980). The same concept as outlined by the Caribbean Fishery Management Council; Dr. Ken Lindeman, Environmental Defense; and the NOS Biogeography team (Kendall et al, 2001) and also in "Etude pilote de la Cartographie de Mahe, 1998" is further developed to classify the ecological community to the dominant species level. In doing so, we have used the term "reef typology" in this study to describe the habitat of the marine environment from a geomorphology and ecological point of view.

The uniqueness of the South Eastern coast is described as a complex reef geomorphology system showing the co-existence of a fringing and a barrier reef. At this stage, the reef geomorphology concept (Montaggioni & Faure, 1981) enabled the delineating of the typology into the five basic entities, namely: outer reef slope, external reef flat, reef flat, inner reef flat and the back reef depression.

It is shown that aerial photography gives an accurate medium to map the typology which is further classified to depict their respective ecological richness. The classification scheme has been adopted in accordance with the guidelines (COI/UNESCO, 1998). The scheme adopted comprised four basic indexes ranging from very rich to less rich.

The Photo Tow: A New Technique for Estimating Coral Reef Status on Large Spatial Scales

*Yannick CHANCERELLE**, Rene GALZIN
BP 1013, 98 729 Papetoui, Moorea island, French Polynesia
criobe@mail.pf

The concept of the *Photo Tow* technique to estimate coral reef status on a large spatial scale has been developed at Moorea island (French Polynesia) outer reef slopes. This technique has permitted to collect data, faster and more accurately than ever before with classic visual methods. It is based on the principle of manta tow survey but combines a manta board towed by a boat, with a camera and flashes to replace the data sheets. At regular chosen time intervals (30 sec. to 2 mn) and at a constant depth, an operational towed diver takes pictures of the reef on the chosen trajectory to be sampled. Further devices, such as cross-beamed lasers and depth and time logger, enable the diver to measure the precise depth and time intervals at which the photos are made. Moreover, the boat is equipped with GPS and log and sounder allow the diver to be towed at a constant speed and depth. At each time interval, the boat speed is reduced to allow the towed diver to take the picture. Once taken, the pictures are analysed at the laboratory to record live coral cover percentage. On Moorea outer reef slopes, the *Photo tow* showed coral status differences with increasing coral coverage from southern to northern exposed coasts. Data were added in a GIS program to produce a map with large spatial scale representation of reef status around the island. Moreover, the *Photo tow* technique could be adapted for other studies concerning the large scale assessment of coral reef stresses (e.g.: bleaching, COT infestation) or counting of distinct benthic organisms. Therefore, it requires good visibility for photography and a sufficient depth profile for a small boat manoeuvrability.

Mapping and Monitoring Coral Reefs from Space Platforms: Sensor Studies for Depth, Band Selection and Temporal Needs

Edward G HOWARD, William SKIRVING*
1335 East West Highway, Silver Spring, MD, 20910, USA
Edward.Howard@noaa.gov

In recent months, NOAA has increased their advanced studies related to future sensor improvements and focused more efforts on coastal and ocean applications. Last year we completed a large one-meter aperture telescope study for geosynchronous orbit that would permit 18 km pixel size on the earth. This study reports on new work for improving space measurements of coral reefs. The study is in three parts. First, we ask, what improvements could be gained by ability to penetrate to greater depths for coral reefs? We envision improved sensors of the future like our new Geostationary Series of GOES R. And we believe there will be hyper-spectral sensors even earlier—perhaps using polarizing filters and special processing. We have processed hyper-spectral images from the Hyperion sensor on EO-1 satellite. In the second part of our study, we explore the trades between greater spatial resolution (with multi-spectral) and narrow spectral bands (with hyper-spectral) in order to operate both on the surface and underwater. This technical trade can be critical to give the scientist or coral resource manager what he/she needs to make decisions. This trade also sets better limits on the amount of data processing and calibration that must be done for accurate and faster distribution to the user. Finally, the third element in our study looked at required temporal resolution needed for assessing coral reef health including bleaching events. How often does the data really need to be updated? Needs are not the same for different times of the year or for different regions of the world and coral reef locations. The total paper presents a matrix of values for coral reef users by considering depth, spatial and spectral resolution, and temporal resolution for diverse coral reefs and regions.

Coral Bleach Survey by Landsat/TM and ETM Using Bottom Index in Kerama Islands

*Takeharu IKEMA**, Yukihiro NAKATANI, Yoshihiro SEKIGUCHI, Asaka HAGIWARA
11F-1, Asahi, Naha, Okinawa 900-0029 Japan
ikema@subtropics.or.jp

The data from the Earth-observation satellite Landsat at three different times, September 15 1995, September 18 1998 and October 1 2000, were used to detect coral reef of Kerama Islands, where are 60km west away from Okinawa island. The data were analysed to derive bottom index (BI) by applying an algorithm of the Lyzenga equation. The analysis resulted in classification of the sand areas and benthic community areas, including corals and sea grasses. The image data can be classified up to a water depth of 7m. The BI images in different year indicate the change of benthic community distribution. In 1998, when the coral bleaching occurred world widely, that event in Kerama Islands were also reported. In the BI image in 1998, the benthic community including coral reef area in west part of Tokashiki Is. was least amongst other years which may detect coral bleaching.

Developing and Applying an Index for Mapping Live Coral Cover Using Remote Sensing

*Karen E JOYCE**, *Stuart R PHINN*, *Chris M ROELFSEMA*, *Peter F SCARTH*
Biophysical Remote Sensing Group, School of Geography, Planning and Architecture, University of Queensland, St Lucia QLD 4072 Australia
k.joyce@uq.edu.au

Remotely sensed spectral indices are widely used in a range of environments for estimating biophysical parameters related to ecosystem health for vegetation, soil, and water bodies. However, to date, a simple and effective index has not been designed specifically for mapping live coral. Here we outline the development and application of an index sensitive to the areal cover of live coral, using in-situ spectral reflectance data from the Great Barrier Reef, Australia and Hawaii; and CASI-2 hyperspectral imagery from Heron Reef, Australia. From an initial spectral reflectance library, simulated combinations of substrates representative of the reef environment were developed using linear spectral mixing. The correlation between the proportion of live coral and the mixed reflectance signal was calculated to determine the wavelengths most sensitive to variations in the amount of live coral. Derivatives of the reflectance spectra, in addition to simple and normalized band ratio were also tested. Results presented here show that the second derivative of reflectance at 529nm was most sensitive to variations in live coral cover, though only marginally more so than several band ratio combinations. The band ratio deemed most sensitive to total live coral (blue and brown coral) variations was 594:614nm. As band ratio operations are simpler to perform and require fewer spectral bands than derivatives, we present these results as a simple and viable method for determining live coral cover under theoretically optimal conditions. This ratio was then applied to the CASI-2 image data and the results verified with co-registered field survey. The wavelengths used in this combination are not affected strongly by atmospheric attenuation, air-water interface effects or the scattering and absorption associated with the constituents of an ocean-coastal water column. Further applications and validations are required to determine the range of conditions and environments under which the index is effective.

On Suitability of the Reef Check and Video Transect Substrate Classification Schemes for Mapping of Coral Reef Habitat by Remote Sensing

*Tiit KUTSER**
Akadeemia tee 21, 12618, Tallinn, estonia
tiit@phys.sea.ee

Mapping of coral reef benthic habitat with remote sensing requires a classification scheme that can be used in interpreting the image data. In situ coral reef monitoring programs use different habitat and substrate classification schemes. The only information remote sensing instruments can detect about the coral reef habitat is their optical signature. However, the classification schemes do not take into account optical properties of coral reef substrates or life forms covering the substrates. Suitability of the commonly used Reef Check scheme and video transect scheme for interpretation of remote sensing data was tested comparing spectral signatures of different coral reef habitats with habitat classes in the classification schemes. In situ measured optical properties of different coral reef habitats suggest that these two classification schemes cannot be used without modification in interpretation of remote sensing data. Reflectance spectra of some benthic habitats are too similar to each other to allow resolving of the substrate based solely on their optical signature. On the other hand some benthic habitats may be mapped by remote sensing instruments in greater detail than they are classified in the Reef Check or video transect scheme.

Mapping Coral Reef Benthic Substrates Using Hyperspectral Space Borne Images and Spectral Libraries

*Tiit KUTSER**, *Ian MILLER*, *David L B JUPP*
Akadeemia tee 21, 12618, Tallinn, Estonia
tiit@phys.sea.ee

Hyperion, the first civilian hyperspectral sensor in space, was designed as a technical demonstration with initial expectation being that land applications would see greatest benefit. The suitability of Hyperion for mapping coral reef benthic substrates is tested in this paper. An image of Cairns Reef, in the northern section of Australian Great Barrier Reef, was acquired during Hyperion Cal/Val activities. A field experiment was carried out in Cairns Reef to collect information about the optical properties of the water in the area and to map benthic cover by means of video transects. A new physics based approach was used in classifying the Hyperion images. A hyperspectral library of radiance at Hyperion altitude was simulated using a spectral library of GBR benthic substrates, a Hydrolight 4.1 radiative transfer model, and an in house atmospheric model similar to Modtran-3.7. The image was then classified using Hyperion at-sensor radiance data and the Spectral Angle Mapper metric with the simulated at-sensor spectral library. The new method allows mapping of the benthic substrate type and water depth simultaneously. The results suggest that Hyperion is potentially suitable for mapping coral reef benthic habitat to a useful and applicable extent, that the method used is suitable for image classification to carry this out, and that Hyperion performs much better than initially expected in shallow water applications.

Evaluation of Spatial Statistics for Change Detection of Coral Reef Stress Using a Time Sequence of Imagery of Varying Spatial Resolution

*Ellsworth F LEDREW**, *Candace M NEWMAN*, *Alan H LIM*
200 University Avenue West, Waterloo, Ontario, N2L 3G1, Canada
ells@watleo.uwaterloo.ca

We have been able to verify that the difference in the Getis Statistic, a spatial local operator, between image dates can be useful for identification of possible stress in submerged tropical coral reefs. This analysis has been done on sequential SPOT imagery for field sites in Fiji and north Sulawesi. The potential for this is enormous when historical archives of registered image data are available for a potential target area. With new imagery of higher spatial resolution, such as IKONOS, there may be an opportunity to identify coral stress for spatial features approaching the natural dimension of coral heterogeneity. Typically, however, we do not have sequential IKONOS imagery over an appropriate time scale, which may be two to five years. The problem becomes one of integrating information from historical image sequences of varying spatial resolution when using a spatial operator. In this study we evaluate the potential of the Getis statistic to reveal coral stress anomalies using recently collected IKONOS imagery with coregistered archival SPOT imagery. We examine the performance of the spatial Getis operator for field sites around Bunaken and Siladen Islands near Manado, North Sulawesi.

Reef Mapping Accuracy Comparison among Medium Spatial Resolution Satellite Sensors - TM/ETM+, ASTER, ALI, and Hyperion -

*Tsuneo MATSUNAGA**, Akira IWASAKI, Satoshi TSUCHIDA, Hiroya YAMANO

16-2 Onogawa Tsukuba Ibaraki 305-8506 Japan
matsunag@nies.go.jp

Although satellites with 1-meter spatial resolution imaging sensors become more popular, medium resolution satellite sensors are still being and will be used to map and monitor coral reef environment with the scale of tens of kilometers. In this presentation, reef mapping accuracy of this kind of satellite sensors are compared and discussed to give some insight to future monitoring programs using satellite remote sensing. The study area is the fringing reef along the eastern shore of Ishigaki Island, Japan. As for ground truth in Ishigaki, results from recent field surveys and manual interpretation of aerial photographs were used. It is shown that spatial resolution difference, 10-30 m, and the number of the spectral bands affect the mapping accuracy in many cases. In addition, the difference in radiometric resolution also give a significant impact on the benthic classification. Based on these results, some recommendations on future coral reef mapping programs using satellite remote sensing will be given in the presentation.

Acoustic Remote Sensing: A Useful Tool for Producing Maps of Highly Variable Coral Reef Communities in Southeast Florida (USA)

*Ryan P. MOYER**, Bernhard RIEGL, Richard E. DODGE

8000 North Ocean Drive, Dania Beach, Florida, 33004-3078 USA
moyerr@nova.edu

The Atlantic coast of southeast Florida (USA) is paralleled by a series of progressively deeper, shore-parallel coral reef communities. Two of these communities occur on drowned early Holocene coral reefs of 5ky and 7 ky uncorrected radiocarbon age. In response to changes in environmental factors (hydrodynamic exposure, ambient light, depth, etc.) the composition, density, and distribution of these benthic communities change. Due to water quality issues, optical methods of mapping these communities have proven unsuccessful. Acoustic bottom classification using the acoustic seafloor discrimination system QTCView 5 has been used in this area in order to produce maps documenting the variable spatial distribution of these communities. Surveys using a 50 KHz transducer gave good differentiation of hard and soft substrates, and showed different acoustic classes corresponding to shallow hardgrounds and the two deeper reef-lines. *In situ* ground-truth data collected by SCUBA divers were analyzed using multivariate non-metric statistics and show distinctly different benthic communities across several spatial gradients along these communities. Subsequent confusion analysis shows the 50 KHz system to be 70-80% accurate in determining reef vs. non-reef substrates and 50-60% accurate when mapping resolution (i.e. minimum mapping unit) is increased to identify different benthic communities. In attempts to further increase mapping resolution, surveys were also conducted using QTC with a 200 KHz transducer. The increased signal strength produced a smaller footprint at depth, thereby increasing the mapping resolution. Preliminary results indicate that the identification of within-reef spatial patterns of discrete ecological patches may be possible with at least 50-60% accuracy using the 200 KHz transducer. If this holds true, maps produced using a synthesis of the 50 and 200 KHz acoustic mapping systems and *in situ* ground-truthing may be a useful tool for managers of coral reef ecosystems and MPA's.

Mapping Coral Reef Attributes from High-spatial Resolution, Multi-spectral Image Data

Stuart R PHINN, Karen E JOYCE, Serge ANDREFOUET, *Chris M ROELFSEMA**, Peter F SCARTH

School of Geography, Planning and Architecture, University of Queensland, Brisbane, QLD, 4072 Australia
s.phinn@uq.edu.au

Recent studies have demonstrated the potential for mapping select environmental parameters of coral reefs from commercially available high-spatial resolution image data. Environmental parameters of concern include substrate type and water depth. The aim of this paper is to demonstrate a processing model for extracting these parameters from high-spatial resolution images for use in coral reef monitoring and management activities. The processing model is a linked sequence of image processing operations. Controls on the interactions of sunlight with the atmosphere, air-sea interface, water column and substrate types were used to define the components of the model. The model was used to define the assumptions and type of processing operations required to extract a specific type of coral reef environmental parameter. The model contains specific stages for mapping water depth and substrate properties, taking into account variations in optical properties of reef water bodies. An example application is presented using an Ikonos-2 image of Heron Reef, southern Great Barrier Reef, Australia. The image was corrected for atmospheric and air-water interface effects to sub-surface irradiance reflectance. The proposed model was applied to map water depth and substrate type. Substrate type maps were based on a combination of spatial (texture) and spectral information. Field survey data on water depth and substrate type were then used to validate the substrate and bathymetric map products. The depth and substrate components of the signal in each image pixel were then removed to examine remaining variations in pixel values. Observed variations may be attributed to spatial variations in optical properties of the water column over the reef.

An Optical-Acoustic 'Reef-up' Approach to Classifying Coral Habitats from Ikonos Imagery (Arabian Gulf, Dubai, UAE)

*Samuel J PURKIS**

8000 N. Ocean Drive, Dania FL 33004, USA
purs@geo.vu.nl

Monitoring coral reef benthos with satellites typically follows a 'sensor-down' approach, with the classification algorithm driven by statistics derived from the imagery. We adopt a 'reef-up' method with a classifier trained exclusively using *in situ* optical measurements, linking the satellite and *in situ* data using common units of substrate reflectance. Metre-scale ground-verification was used to determine the dominant benthic substrates which were subsequently targeted for optical measurement. For each target, a suite of inter-calibrated radiometers were used to concurrently evaluate; (i) the attenuation of the water body, (ii) the downwelling irradiance in air, (iii) downward radiance of skylight, (iv) reflectance just above the water/air boundary and (v) a signal approximating to substrate reflectance, evaluated in close proximity to the seabed. The study area (7x1.5km) was surveyed for bathymetry using a vessel-based multi-frequency (50 and 200 kHz) echo-sounder, the data from which was also processed to yield ground-discrimination information through statistical analysis of the reflected acoustic waveform. An empirical model was used to correct the IKONOS imagery for the effect of the water column using the spatially-detailed bathymetry and optical properties of the water column as input, yielding pixel values of substrate reflectance. The *in situ* reflectance spectra, resampled to the bandwidth and sensitivity of IKONOS, were used as training data for a probability-driven classifier which was found to yield a predictive habitat map of comparable accuracy to more conventional 'from-image' trained algorithms. The predictive map was draped over a DEM constructed using the bathymetry data to construct a three-dimensional model of facies distribution on the seabed, which was used to infer relationships between substrate distribution and seabed topography. In conclusion, the synergy of optical and acoustic data sets produced a prediction of benthic cover with greater potential than could be produced using only one of the two technologies.

Airborne Hyperspectral Coral Reef Surveys - A Review of Progress from 1995 to Present

*Herbert T RIPLEY**, *William B JONES*, *Laura A ROY*

7071 Bayers Rd, Suite 119, Halifax, N.S., Canada, B3L 2C2 Canada

herb.ripley@hdi.ns.ca

Airborne hyperspectral surveys have become a key tool in the expanding requirement to obtain information on the state of coral reefs. However less than a decade ago this was not the case as hyperspectral or multispectral surveys were just starting to be considered for use. Hyperspectral Data International and the author of this paper, carried out one of the earliest uses of hyperspectral imaging for coral reefs on a project in the Turks and Caicos in 1995. Since that initial survey HDI has worked with many leading coral reef researchers and has collected hyperspectral data for coral reefs in such areas as the Caribbean, the Red Sea, the Indian Ocean, French Polynesia and Hawaii. Knowledge of just what such surveys are capable of and the understanding of how they are best applied has grown considerably over the last decade. This paper will review a number of projects conducted over the last several years and will show how each has contributed significantly to the current use of hyperspectral imaging for coral reef surveys. Early efforts will be compared with current practices

Hyperspectral Surveys and the Creation of Effective Management Systems

*Herbert T RIPLEY**, *William B JONES*, *Laura A ROY*

7071 Bayers Rd, Suite 119, Halifax, N.S., Canada, B3L 2C2 Canada

herb.ripley@hdi.ns.ca

The past decade has been characterized by a strong demand to use remote sensing as a tool to obtain information about coral reefs including such things as where they are, what type of species exist and are they healthy or not. Remote sensing has also been used to determine what type of relationships exist between differing benthic communities. The knowledge of how to make remote sensing provide this information has come a long way. The next challenge is how does this information get incorporated into information management systems. This paper will look at the issues that are faced when setting up information management systems and how such systems should be operated so that effective management decisions can be made quickly and effectively. Such things as types of data sources, GIS software, data integration, etc will be discussed. HDI has extensive experience in remote sensing (dating back to 1995) of coral reefs and also has experience in setting up and operating information management systems for agriculture and forestry.

Northern Persian Gulf (Iranian Side) Coral Reefs Status and their Changes from 1990 to 2001 Using Remotely Sensed Satellite Images (TM and ETM) and Under Water Survey

*Omid SEDIGHI**, *Hamzeh VALAVI*, *M. MORADI*, *M R VARASTEH*, *A SAFFARIAN*

187, Nejatollahi, Ave., 15187, P O BOX: 5181, Tehran- Iran

osedighi@hotmail.com

In this study the distribution of coral reefs and their areas in the northern Persian Gulf (Iranian side) were studied. The Landsat- 5 TM and Landsat- 7 ETM data path (images) covering study area on 1987-1990 and 2001 respectively were used in this study. Geometric and radiometric correction, evaluation of proposed model and accuracy estimation was carried out. The overall accuracy of classified coral map is equal to 89.85%. The biggest and best-developed coral areas were found around Kharkoo Island in the northern part of the Persian Gulf (Iranian side) with approx. area of 310 ha in 1990 decreased to 266 ha in 2001, followed by Khark Island With 250 ha in 1990 decreased to 188 ha in 2001 and Nayband bay with area of 181 ha of coral reef in 2001. Change detection survey by comparing two periods of 1990 and 2001 showed significant decrease of coral reefs areas in many parts of the northern Persian Gulf were detected. The field under water survey indicated that best-developed coral reefs (in terms of coral coverage) are located at Kharkoo followed by Nayband bay and Khark, which approve remotely sensed images results. The highest live coral coverage was 32% at Kharkoo Island and lowest in Kish Island with 10% while the highest diversity was found in Kish Island. The most abundant frequently occurred family with highest coverage in the study area was Poritidae. Despite of recent growth and development of Acropora in shallow waters of Kish Island and some other parts, its high coverage and abundance has been decreased to minimum in shallow waters of many fringing Islands caused by anthropogenic and natural impacts and stresses.

Comparisons of Tropical Patch Reef Habitat Maps in Biscayne National Park, Florida Using Airborne Hyperspectral and Satellite Multispectral Data

Damaris TORRES-PULLIZA, *Serge ANDRÉFOUÉT**, *Fernando GILBES*, *Frank MULLER-KARGER*

140 7th Avenue South, Saint Petersburg Florida 33701-5016 United States of America

dtorres@seas.marine.usf.edu

Reef scientists continue to explore new methods to characterize the status of coral reefs environments. Habitat maps are fundamental tools to geographically describe the marine environment in a coherent fashion. Remote sensing provides a cost-effective way to map coral reefs. We analyzed a suite of recent air and spaceborne scenes acquired by sensors with varying spatial and spectral resolution. We used AISA (1meter, 24 bands), IKONOS (4m, 4 bands), ASTER (15m, 3 bands), and Landsat-7 ETM+ (30m, 4 bands) data for high latitude patch reef habitat mapping in order to increase the small number of pilot sites (Turk and Caicos, Tahiti) where multi-sensors comparisons are now available. The benefits of different image processing methods on the accuracy of classification maps are also assessed. Image processing included removing atmospheric effects using 6S and Hydrolight radiative transfer codes. The water-column effect removed following both the empirical Lyzengas (1978, 1981) approach and the analytical Maritorenas (1994) model. The latter model requires pixel-specific depth measurements and information on the characteristics of the water column. Depth was provided by a bathymetric lidar airborne survey. The imagery was analyzed with at-sensor radiance, remote sensing reflectance, depth invariant bottom indexes, and bottom reflectance. Benthic habitats encountered in Biscayne National Park were defined based on field data categorized using a hierarchical classification scheme. The Maximum Likelihood algorithm provided habitat maps in 13 to 4 classes, at five different complexity levels. Selected areas with abundant ground-truth data allowed estimating the accuracy of each map. AISA products were consistently more accurate than spaceborne products (e.g. >10% more accurate than IKONOS). Also, water column correction proved to be beneficial by generally improving classification accuracy for the processed scenes (e.g. +25% accuracy for ASTER results). However, for this particular study, the accuracy gained using Maritorenas model over Lyzengas was not very significant.

Development of New Algorithm for Coral Reef Mapping by Using Satellite Data in Okinawa and Kerama Islands

Tomohiro WATANABE, *Satomi KAKUTA**, Masahiro NISHIMORI, Kazuya SAITO, Shigenobu KINOSHITA

Harumi Island Triton Square Office Tower X 23F, 1-8-10 Harumi, Chuo-ku, Tokyo 104-6023 Japan

watanabe.tomohiro@jaxa.jp

A new algorithm has been developed to monitor coral reef distribution in Okinawa and Kerama Islands with satellite remote sensing technique. We have validated our method at Kerama Islands and verified it with 77% success rate for the distribution at the shallow-water area (the depth of 2-3 meters). And this algorithm can be applied to the ALOS/AVNIR-2 which will be launched in 2004.

Satellite data used to develop our algorithm are QuickBird and LANDSAT/ETM+ data. Furthermore the interpretation of aerial photographs and field survey data are used as supervised data for the classification with maximum likelihood method.

With the isobathic lines, we first selected the area where coral reefs are living likely. And then we performed binary encoding to the Bottom Index, which is estimated from the satellite data and corresponds to the benthic community cover rate in one pixel. After that, two areas were classified for the sand and other benthic community.

For the benthic community area, the ratios (of blue and green, blue and red) were calculated with the DN value for the visible band of the satellite data. Finally three classified items were defined as the colonies of coral reefs, rocks and deep-sea area with the maximum likelihood method.

Global Analysis of Thermal Anomaly Absences on Reefs. A Potential Tool for Siting Protected Areas Resistant to Bleaching

*Kenneth R KASSEM**, Ken CASEY, Marguerite A TOSCANO, Ghislaine LLEWELLYN, Lara HANSEN
1250 24th St NW, Washington DC, 20037 United States of America
ken.kassem@wwfus.org

Mass coral bleaching events have impacted large portions of coral reefs in many parts of the world. This study is part of an effort to develop a new tool that can add to, or enhance, approaches to conservation planning and protected area site selection in light of the emerging threat of global climate change. There is growing evidence that not all reefs or even all parts of a reef are equally susceptible to heightened temperature-anomaly related bleaching. Recent work has shown that reefs may be managed and designed to maximize resilience and resistance to bleaching events. This analysis attempts to locate coral reef areas that have been subjected to fewer sea-surface temperature anomalies and thus be resistant to thermally induced bleaching. We have conducted this analysis using a 16 year time series of high resolution (9 kilometer) NOAA AVHRR sea surface temperature anomaly data. Based on the concept of thermal-anomaly "hotspots," data were prepared by analyzing five day (pentad) averages of the SST data compared to a Maximum Pentad Mean Climatology. Using a Geographical Information System (GIS) we have compared the frequencies of these pentad anomalies to the location of coral reefs, marine protected areas and previous bleaching events. We have found that very few coral reefs have never experienced such anomalies. There do appear to be regional differences in the number of thermal anomaly resistant areas.

Benthic Habitat Mapping at US-Interest Pacific Islands

*John ROONEY**, Joyce MILLER, Scott FERGUSON, Rusty BRAINARD, Bruce APPELGATE, Mark MONACO
Kewalo Research Facility, 1125B Ala Moana Blvd., Honolulu, HI 96814
United States of America John.Rooney@NOAA.gov

Benthic habitat maps are mandated by U.S. law and, as key tools for effective management of coral reef ecosystems, have been requested by resource managers at islands across the Pacific. The NOAA Fisheries Coral Reef Ecosystem Division (CRED) is working with other agencies to meet these needs for waters between the shoreline and the 200-m isobath. Using aerial photographs and satellite imagery, The NOAA Center for Coastal Monitoring and Assessment is producing benthic habitat maps for waters between the shoreline and depths of 20 to 30 m for many of these islands. Both the habitat maps and interim products such as orthorectified imagery have already proved useful. A different approach is required for mapping habitats at deeper depths. CRED and partner agencies are collecting multibeam acoustic data and optical imagery for ground validation to be used to extend benthic habitat maps to the 200-m isobath. A modification to the existing shallow water habitat classification scheme has been adopted to characterize seafloor vertical relief. Although data from thousands of square kilometers must be collected, recent and proposed installations of multibeam systems are enhancing that capability. More pressing concerns include the ability to collect adequate volumes of precisely located ground validation imagery. Although navigation system-equipped remotely operated vehicles will reduce image positional uncertainties, these data may be most efficiently acquired with innovative technology such as a laser line scan system. To preclude serious backlogs in survey data processing, significant advances in both the processing infrastructure and methods are required. In conjunction with the Hawaii Research Mapping Group, CRED is investigating methods for automating the processing and interpretation of multibeam bathymetry and backscatter imagery. Continued progress in these areas is required to enable the timely production of benthic habitat maps.

Integrating Land and Sea Natural Community Mapping in the Bahamian Archipelago with Landsat 7 Imagery: Developing Comparable Ecological Units across Land-Sea Boundaries for Assessment of Island Reef Systems

*Kathleen M SULLIVAN SEALEY**, Vanessa L NERO, Kathleen L SEMON
1301 Memorial Drive, Rm 25 Cox Science, Coral Gables, Florida 33146 United States of America
ksealey@miami.edu

Coral reef research is often limited by the arbitrary boundary between land and sea. Land-based sources of pollution and changes in land use in drainage basins on land have profound impacts on coastal ecology. This research was designed to examine an integrated mapping of natural communities on small islands to better understand the ecological processes that occur across land-sea interfaces. Classification of natural communities focused on mapping similar ecological units above and below the water line and grouping patterns of landforms into common bank-island systems. The initiative was undertaken with the support of USGS Eros Data Center Caribbean Vegetation Mapping initiative to characterize land cover of the Bahamian Archipelago, based on available LAND SAT thematic Mapper (TM) satellite images and other remotely sensed data. The major steps included: 1.) A review of existing vegetation and marine benthic classification efforts, 2.) The construction of a hierarchical classification of land and sea land cover classes, with a characterization of coastal types based on patterns of landforms, and 3.) The completion of ground-truthing to test map accuracy. Landform characterization defined five bank system types, and a characterization of the nature of reef systems associated with each system in the archipelago. Mapping was most successful for the bigger islands, where a greater number of training points representing vast areas of each land cover class were available. The selection of land cover classes is critical to the mapping process, and the ecological implications of coverage classes are presented.

The Usefulness of Video to Census Massive Fish Recruitment

Tessier EMMANUEL, Chabanet PASCALE*

15 Avenue Rene Cassin - 97 715 St Denis Messag Cedex 09, Reunion, France
French Southern Territories
etessier.crpm@wanadoo.fr

Coastal artificial reefs installed in Reunion Island - SW Indian Ocean - periodically attract a high density of recruits and juvenile coral reef fish. High densities render conventional visual census methods inefficient. An experiment was conducted to test two visual techniques, in situ recording slate and video census. A frame of rope - 4 belt transects of 24 m x 3 m - was used as a network in order to facilitate the movement of the divers. To avoid bias due to time variations, the study was conducted under limited time in situ. Advantages and disadvantages of the two techniques regarding the accuracy of qualitative and quantitative results are discussed. The correlation between video and slate census is high, but, in regards to slate census, video census underestimates abundance, especially for low values. A corrected index is proposed to rectify this underestimation and could be used for video survey conducted on species well-detected by video. Furthermore, in case of mass recruitment, more than 20 000 recruits, high differences in abundance are observed between data recorded by slate census and video census techniques (video much more than slate method). These differences arise mainly from the high density of recruits concentrated in a small area. In this case, the video technique is of real interest compared to the slate census technique, which is limited by the human capacity to intercept visual cues.

Long Term Changes of Coral Reef Communities in the Gulf of Mannar during the 7 Years of Bio-physical Monitoring

Kannan JAYAKUMAR*, Arumugam Kuppusamy KUMARAGURU

Center for Marine and Coastal Studies, School of Energy, Environment and Natural Resources, Madurai Kamaraj University, Madurai, Tamil Nadu, PIN:625021 Republic of India
kjaykumar1@rediffmail.com

Status of Coral reef communities (such as Live coral cover, Dead coral with algae, Dead coral rock, Algae, Sea grass and Sand and Rubble; coral bleached and coral dead due to bleaching during the year 1998 and 2002) were surveyed annually in the 21 islands belonging to the four groups (Tuticorin, Vembar, Keezhakkarai and Mandapam) of the Gulf of Mannar Marine Biosphere reserve from 1996 to 2002. Fixed 50m Line Intercept Transects were used for this study in all the islands. This 7 year period included the occurrence of two major Coral Bleaching Phenomena caused by the elevation in the Sea Surface Water Temperature (SST), which has resulted in severe mortality of reef building corals during 1998 and 2002. One-way ANOVA tests indicated significant differences of percent cover of mean values of the coral communities among the individual islands and among the groups during the 7 years period of Monitoring in the Gulf of Mannar. The average percent cover of live corals for the study period has showed significant variations between the four groups ($P < 0.05$; $F_{3,1137} = 14.96$). Distribution of algal cover among the four groups of islands in the Gulf of Mannar was varied significantly ($P < 0.05$; $F_{3,1137} = 26.30$). Bleaching related coral mortality reduced the live coral cover and an increase in the algal cover was noticed in this study. The most widespread effect was observed as high mortality in the corals such as *Acropora* sp., *Pocillopora* sp., *Porites* sp., and *Faviids* sp.

Fluorescence Techniques for Reef Research

Charles H MAZEL*, David ZAWADA

20 New England Business Center, Andover, Massachusetts, 01810 United States of America
mazel@psicorp.com

When you look at the reef in a new way, you often see new things. One new way of looking at the reef is through fluorescence, the property by which a substance absorbs light of one wavelength and re-emits light of another wavelength. (This differs from bioluminescence, in which organisms possess the chemistry necessary to produce light on their own.) It is now well known that fluorescence is widespread in corals, and much work has been done to identify the pigments responsible and to investigate the connection between fluorescence and color. It is less well known that many other reef invertebrates, and even some vertebrates, exhibit striking fluorescence. We have found instances of fluorescence in bristleworms, isopods, crinoids, mollusks, shrimp and crabs, ostracods, stomatopods, fish, and more. The source and significance of the fluorescence in these organisms is not known, and in many cases probably serves no specific function. The existence of fluorescence, however, increases visual contrast and makes the fluorescing specimens easier to locate and study. This is especially valuable if the organisms are very small or cryptic. This presentation will show examples of fluorescence in a wide variety of reef organisms, and will illustrate the equipment and techniques for viewing and photographing fluorescence.

A New Technique for Generating Experimental Sediment Regimes *in Situ*

Jeremy J SOFONIA*, Kenneth ANTHONY, Bette WILLIS

Townsville, Queensland 4811 Australia
jeremy@sofonia.com

A new method for the application of sediments to coral reefs *in situ* is described. Specifically, six erosion blocks, comprised of plaster of paris and silicate based sediment were positioned 1m above the coral reef along the southeast shore of Pelorus Island, Australia. Predictions of sedimentation rates, turbidity, and the size of the impacted area were derived from a series of pilot studies and a computer model of particle behavior based on Stokes Law. Sediment traps were deployed and the bleaching response of *Acropora* sp., *Montipora tuberculosa*, and *Porites cylindrica* were recorded. Results indicate a predictable decrease in sediment concentration with increasing distance from the erosion blocks (Linear Regression: $B = .517$, $t = -3.5$, $P = .001$). When grouped into 0.5 m increments, mean sedimentation rates produced by the erosion blocks were: $215 \pm 51 \text{ mg cm}^{-2} \text{ d}^{-1}$ ($< 0.5 \text{ m}$), $65 \pm 19 \text{ mg cm}^{-2} \text{ d}^{-1}$ ($0.5\text{-}1.0 \text{ m}$), $31 \pm 15 \text{ mg cm}^{-2} \text{ d}^{-1}$ ($1.0\text{-}1.5 \text{ m}$), and $3 \pm 1 \text{ mg cm}^{-2} \text{ d}^{-1}$ ($> 1.5 \text{ m}$). Interestingly, the different coral species showed varying responses. Specifically, *M. tuberculosa* was heavily bleached in the vicinity of the erosion blocks, but showed a significant decrease in bleaching response with increasing distance from the sediment source (Linear Regression: $B = 29.0$, $t = 5.5$, $P = 0.00$), while *Acropora* sp and *P. cylindrica* showed no significant pattern. The method described here successfully demonstrates the application of sediments to corals, *in situ*, in a predictable, continuous and controllable manner. The technique offers a cost-efficient way to investigate sediment effects on benthic environments in large- or small-scale experiments.

Preliminary Estimation of Lagoon Production and Respiration in Coral Reef of Aka Island by Underwater *in-Situ* Photosynthesis/Respiration Meter

*Yutaka TATEDA**, Kenji IWAO, Kazuyuki SHIMOIKE, Hiroki TANIGUCHI
1646 Abiko Chiba Japan
tateda@criepi.denken.or.jp

Underwater instrument composed of plastic chamber with water exchange pump, data logger, sensors of light, DO, salinity, temperature was applied to measure respiration and photosynthesis of coral, algae, *Zostera* and benthic sediment in coral reef at Kushibaru, Aka island, Okinawa, Japan. The production and respiration rates of lagoon biota estimated by this underwater instrument was compatible with evaluated values by DO analysis during slack water in reef, indicating this underwater multi-sensor *in-situ* chamber type photosynthesis/respiration meter is useful instrument to measure reef net production at coral reef, especially for reefs of different biological community. Preliminary estimated net production of coral reef lagoon at Kushibaru, Aka island was high during summer while low in winter, resulting annual production and respiration by reef biota community was almost balanced at this lagoon, demonstrating that Kushibaru reef is in healthy state.

Visual Monitoring System Plans for Coral Reef Conservation in the Eastern Coast of the Gulf of Thailand

*Kenichi TATSUKAWA**, Mickmin CHARUCHINDA, Potchana BOONYANATE, Supawat KAN-ATIREKLAP, Hiroyuki MATSUDA
15-1, Minamidai-1, Nakano-ku, Tokyo 164-8639 Japan
tatukawa@ori.u-tokyo.ac.jp

Comprehensive coral reef surveys were made in Thailand from 1995 to 1998 by mainly coral reef mapping and field surveying. The condition of coral reefs in the Gulf of Thailand has worsened since the late 1980s. The condition of reefs was usually checked by diver's observation reports and under water photographs. However, both methods need long running and exacting works in the sea to get enough data of the reefs every time. We tried to use the portable under water video camera as an additional survey tool to cover up these faults. In the case of test survey for coral reefs around the Mannai Island, in the eastern coast of the Gulf of Thailand, we could get good results to take digital images of coral reefs cover a wider area and in a short time. It was so easy to show fresh visual data of coral reefs on time and explain the condition of reefs to ordinary persons interested in coral reef conservation. Now we are going to monitor the reefs on the fixed survey line every month and compare present images of reefs with past images to check conditions of reefs using a DVD system. Our visual monitoring system with a portable under water video camera may be useful to protect and conserve successively coral reefs.

Long-term Ecological Impacts of Dredging on Coral Reefs in Kaneohe Bay, Hawaii

*Kanako UCHINO**
1324A St.Louis Dr. Honolulu HI 96816 United States of America
kanau531@hotmail.com

Coral reefs in Kaneohe Bay, Oahu, experienced extensive dredging in the 1950s. Benthic community structure, fish assemblage, and physico-chemical parameters were quantified after 60 years of dredging. This research was the first to quantify the long-term consequences of dredging activities on the structure and function of a coral reef ecosystem in Hawaii. Results indicated significant degradation of coral and fish community structure at the dredged site. The corals, which experienced direct physical destruction by dredging, did not show any significant recovery, and the corals in surrounding areas showed significantly lower coral cover. The number of coral colonies at the dredged sites were extremely low, and coral size frequency distribution was centralized with a distinctive lack of small colonies. These results indicate the sublethal effects of dredging, including declined growth rate, increased mortality and lower recruitment still affect benthic community structure. The fish assemblage (fish biomass, fish number, size distribution) was also significantly degraded at the dredged site. At the dredged site, fish biomass was less than one-fifth of that at the control site, and more than 70% of the fishes were in small fish category (< 10 cm). Habitat destruction appeared to be one of the greatest threats to reef fish population for the longer time period. Water quality and sediment composition, were similar between the sites, indicating that the impacts such as increased turbidity and sedimentation caused by dredging may be short-lived. Thus, changes in substratum and morphology are the major factors responsible for the lack of recovery. This study has identified the long-term impacts of dredging activities and developed information linking this stress factor with the condition of coral reef habitats. From a management perspective, this information is important for improving design and siting of coastal projects, as to avoid or reduce ecological impacts.

Recovery of Corals from 2002 Bleaching Event in the Palk Bay, Southeast Coast of India

*J.Jerald WILSON**
3/1392, Majidnoor Jamad Building, University lab, Middle Street, Pudumadam-623 524, Ramnad Dist, Tamilnadu, India
jjeraldwilson@hotmail.com

A study was carried out to assess the recovery of corals in Palk Bay, Southeast coast of India. After the 2002 bleaching event, the Palk bay reefs had faced severe mortality. The biophysical status of this corals was assessed using Line Intercept Transect and SCUBA diving Methods. The corals of Palk Bay were divided into three zones and each zone was observed repeatedly for biophysical status of the corals. The highest overall percentage of live coral cover was recorded in the Mandapam zone (38.72%), followed by Rameswaram East zone (37.65%) and Rameswaram North zone (22.73%). Water samples were also analyzed at fortnightly intervals to estimate the physico-chemical parameters. Nearly 90% of the corals were found to have recovered from the 2002-bleaching event. Acroporidae family faced severe mortality compared to the other families Poritidae and Faviidae. Keywords: *Coral bleaching, Recovery, Biophysical status, Palk Bay, LIT*

Distribution of Deep-water Corals on the Southwestern Margin of Little Bahama Bank, Bahama Islands

Charles G MESSING, Ryan P MOYER*, Richard SHAUL, Richard E DODGE
8000 North Ocean Drive, Dania Beach, FL 33004 United States of America
messing@nova.edu

Little Bahama Bank (LBB) is the northernmost of a series of carbonate platforms along the continental margin of southeastern North America. We used a Phantom class Remotely Operated Vehicle (ROV) interfaced with an Integrated Video Mapping System (IVMS) to investigate the distribution of benthic macroorganisms along the bank margin below depths accessible by SCUBA. We recorded video in 40-200 m along seven parallel transects and documented faunal distributions at 1.5-m depth intervals. With the exception of a few green macroalgal species (e.g., *Rhipiliopsis profunda*) above 117 m, octocorals and antipatharians are the most abundant attached macroorganisms at all depths, although sponges are more speciose. The octocoral *Pseudopterogorgia ?bipinnata* dominates a bank-margin reef in ~52-69 m, accompanied by macroalgae, sponges, ellisellid octocorals and small scleractinians. Below this, the deep fore reef is a chiefly low-relief, sediment-veneered, hardbottom slope of usually 40-60°. Although sponges remain the most speciose group followed by octocorals (chiefly paramuriceids below 100 m), antipatharians are the most abundant macroorganisms below 120 m. *Stichopathes luetkeni* usually dominates and may form dense forests in ~130-150 m. Anthozoans account for 0.82-4.55% of bottom cover at four quantitative sites photographed between 98 and 146 m. Hard bottom generally penetrates to 164-180 m, usually ending in substantial talus and followed by chiefly unconsolidated sediment. Hard bottom penetrating to ~190-200 m along one survey line uniquely supports large solitary corals (probably *Desmophyllum dianthus*). Submersible surveys to the northwest in 325-430 m reveal mounds of up to 30 m vertical relief that exhibit a current-mediated local zonation of suspension feeders (e.g., the scleractinian *Madrepora carolina*, stylasterids, primnoid octocorals, crinoids and ophiuroids). Along the western bank margin in 580-700 m, elongated lithoherms of up to 50 m vertical relief support a different current-mediated zonation of suspension feeders that may include extensive thickets of *Lophelia pertusa*.

Distribution of Deep-water Corals (Alcyonacea, Gorgonacea, Scleractinia) in Atlantic Canada

Paal MORTENSEN*, Lene BUHL-MORTENSEN, Donald C GORDON
Institute of Marine Research, N-5017 Bergen, Norway
paal.mortensen@imr.no

New data on the distribution of deep-water corals in Atlantic Canada were collected during benthic video surveys using Remotely operated vehicle, tethered video camera system (CamPod) and material collected incidentally in trawl during groundfish surveys (Canadian Department of Fisheries and Oceans). The analysis of distribution patterns in relation to environmental variables also includes available previous records. In total, 28 species of deep-water corals (Gorgonacea, Scleractinia, Alcyonacea, and Antipatharia) were identified from the area. The corals were most common in the outer part of channels along the shelf break and slope than on the shelf in inner parts and on the shelf. Three hotspot areas were identified along the Scotian slope (Northeast Channel, The Gully and Stone Fence). These areas have different coral communities reflecting differences in local environmental settings. Corals were more common and abundant on the western side of the channels and the Gully. This coincides with areas with outflow of water from larger basins thought to be more nutrient rich and hydrographically stable than the opposite side. The abundance of corals was negatively correlated with average temperature and positively with cover of cobble and boulder. High temperatures probably control the upper depth limit of the corals, and different species seem to have a different tolerance to high temperatures. Unfortunately, the video surveys were limited to sites <ca 500 m, because the inspection gear could not reach deeper. What controls the lower depth limit of corals is thus less known but low temperatures and low productivity is likely to play an important role.

Captivity and Exhibition of Precious Corals

Masamori NONAKA*, Katherine M MUZIK, Senzo UCHIDA

424 Ishikawa, Motobu-cho, Kunigami-gun, Okinawa 905-0206 Japan
m_nonaka@kaiyohaku.or.jp

Species of the family Coralliidae (Octocorallia: Gorgonacea) have been known since antiquity as precious coral, because their beautiful and hard skeletons have been very valuable for jewelry, medicinal, and other products. There are few reports about their natural history because they generally live in the deep-sea, over 200 m deep, and it has until now been difficult to collect samples in good enough condition to maintain in captivity. In Okinawa Churaumi Aquarium (Okinawa, Japan), we have successfully kept colonies of *Paracorallium japonicum*, *Corallium konojoi*, *C. sp.1* and *C. sp.2* for 1 year 10 months as of December 2003. They were collected from the northwest part of Okinawa Island (26°36'00N, 126°44'74E), by a remotely operated vehicle (ROV) at a depth of about 250 m. The colonies (3 of *P. japonicum*, 3 of *C. konojoi*, 2 of *C. sp.1* and 2 of *C. sp.2*) have been kept and exhibited in our 3 cubic meter tank. Water quality (pH:8.3, WT:19.0°C, DO:10.6-10.7mg/l, specific gravity:25.8-26.5) of the tank is constant throughout the year. Four or five times a day, three sizes of frozen copepods are fed to the corals. We have so far observed the tentacles of the polyps extending to feed. We are measuring growth rates of the colonies, and in the future, we hope to make observations about their reproduction.

Octocoral Diversity on New Zealand Seamounts

Juan A SANCHEZ*, Ashley A ROWDEN

Private bag14-901, Kilbirnie, Wellington, New Zealand
j.sanchez@niwa.co.nz

Seamounts, elevated topographies from deep ocean basins, usually harbor unique and highly diverse invertebrate assemblages. These environments, widespread around New Zealand, are also targets for important commercial fisheries. In order to assess the octocoral diversity of seamounts, collections from eight seamounts, ranging 34-51°S/164-180°E latitude/longitude and 200-2000 m in depth, were examined. The octocorals identified were both numerous and phylogenetically diverse, such as Isididae (Mopseinidae: *Minuisis* spp., *Primnois* spp., *Echinis* spp., *Scleris* spp.; Keratoisidinae: *Keratois* spp., *Lepidisis* spp.), Primnoidae (*Thouarella* spp., *Narella* spp., *Callogorgia* spp., *Calyptrophora* spp.), Plexauridae (=Paramuriceidae) (e.g., *Villogorgia* spp., *Muriceides* spp., *Placogorgia* spp.) and Acanthogorgiidae (*Acanthogorgia* spp.) among others, prevailing groups requiring hard substrate. Large branching non-gorgonian octocorals such as *Anthothela* spp. and *Paragorgia* spp., and alcyoniid (e.g., *Anthomasthus* spp.) and stoloniferous soft corals (e.g., Clavulariidae: *Telestula* spp., *Telestio* spp., and *Rhodelinda* spp.) were also common on seamounts. New, and apparently unique, genera of isidid and primnoid octocorals were also found among the collections. Overall, there is high incidence of endemism in certain groups, particularly Isididae and Primnoidae. Statistical analyses of seamount octocoral data revealed distinct and spatially explicit assemblages. The octocoral diversity on New Zealand seamounts can in part be explained by the region geological history, during which clusters of seamounts were semi-isolated in different ocean basins.

Genetic Diversity of Deep Water Coral Species in Canada

*Kevin B STRYCHAR**, *Lorraine C HAMILTON*, *Ellen L KENCHINGTON*,
David B SCOTT
1355 Oxford Street Canada
strychar@dal.ca

Many deep water coral species have very broad global distributions and are eurybathic from depths of meters to kilometers. Such ecological breadth may be confounded by the presence of cryptic species. We are currently comparing the genetic distances between *Paragorgia* sp. and *Primnoa* sp. across their distribution and depth range in Canada using 18S ribosomal DNA (rDNA) sequences. Initial results show a confusing picture amongst the geographically distant *Paragorgia* taxa. Specimens of *P. arborea* from the Canadian Atlantic are very divergent from the specimen from the Canadian Pacific. The placement of *Pennatulula* and *Anthomastus* relative to these taxa is also unexpected. We expect this topology to alter with the addition of more taxa and further testing.



Poster Session
July 1 (Thu)



Genetic Diversity of Zooxanthellae in Species of *Acropora* from Australian Temperate Coral Reefs

Mariko ABE*, Madeliene J H VAN OPPEN, Bette L WILLIS

Townsville, QLD 4811 Australia

shark@xc4.so-net.ne.jp

Zooxanthellae form an endosymbiotic association with scleractinian corals, and this is considered essential for building coral reefs, however the relationships between host and algal genotypes are not yet fully understood. This study explored the genetic diversity of dinoflagellates (*Symbiodinium* sp.) living in association with the widely distributed coral species *Acropora* from Lord Howe Island and the Solitary Islands, located in the southernmost coral reefs on the east coast of Australia, by using RFLP (Restriction Fragment Length Polymorphism) of the ribosomal DNA large subunit gene and SSCP (single stranded conformation polymorphism) analysis of the internal transcribed spacer 1 region of DNA. The results revealed that 13 species of *Acropora* from these areas contained two types of zooxanthellae belonging to clade C, which is the same as found on the Great Barrier Reef. In the case of *Plesiastrea versipora*, colonies at high latitude reefs host a different clade of zooxanthellae (clade B) compared to those from tropical reefs (clade C), however in the case of *Acropora*, the pattern was not the same. This project provides a greater insight into the coral-dinoflagellate association along a latitudinal gradient. The fact that different coral species have different strategies on coral algal symbiosis has important implications for the capacity of corals to adapt to cooler water environment. Further studies on zooxanthellae diversity of different host species, different latitudinal gradients, and different regions of the world will be valuable in understanding how corals and zooxanthellae acclimatize different environments.

Genetic Structure of Ecomorphs in the Brooding Coral, *Acropora (Isopora) palifera* (Scleractinia; Acroporidae; *Acropora*) in Taiwan Based on Mitochondrial and Nuclear DNA Analyses

Allen C CHEN*, Carden C WALLACE, Ho-I LIN, Ching TSENG, Vivian N WEI

128, 2nd Section, Academia Road, Nankang, Taipei, Taiwan

cac@gate.sinica.edu.tw

Reef-building corals exhibit morphological variations (ecomorphs) over a series of contiguous biotopes in response to gradient environmental changes. Over a wide depth range, such as between reef flat and slope, morphological variations of ecomorphs can be enormous. In this study, we applied a nuclear and mitochondrial marker to documented genetic variations between two distinct ecomorphs namely, plate-form (PF) and branch-form (BF), of *Acropora palifera* from the Kenting reef off southern Taiwan and the Lutao island off eastern Taiwan. Both nuclear and mitochondrial markers showed a high proportion of genetic variability occurred at the within-population level, and no genetic isolation between PF and BF was detected in each population. In contrast, pairwise distance (F_{st}) and nested clade analysis (NCA) of mitochondrial marker revealed a significantly different between Kenting and Lutao, suggesting a restricted gene flow due to isolation by distance between the sites. The contribution of reproductive mode, larval dispersal, and sea surface currents around Taiwan to the genetic differentiation of *Acropora palifera* are discussed.

Advances in Comparative Coral Cytogenetics

Jean-Francois FLOT*, Catherine OZOUF-COSTAZ, Robert VAN WOESIK, Makoto TSUCHIYA

43 rue Cuvier, 75005 Paris French Republic

jfflot@mnhn.fr

In spite of the huge interest on chromosomes in most other groups of living organisms, there is little information available concerning scleractinian coral chromosomes. Until now, the chromosome numbers of only 29 of the 800-odd species of tropical reef corals have been published, which represents less than 4%. Furthermore, only 6 genera (out of about 110), in 4 families (out of 18) have been examined. The data available show a great variety of chromosome numbers in the genus *Acropora*, which is consistent with a reticular evolution of this group of marine invertebrates (Kenyon 1997). It also shows a remarkable conservation of a chromosome number of 28 across 4 families of scleractinian corals, which may represent the basic chromosome number of this group. Details on chromosome morphology have only been published in 4 species (Heyward 1985); in these species, all chromosomes were found to be metacentric or submetacentric, and as each of these species comported 28 chromosomes they shared the same fundamental number (number of chromosome arms) of 56. Here we present new data regarding chromosome numbers and morphologies in several *Acropora* species as well as in *Favia pallida* (Dana, 1846) and *Galaxea fascicularis* (Linnaeus, 1767). We also compare previously used methods of chromosome preparation and observation with innovative approaches we have been developing such as the use of fluorescent stains. Heyward, A. (1985). "Comparative coral karyology - caryologie comparative des Scleractiniaires." Proceedings of the 5th International Coral Reef Society Congress, Tahiti 6: 47-51. Kenyon, J. C. (1997). "Models of reticulate evolution in the coral genus *Acropora* based on chromosome numbers: parallels with plants." Evolution 51(3): 756-767.

Mitochondrial Group I Introns in the Scleractinian Corals

Hironobu FUKAMI*, Nancy KNOWLTON

9500 Gilman Drive, La Jolla, CA 92093-0202 United States of America

hfukami@ucsd.edu

Mitochondrial introns are present in plants, fungi and protists, but are absent in metazoans with the exception of the Anthozoa. Mitochondrial group I introns (ribozymes that catalyze their own excision/splicing) have been reported in the cytochrome oxidase subunit I (cox1) and NADH dehydrogenase subunit 5 (nad5) genes of three sea anemones (*Metridium senile*, *Anthopleura elegantissima* and *Tealia* sp.) and in the nad5 gene of the coral *Acropora tenuis* and other acroporids. The nad5 group I intron encodes essential mitochondrial coding genes, but the cox1 group I intron encodes a homing endonuclease. We investigated the existence of these introns in the scleractinian suborder Faviina. All genera that we analyzed had the nad5 intron at the same insertion site and with the same genetic composition as *Acropora*, suggesting a common origin for scleractinian corals. The insertion site of the nad5 group I intron is also the same in sea anemones and corals, but the gene composition differs greatly, suggesting that this intron had a common origin in the Scleractinia and the Actiniaria, followed by gene rearrangements in ancestral scleractinians. In contrast, cox1 introns were found in only 11 of 39 genera examined, all of them from the Pacific. This suggests that this intron was inserted in Pacific corals after the split between the Pacific and Atlantic lineages. Phylogenetic analyses revealed very similar topologies and evolutionary rates between cox1 and the cox1 intron for these Pacific corals. This suggests loss of this intron for many genera, rather than independent insertions within this group. Genetic similarity of scleractinian and fungal cox1 introns was greater than that between corals and the sea anemone introns, suggesting horizontal transfer of this intron from a fungal donor and independent insertion in the sea anemone and corals.

Rediscovery of *Virgularia juncea* (Octocorallia, Pennatulacea) from a Tidal Marsh in Okinawa, with a Short Note on its Peculiar Behavior

*Yukimitsu IMAHARA**, Kazunari OGAWA

370-1 Funo Kainan-shi, Wakayama Prefecture Japan

imaharay@k.email.ne.jp

Only two species of *Virgularia*, *V. mirabilis* (Mueller) and *V. multicalycina* Thomson & Henderson, have been recorded from the intertidal zone in any part of the world, although sea pens are well known as octocorals living in seas all over the world and at virtually all depths from the intertidal zone to deep waters. A large population of sea pens was found in the tidal marsh of a river mouth on Iriomote Island, Okinawa. This marsh was filled with brackish water at high tide, and completely dried up at low tide. The morphological characters of this sea pen agreed well with *Virgularia juncea* (Pallas), except for next two points. The sculpture of this sea pen merely differed from the previously described materials, and this sea pen was provided with zooxanthellae. This species has been recorded from depths of 20 to 40 meters around the Indo-West Pacific tropical region. It was previously recorded from Iriomote Island by Thomson & Rennet (1927), but unfortunately the depth was unrecorded. It was not possible to verify whether the material of Thomson & Rennet preserved in the University Museum of Tokyo University had zooxanthellae, because it had dried up. Many of the sea pens found on Iriomote stood upright. Almost half of the rachis was exposed above the mud when we found them at low tide during the daytime, and they were frequently pecked by crows, although sea pens are known as generally nocturnal animals. According to our preliminary observations, this sea pen expands in the daytime and retracts below the surface of the sediment at night regardless of the sea level. It is thought that this peculiar behavior is related to the fact that this sea pen possesses zooxanthella

Appearance of Predator Planulae

*Naoko ISOMURA**, Kenji IWAO, Masayuki HATTA

2-1-1, Otsuka, Bunkyo-ku, Tokyo Japan

iso@cc.ocha.ac.jp

In Okinawa many reef-building corals in the genus *Acropora* simultaneously spawn eggs once a year as known as mass-spawning. Huge quantities of fertilized eggs often form dense patches called "slicks" in the morning after the mass-spawning event due to their buoyancy and sea currents, and drift during certain periods developing to planula larvae. In the slicks we found curious planulae that were distinguished from acroporids' planulae; they were 2-3 times larger, had a dark green dotted color, and had a hexagonal structural feature in the oral side. We also observed cleavage of eggs and early development to form these planulae. Surprisingly each of these large planulae engulfed an acroporids' planula and ate it up finally. They showed a good appetite eating several planulae everyday, and 10 per day in the maximum case. They survived for 5 weeks, however, we failed to allow settlement and metamorphosis in culture. To quest for the origin of these carnivorous planulae, predator planulae, we conducted DNA phylogenetic analyses. Partial nucleotide sequences of the 18S ribosomal RNA gene were compared with those of anthozoan species common in reefs of our research sites. The inferred phylogeny suggested that the predator planulae belong to one of the actinarian sea anemones. Planulae eat planulae of other cnidarian species; this is the first finding of carnivorous predation behaviors of planula larvae reflecting natural situations. The predator planulae would be sent into a soup of prey by adjusting the spawning timing to mass-spawning of acroporids, and acquire energetic benefits for longevity during the drifting period.

Genetic Analysis of the Genus *Stylophora* (Cnidaria: Scleractinia) in the High-latitude Environment of South-East African Reefs

*Angus H.H. MACDONALD**, Michael SCHLEYER, Michael MEUSEL

2 West St., Marine Parade, Durban, 4001 Republic of South Africa

angus@ori.org.za

Stylophora colonies were observed in the natural reef environment on the east coast of South Africa displaying a large number of growth forms (morphotypes) sympatrically. Morphological differences between populations in the northern range of the study and those in the south become pronounced to the extent that speciation may have occurred. A genetic analysis of these populations was undertaken to determine whether or not these populations have speciated. Previous studies have shown Pocilloporid corals to have homogenous genetic structure on reef systems on part of the coastline (50 km) analysed in this survey. Both population connectivity and similarity between morphotypes thus need to be resolved. Using both traditional morphological and more recently developed molecular techniques a range of morphotypes from the *Stylophora* species group was analysed. This study encompasses a larger sampling area (600km) than previous work in the area and the methods used have been shown to be more sensitive in detecting intra-specific variation. Samples displaying various morphotypes were collected from reef systems along the south-east African coast. The internal transcribed spacer-1 region on the ribosomal DNA was amplified using the polymerase chain reaction; this amplified region was sequenced and used to compare genotypic variation in morphotypes and latitude.

Structural and Textural Fractal Dimensions to Quantify Coral Shape at Calicular and Septal Levels

*Bertrand MARTIN-GARIN**, Bernard LATHUILIERE, Joern GEISTER

Baltzerstrasse 1, CH-3012 BERN Swiss Confederation

bertrand.martin-garin@geo.unibe.ch

Introducing the notion of "fractals" by Mandelbrot (1967) was a major revolution in several branches of science such as physics, medicine, microbiology, and botany (to characterize the leaf shape). It is normally considered that lines have a dimension of 1, surfaces a dimension of 2 and solid bodies a dimension of 3. The notion of fractional dimensions provides a way to measure the roughness of fractal curves. This note proposes a new method for the morphometrics of corals, which describes and characterizes the calicular and septal morphologies of five Recent scleractinian species: *Montastraea franksi*, *M. faveolata*, *M. annularis*, *Eusmilia fastigiata*, *Dichocoenia stokesi* and one Jurassic species: *Aplosmilia spinosa*. The Counting-Box Method is a technique permitting to grasp a complex form by laying a square mesh over the image object and then evaluating how many boxes are needed to cover it completely. Repeating the measurement with different sizes of boxes (expressed in pixels) results in a plotting at the log-log scale (known as a 'Richardson Plot'): box size (on x-axis) versus the number of black and white boxes needed to cover the object (on y-axis). An inflexion point reveals two straight lines, which are identified in a linear regression analysis by an equation and a maximal r-squared coefficient of determination. The slope coefficients are identified as (1) the structural fractal dimension (D_s), which is characteristic for the overall structure of the corallite (calicular level) and (2) the textural fractal dimension (D_t), which describes the texture or fine details at the septal level. Methods taken from physics and fractal structures enable the characterization of complex forms. Only 2 parameters are necessary to characterize a fractal object. In case the fractal dimensions are not sufficiently discriminating, morphological (e.g. length) or mathematical criteria (e.g. Fourier parameters) may be added in the statistical studies.

Phylogenetic Analysis of DNA Sequences of an Aflp Marker Reveal Porous Species Boundaries within the *Montastraea annularis* Species Complex in La Parguera, Puerto Rico

Michael M MCCARTNEY, Alina M SZMANT*, Amy POGGE

Center for Marine Science, 5600 Marvin K. Moss Ln, Wilmington NC 28409 USA

mccartneym@uncw.edu

Members of the dominant Caribbean hermatypic *Montastraea annularis* species complex were analyzed in an attempt to phylogenetically assess the status of species boundaries within the complex. We used cloned DNA sequences of an Amplified Fragment Length Polymorphism (AFLP) marker that was earlier shown to differentiate *M. faveolata* from the other members of the species complex. Sixty six colonies haphazardly collected from reefs near La Parguera, PR, included many colonies with colony morphology "intermediate" between morphotypes described as *M. annularis*, *M. faveolata*, and *M. franksi*. Phylogenetic analysis revealed three distinct genetic groups distinguished by a combination of fixed insertion/deletions and several nucleotide substitutions. One group formed a clade that included all 20 colonies assigned to *M. faveolata*, based on gross colony morphological characteristics, as well as seven colonies classified as "intermediates" also based on gross morphology, and one typical colony of *M. annularis*. The DNA sequence of this *M. annularis* colony, and that of four *M. faveolata* colonies, showed evidence of recombination with members outside the *M. faveolata*-containing clade, providing evidence of past hybridization events. The remaining two genetic clusters each contained an approximately equal number of *M. franksi* and *M. annularis* colonies. These results suggest that colony gross morphology is a poor predictor of genetic relatedness. They also indicate that random mating is not occurring within the *M. annularis* species complex, and that consistent with previous analyses, *M. faveolata* appears to be the most genetically distinct morphospecies, despite its lesser degree of morphological distinctiveness. The genetic data suggest occasional hybridization and/or incomplete lineage sorting, both commonly associated with incipient speciation. Long generation times, low recruitment rates, long-lived colonies, and incomplete reproductive isolation are all factors that may contribute to the porous species boundaries and complex genetic structure of this *M. annularis* complex.

Mitochondrial Genome Evolution in Scleractinian Corals

Monica MEDINA*, Tori TAKAOKA, Jeffrey BOORE, Jennifer KUEHL, David ENGLE

2800 Mitchell Drive, Walnut Creek CA 94598 United States of America

m_molina@lbl.gov

Scleractinian (hard-bodied) corals have been considered to be a monophyletic group. Sequences from both mitochondrial ribosomal RNA subunits have shown that two distinct clades exist, complex (long) and robust (short). This evidence suggests that the scleractinian skeleton may have evolved up multiple times from soft-bodied ancestors. There is little resolution, however, within each clade and limited sequence data is available for other anthozoan taxa. We are sequencing complete mitochondrial genomes from several scleractinian corals and other soft-bodied anthozoans in order to 1) improve phylogenetic resolution 2) clarify whether soft-bodied anthozoans are nested within the scleractinian clade 3) determine if the long and short mitochondrial ribosomal gene pattern is persistent across the entire organelle genome in these organisms.

The Occurrence of Caribbean *Siderastrea* Species (Scleractinia, Anthozoa) in Brazil

Elizabeth G NEVES*, Fabio Lang DA SILVEIRA, Michel PICHON

Rua do Matao, trav. 14, no. 321, Cidade Universitaria, CEP: 05508-900, Sao Paulo - SP Federative Republic of Brazil

egneves@ib.usp.br

The Atlantic *Siderastrea* complex comprises three species: *Siderastrea radians* (Pallas, 1766), *S. siderea* (Ellis & Solander, 1786), and *S. stellata* Verrill, 1868, and the group has long puzzled taxonomists due to high intraspecific variability and interspecific overlapping of taxonomic characters. Approximately 400 specimens of *Siderastrea* from Brazilian shallow-water reefs and coral communities were examined. Focusing largely on corallite structures but also on enzyme data, the analyses pointed out to the occurrence of *S. radians* in Brazil, where the genus was hitherto expected to be uniquely represented by *S. stellata*. Furthermore, unidentified samples collected in 1876 by the geologist C. F. Hartt, member of the Agassiz's Thayer Expedition, and deposited in the collections of the National Museum of the Natural History, Smithsonian Institution, have been re-examined. Diagnostic skeleton traits contributed to determine the taxonomic status of a colony collected offshore at Salvador, Bahia State, and to identify it as *S. siderea*. Therefore, both Caribbean species *radians* and *siderea* are actually present in Brazil in addition to *S. stellata*. These findings provide additional and important data on the distributional pattern of species within the genus *Siderastrea* and introduce a new perspective to assess intra- and interpopulational variation of the endemic *S. stellata*.

A Recent Revision and a Key Identification to *Millepora* Species in Indonesian Waters

Tries B RAZAK*, Bert W HOEKSEMA

Jalan Belimbing No. 14, Kemang Timur, Jakarta Republic of Indonesia

platygyra@yahoo.com

The present taxonomic revision on Indonesian *Millepora* was conducted on the basis of pore characteristics and corallum growth forms. A number of literatures recognised twelve species of *Millepora* to occur in the Indo-Pacific. However, this study synonymises those species to only six species and confirms their occurrence in Indonesian waters. The six species are *M. dichotoma* Forskal, 1775; *M. intricata* Milne-Edwards, 1857 (including *M. intricata* f. *murrayi* Quelch, 1884); *M. tenera* Boschma, 1949; *M. exaesa* Forskal, 1775; *M. platyphylla* Hemprich & Ehrenberg, 1834 and a new record of *M. boschmai* de Weerd & Glynn, 1991 that is previously known as endemic species to the eastern Pacific (de Weerd & Glynn, 1991; Glynn & Feingold, 1992). The classification of branched milleporids into different species is a very ambiguous issue, since the pore characters give only little taxonomic value and intermediate growth forms are often found. However, the (sub-) massive milleporids are relatively easy to classify. Unfortunately, the present classification is merely based on the morphological features without considering the environmental condition that is believed to have a great influence on the morphological characteristics, as in many other marine organisms. Detailed taxonomic descriptions, species distributions and a new key identification to *Millepora* species occur in Indonesia are given as the final result.

A New Shallow-water Relative of Atlantic Gorgonian Octocorals (Cnidaria: Octocorallia: Gorgoniidae) Revealed by DNA Sequences

Juan A. SANCHEZ*, Alison R. ACOSTA-DE-SANCHEZ

Private bag 14-901, Kilbirnie, Wellington, New Zealand
j.sanchez@niwa.co.nz

The availability of DNA sequences and ever-easier methods of sequencing have started a revolution in the way we understand the relationships among organisms. The octocoral fauna worldwide is one of the most difficult systematically, which has prevented a clear understanding of its phylogeny and diversity. This problem is rooted in the lack of a reliable set of characters to construct octocoral relationships towards a natural classification. Here, we are presenting a case where DNA sequences assisted in the classification of a new shallow-water (27 m) gorgonian coral from the Western Atlantic, Tobago, Trinidad and Tobago, which presented indecisive morphological similarity respect to other Atlantic congeners. Both mitochondrial (ND2 and MSH1) and nuclear (ITS-1) DNA sequences placed the new genus and species, basal respective to other members of Gorgoniidae such as *Pacifigorgia* and *Leptogorgia*, but the latter is paraphyletic respect to four other gorgoniid genera. A notable difference between the new taxon and other *Leptogorgia* spp., is the distribution of polyps over the entirety of its cylindrical branches. The African species *L. schoutedeni*, is the closest to the new taxon according to the molecular data, also has bent and asymmetrical spindles but does not present the notorious spines on the girdles of the sclerites. There may be analogy (e.g., homoplasy) with the *Leptogorgia* disk-spindles present in some Western Atlantic species and the external sclerites of the new taxon but not common ancestry. The number of molecular characters restricted to both *L. schoutedeni* and the new taxon suggest a divergence respect other Atlantic genera such as *Pacifigorgia*, and *Leptogorgia* (= *Lophogorgia*). Atlantic gorgoniid octocorals present very few sclerite and colonial characters as to provide a clear basis for a generic monophyletic classification. Molecular phylogenetics provided reliable evidence on the relationships of gorgoniid octocorals and support to create a new genus and species.

Morphological Comparison of *Favia gravida* and *Siderastrea stellata* from Brazil with Panamanian Congeneric Species

Michelle SANTOS, Fernanda AMARAL*, Nancy KNOWLTON, Javier JARA, Malva HERNANDEZ

Programa de Pós-Graduação em Ciências Biológicas Área de Zoologia, Universidade Federal do Pará, 58.059900 Joao Pessoa, PB, Brazil
siderastrea@yahoo.com.br

The aim of this study was to describe the morphological variation of the skeleton of two species of corals endemic to the Brazilian coast: *Favia gravida* and *Siderastrea stellata*, as well as to compare their morphology with congeneric species of Bocas del Toro, Panama: *F. fragum*, *Faviasp.*, *S. siderea*, and *S. radians*. Qualitative and quantitative characters were analyzed in twenty corallites per colony. Skeletal fragments were worn out manually, producing thin sections of 10 corallites per colony. The corallites of *F. gravida* showed septae and costae with dentations at the upper margins and more spines than the Panamanian congeneric species. These latter showed a solid and evident coenestum. The quantitative analysis showed that length and width of the corallite, distance between columella centers, and the number of septae varied significantly. The variation between populations of *F. gravida* was strong, with a differentiation of the colonies from Espírito Santo State in relation to the other Brazilian populations. The morphometric analysis allowed separation of the three species of the *Favia* genus, and *F. gravida* is a valid endemic species of Brazil. For the *Siderastrea*, only the colony shape of *S. stellata* from Pernambuco State (Enseada dos Corais) was spherical and did not attach to the substrata. The polygonal shape of the corallites of *S. siderea* was an intrinsic character to this species. From the quantitative analysis, the diameter of the corallite, length of the columella, columellar distance, and total number of septae showed significant differences between populations. The overlap of the characters of *S. stellata* from Pernambuco with *S. radians* suggests the occurrence of the latter on the Brazilian coast. However, the absence of consistent skeletal characteristics for differentiation of the species of *Siderastrea* indicates the existence of a morphological series, with several intermediate forms, making clear the genus is high variation.

Comparing the Information Content of Multivariate Morphometric Data Extracted from the Living Polyps and Tissue-free Corallites of *Favia speciosa*

Peter A. TODD*, Richard J. LADLE, Nicholas J. LEWIN-KOH, Loke Ming CHOU
School of Life Sciences, Napier University, 10 Colinton Rd, Edinburgh, EH10 5DT, UK. United Kingdom of Great Britain and Northern Ireland
p.todd@napier.ac.uk

Traditionally, small-scale coral morphology has been quantified by the careful examination of tissue-free skeletons. Such an approach requires whole colonies, or colony sections, to be removed from the reef. This undesirable destruction may be mitigated by the use of a with-tissue technique based on photographic imagery of living corals. The present study, based on both with-tissue and without-tissue data collected from a reciprocal transplant experiment, tests two hypotheses: 1) the information content of morphometric data extracted using with-tissue and without-tissue techniques are comparable and, 2) with-tissue data can be used to quantify morphological changes in individual polyps over time. Although this study focuses on one species and one experiment, the results indicate that there is a role for the with-tissue technique in studies of small-scale coral morphology. With-tissue morphometric data contains comparable information to skeleton-derived data and can help identify phenotypic plasticity in the massive coral *F. speciosa*. With-tissue data can also be used to discern changes with time in individual polyps exposed to new environments.

Scleractinian Coral Biodiversity in the Caribbean Revisited: Are There More Species?

Ernesto WEIL*, Jean LOCKE
PO BOX 908, Lajas PR 00667, USA
eweil@caribe.net

Increasing reef deterioration and lack of consensus on the status of many species of corals in the Caribbean are current challenging problems. Lack of a major quantitative review of the extant scleractinian coral diversity in recent times could compromise attempts to efficiently manage coral reefs in this region. Many published lists of species are for restricted geographic areas and are mostly based on older, usually incomplete descriptions and classification keys lacking good diagnostic characters (those that unambiguously separate two species), which can confuse biogeographic biodiversity patterns in the region. In general, the taxonomic problems posed by the natural variability in calice structures and colony form in natural populations have been exacerbated by: (1) the longstanding emphasis on the importance of non-genetic sources of variation, (2) the use of very few specimens and very few characters from a reduced number of calices with no description of diagnostic characters, (3) lack of quantitative morphometrics and statistical analyses, and (4) lack of information about the natural variability, the ecology, and the geographic range of the taxa being studied. Historically, coral diversity in the Caribbean has bounced back and forth depending on where and who does the observations, with "reductionists" synonymizing many species and "splitters" describing true ecomorphs as separate species. Of the 27 genera (with some 65 described zooxanthellae species) currently described, one genus, *Goreaogya*, has a doubtful status (only one holotype specimen found), and 20 (78%) have some taxonomic problem. Recent studies using multivariate approaches point to a much more diverse and specialized zooxanthellae coral fauna that could significantly increase the number species (± 80) in the near future. *Montastraea*, *Meandrina*, *Agaricia*, *Colpophyllia*, *Porites*, *Madracis* and *Diploria* are some of the most important reef-building genera that still have taxonomic-unclear ecomorphs, which can potentially become new species after further studies.

EST Project on *Acropora muricata*: Searching for Novel Gene Loci in Evolutionary Study of *Acropora*

*Ya-Ching ZERN**, *Chau-Ti TING*, *Vivian N WEI*, *Ho-I LIN*, *Carden C WALLACE*,
Allen C CHEN

128, 2nd Section, Academia Road, Nankang, Taipei Taiwan
yeayea@gate.sinica.edu.tw

Acropora, comprising of 113 described species, is the focal genus in evolutionary studies of reef-building corals. However, the fundamental issue of species relationship is still unsolved for this genus. Although efforts in developing conventional molecular markers, such as ribosomal genes, mitochondrial genes and non-coding regions, nuclear introns, and microsatellites have been made in the last decade, none of them clearly resolved the phylogenetic relationships among *Acropora* spp. This obstacle is probably due to the unusual features of *Acropora* genome, including slow evolution of mitochondrial genome, small nuclear genome size, and existence of ribosomal pseudogenes, which lead to the conclusion that reticulation is the major force for *Acropora* evolution. In order to search for novel gene loci to resolve *Acropora* phylogeny, we take the advance of genomic science by sequencing an egg cDNA library of *Acropora muricata*, a type species of genus *Acropora*. Among 158 expressed sequence tags (EST) sequenced so far, 68 (43%) showed high similarity to vertebrates, 26 (16%) to polychaetes, 16 (10%) to tunicates, and only 4 (3%) and 3 (2%) to nematode and fly, respectively. This is concordant to the result derived from 1,300 EST database of *A. millepora* that corals share a high proportion of genes with vertebrate origin (Kortschark et al. 2003). Excitingly, over 40% of EST clones are marine invertebrate related and new to corals. This result highlights that novel genes of *Acropora* can be identified efficiently throughout EST sequencing project, providing a potential future for revealing *Acropora* evolution.

Coral Reef Health at an Industrial Complex at the Southernmost Portion of Jordanian Gulf of Aqaba, Red Sea

*Mohammad K AL-ZIBDAH**, *Yousef JAMAL*

Marine Science Station, PO Box 195, Aqaba-Jordan
mzibdah@yahoo.com

The concern about modification of the natural marine environment is steadily increasing in front of the Industrial Fertilizers Complex at the southernmost portion of the Jordanian coast of Gulf of Aqaba. Fringing coral reef is the main building frame of the industrial coast that extends for about 5 km and ends at the Saudi boarder. In this study the degree of modification due to industrial activities on species composition, diversity, and abundance of macrobenthic (coral, molluscs, echinoderm, and algal) communities were assessed during the last three successive years. Three locations of two depths each (8 & 15 m) were selected for comparison that covers more than 3000 m² of study area. Two methods were compared for assessment of the coral reef benthos, point-intercept and video transects. Macrobenthic communities occurred close to the industrial jetty were characterized by low diversity and strong dominance of soft coral. The percent cover of soft corals reached relatively high values (16-30% cover). In deep transects (15m depth), live coral cover was higher than shallow transects reaching 30-55% cover. Correlation analyses indicated that species richness increases with increasing distance away from the industrial jetty. Species richness of corals, echinoderms, and macroalgae was also higher as depth increase. Results revealed that the distribution and the relative abundance of coral, echinoderm and macroalgae species were correlated to the relative importance of bottom modification within the various locations at the entire site, whereas its degree was also relevant for corals and influence the identity and the abundance of most macrobenthic species at the different locations and depths.

Direct Estimation of Bioerosion in Several Reefs at Bahia Las Minas, Panama

*Aldo CROQUER**, *Hector M GUZMAN*, *Elia M GARCIA*

Sartenejas, Caracas, Miranda Republic of Venezuela
croquer@telcel.net.ve

Bioerosion is considered an important process controlling reef accretion. Several reef taxa contribute to CaCO₃ loss in coral reefs. Bioerosion can be directly determined by measuring the total area (crevices) removed by some organisms from the calcareous matrix. Herein, we determined the total bioeroded area in three different sites within Bahia Las Minas, Panama: Punta Galeta (PUGA), Largo Remo-Payardi (LRPAY) and Rio Viejo-Punta Muerta (RVPM). A total of 45 X-radiographs (fifteen per sites) of *Montastraea* spp drilled-cores were analyzed by measuring the total eroded area of each crevice for main bioeroder groups (sponges, encrusting algae, polychaetes, bivalves, fungi-bacteria and other organisms) found in the carbonate matrix. Bioeroded area was estimated from radiograph pictures using the image J software. The total bioeroded area between sites and total bioerosion for each group was compared by a Kruskal-Wallis Analysis of Variance and the Duncan test for post-hoc comparisons. Total bioeroded area in LRPAY was significantly higher (28.01±23.8cm²; p<0.01) than PUGA (12.4±18.9cm²) and RVPM (8.4±11.2 cm²), where the lowest total bioerosion was recorded. The group that mainly contributed to bioerosion at all sites was the sponges (162.2±85.1cm²), which significantly (p<0.01) differed from the other groups: encrusting algae (53.4±63.0cm²), polychaetes (11.3±8.8cm²), fungi-bacteria (4.0±2.4cm²), bivalves (3.4±3.1cm²) and other taxa (10.4±9.0cm²). The area of Bahia Las Minas has been historically subjected to chronic anthropogenic disturbances (oil spills, dredging, and runoff). These disturbances may be contributing with the patterns of bioerosion described in this study.

The Study of Pollution of Seaweeds and Phytoplankton of the Coral Reefs by Polyvalent Metals

*Tatjana DOVBYSHEVA**, *Peter GORBONOS*

Str.Gudro., 23-20, Minsk 220121 Republic of Belarus
tdovbysheva@bntu.by or tdovbysheva@yahoo.com

The seaweeds are one of the most ancient groups of organisms having essential value for geochemical processes at ocean. It is known, that blue-green seaweed *Trichodesmium* are the major component of the phytoplankton in biosystems of northern coral reefs of Pacific ocean. The production of the phytoplankton in water above reefs makes about 5 mg C in day. During mass flowering of the blue-green seaweeds their biomass can reach up to 20 g/m³ near a surface of the water on the big area. In the waters of the ocean contains about 2.95 x 10¹⁰ ton of polyvalent metals. In circulation of chemical elements at ocean of a plant take great interest transferring heavy metals in the form of various connections. The study of the content of the polyvalent metals in seaweed of coral reefs has been carried out. The concentration of iron in brown and blue-green seaweeds had account for n x 10⁻² % in recalculation of the dry weight. Concentration of manganese, the titan and nickel had account for n x 10⁻³ %. Concentration of copper, cobalt and chromium had changed in limits n x 10⁻⁴ % in recalculation of the dry weight. It is necessary to note, that the big fluctuations in the contents of copper, nickel of vanadium and iron the big fluctuations in the contents of copper, nickel of vanadium and iron not observed of the different kinds of seaweeds. The concentrating of the polyvalent metals occurs in thousand times that is typical of alive vegetative cages. The majority of polyvalent metals in the plants are formed many bond endocellular compounds with substance of cages which possess the big durability. The process of the concentrating of the polyvalent metals by vegetative cages depends on a metabolism and seasonal changes in development of seaweeds.

The Effects of Sediment on the Bioerosion of Framework-building Corals: The Role of "Sediment Accumulation" versus "Sedimentation Rates"

*Iain A MACDONALD**

E402, John Dalton Building, Chester Street, Manchester, M1 5GD United Kingdom of Great Britain and Northern Ireland
i.macdonald@mmu.ac.uk

The significance of bioerosion to reef development within marginal environments has only received cursory examination. In addition, there is a paucity of information regarding the interactions of sediment and the taphonomy of framework-building corals. This study examined the bioerosion of three important framework-building corals (*Agaricia* spp.; *Montastraea annularis*; *Siderastrea siderea*) from three different depth zones (Shallow 0-8 m; Intermediate 8-16 m; Deep 16-25 m) and from two different reefs. The study sites were Columbus Park and Red Buoy reefs, within Discovery Bay, north Jamaica. Both reefs are situated in turbid-water and subjected to elevated sedimentation rates. The reefs increase in sediment-dominated substrate with increasing depth. These sediments have a higher proportion of muds with increasing depth. The results are compared against comparable clear-water fore-reef data sampled < 1 km away (see Perry 1998). Coral samples were slabbed and the level of bioerosion was calculated as the bored percentage of the slabbed surface area. The results revealed increasing levels of internal biological degradation by macroborers at Red Buoy (8.3%; 10.7%; 18.5%) that were similar to fore-reef levels. At Columbus Park, however, levels of internal biological degradation by macroborers varied with depth (6.5%; 11.4%; 6.8%). The species community compositions of the deep depth zones were similar, with sponges (66.1% at Red Buoy and 49.1% at Columbus Park) and bivalves (23.7% at Red Buoy and 36.9% at Columbus park) dominating. This differs from previous fore-reef studies that were sponge-dominated (> 90%). Sedimentation rates near the deep depth zones were approximately the same. Sediment-dominated substrates were greater at Columbus Park and this may indicate increased sediment accumulation rates that inhibit internal biological degradation of framework-building corals rather than the local sedimentation rates. This highlights the importance of interpreting and understanding local sediment dynamics including: input; throughput; resuspension; erosion and accumulation in future studies.

The Different Erosion Rates by *Echinometra mathaei* from Topographic Zone to Zone in the Shiraho Reef, Ishigaki Island, Ryukyus, Japan

*Rintaro SUZUKI**

2-4-10-2 Shouan, Suginami-ku, Tokyo Japan

YHU00511@nifty.ne.jp

To clarify the relationship between topographic zone of coral reef and bioerosion, the author surveyed the distribution and measured the erosion rate of *Echinometra mathaei* according to each topographic zone of Shiraho reef, Ishigaki Island, Ryukyus, Japan. The distribution of *E. mathaei* changes with every geographical zones. Judging from the result of analyzing the gut contents, it is clear that *E. mathaei* grazes not only coral limestone but also sediment from sea bottom. Therefore, measurement of the erosion rate by *E. mathaei* was carried out in the clean seawater with no bottom sediment. In addition, it was measured for four types of *E. mathaei* and in every season. Consequently, the erosion rates of *E. mathaei* change from four season to season by the differ of types. Moreover, the erosion rate obtained from this measurement was lower than those of the previous researches. Then, the annual erosion rates of every topographic zones by *E. mathaei* were estimated from these results. The erosion rates by *E. mathaei* are as follows; landward reef flat: 0.0 g/ m²/y, shallow lagoon: 30.4 g/ m²/y, inner reef flat: 161.2 g/ m²/y, reef crest: 42.5 g/ m²/y, outer reef flat: 635.1 g/ m²/y, reef edge: 529.6 g/ m²/y and reef slope: 30.7g/ m²/y. The erosion rates by *E. mathaei* well correspond to the distribution density of *E. mathaei*. And the erosion rates change according to the distribution of different types of *E. mathaei* in each topographic zone of fringing reef. Therefore, It is thought that the relationships between the bioerosion and reef formation by *E. mathaei* have different influences on each geographical zone of coral reef.

Status, Diversity and Abundance of Coral Reef Associated Sponges in Gulf of Mannar Marine National Park

Balaiyan ASHOK KUMAR*, Krishnamoorthy VENKATARAMAN
130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
dugong@md2.vsnl.net.in

The current status and diversity of reef associated sponges in Gulf of Mannar Marine National park was intensive survey conducted in 21 islands categorized into three groups, the Mandapam group, the Keelakarai group and the Tuticorin group of Islands. The baseline inventory on the sponges of Gulf of Mannar was compiled based on the earlier reports. The inventory includes 108 species under 38 families, 8 orders and 1 class. They were surveyed in the different areas of the reefs in Gulf of Mannar to understand their spatial distribution patterns and density. Surveys were conducted in April 2002, December 2002 and March 2003. Invertebrate Belt Transect Technique (Brock, 1954) was adopted to record the density of sponges in the different reef zones. Physicochemical parameters were also recorded parallel to understand the impact of its fluctuations on the density of sponge population in the reef. The sponge diversity was comparatively high in Mandapam group, moderate in Keelakarai group and very less abundance in the Tuticorin group of Islands. The physical stress and the anthropogenic pressure have an impact on the decline of the sponge species in various islands of the marine national park. Various conservational measures have been taken to conserve the coral reefs along with the associated faunal communities.

Ecology of a Marine Sponge, *Petrosia* sp. from Coral Communities in the Gulf of Thailand

Paulwatt NUCLEAR*, Thamasak YEEMIN
Faculty of General Education, Rajamangala Institute of Technology, Bangkok Technical Campus, Bangkok 10120, Thailand
saiprateep@yahoo.com

The sponge is a very important member of coral communities in the Gulf of Thailand. Ecology of a marine sponge, *Petrosia* sp., was studied at Khang Khao Island and Nok Island, Chonburi Province, in the Inner Gulf of Thailand during December 1997 - April 2001. The sponge grew mostly on a dominant massive coral, *Porites lutea*, and obviously showed clumped dispersion. Average of growth rates of *Petrosia* sp. at Nok Island (0.7 cm³/day) was significantly higher than that at Khang Khao Island (0.6 cm³/day). Averages mortality rates of *Petrosia* sp. at Nok Island (0.9 cm³/day) was also higher than that at Khang Khao Island (0.8 cm³/day). Releasing of parenchymella larvae was observed in the morning in aquaria. Most larvae settled on live colonies of *Porites lutea*. Interactions of *Petrosia* sp. with a coral, *Porites lutea* revealed that the sponge mostly overgrows the coral. However, interactions between *Petrosia* sp. and a zoanthid, *Palythoa caesia* were relatively complex. The present study clarifies the important roles of the sponge on coral communities in the Gulf of Thailand.

Host Specificity in Marine Sponge Associated Bacteria

Peter J SCHUPP*, Mike W TAYLOR, Peter D STEINBERG
UOG Station, Mangilao, Guam 96923 United States of America
pschupp@guam.uog.edu

Biodiversity is fundamental to both eukaryote and prokaryote ecology, yet investigations of diversity often differ markedly between the two disciplines. Here we explore the relationship between microbial diversity and host specificity using marine sponge bacteria associations. We used a replicated, hierarchical sampling design and 16S rDNA based denaturing gradient gel electrophoresis (DGGE) to examine whether three cooccurring sponges from Australia, *Cymbastela concentrica*, *Callyspongia* sp. and *Stylinos* sp., contained unique, specialized communities of microbes. Microbial communities varied little within each species of sponge, but variability among species was substantial. Over five seasons, the microbial community in *C. concentrica* differed significantly from other sponges, which were more similar to seawater. Overall, three types of sponge associated bacteria were identified via 16S rDNA sequencing of 1 excised DGGE bands: "specialists" found on only one host species, "sponge associates" found on multiple hosts but not in seawater, and "generalists" from multiple hosts and seawater. Analogous to other high diversity systems, the degree of specificity of prokaryotes to host eukaryotes could have a potentially significant effect on estimates of marine microbial diversity.

Matrix Proteins Involved in Ancestral Biocalcification Processes in the Coralline Demosponge *Astrosclera willeyana*

Gert WORHEIDE*, Joachim REITNER
Goldschmidtstr. 3, 37077 Goettingen Federal Republic of Germany
gert.woerheide@geo.uni-goettingen.de

In contrast to most soft-bodied sponges, coralline sponges (formerly also called 'sclerosponges') secrete a secondary rigid calcium carbonate skeleton. They were primary reef-builders for much of Earth's early marine history, but were thought to have been extinct. However, they have been rediscovered in shallow water reef caves of the Indo-Pacific and Caribbean where they still play a large functional role as internal framework stabilizer. We target these 'living fossils' because they provide valuable model organisms to investigate diverse aspects of coral reef biodiversity and geobiology (i.e. biomineralization). Here, we studied biocalcification processes from the cellular to the proteomic/genetic level in the 'stromatoporoid' taxon *Astrosclera*, which appeared first in late Triassic (200MYA) reef deposits of Antalya (Turkey). Due to its slow growth rate and its calcium carbonate precipitation in equilibrium with the ambient seawater, *A. willeyana* is a good recorder of environmental proxies. The basal skeleton of *Astrosclera* consists of aragonitic spherulites, which are made by biologically controlled and matrix mediated biocalcification processes. We have characterized in detail the cellular processes leading to skeleton formation as well as the amino acid composition of the soluble and insoluble intracrystalline organic matrix. The soluble matrix proteins are characterized by high amounts of acidic amino acids (asp+glu), glycine and proline, typical for Ca²⁺-binding mucus substances. Generally, the calcareous basal skeletons of coralline sponges represent the simplest biologically controlled mineralization, intermediate between biologically induced- (e.g. organomineralization) and the fully enzymatically controlled mineralization of higher Metazoa. We further sequenced the N-terminus of several soluble matrix proteins and screened a cDNA library to fully characterize biomineralization genes. Investigation of genes and regulatory mechanisms involved in poriferan biocalcification and their phylogenetic relationships promises to provide a roadmap for our understanding of the evolution and diversification of metazoan calcium carbonate biomineralization.

Coral Communities on the Flower Garden Banks vs. Drilling Platforms in the Northern Gulf of Mexico

*Amy D DATCHISON**

8124 Highway 56, Chauvin, Louisiana United States of America
aatchison@lumcon.edu

Currently, there are ~4,000 drilling platforms off the Louisiana-Texas coast. These platforms appear to act as artificial reefs in shallow waters nearly devoid of hard substratum, helping to expand coral populations in the Gulf of Mexico. This study focuses on coral adults on drilling platforms in the northern Gulf of Mexico, ~180 km S-SW of Galveston, Texas, to determine whether they are derived from the Flower Garden Banks or another source. Adult coral tissue samples, approximately 1.5 cm² in size, from the three dominant species found on the platforms were collected at a depth range of 8-30 m. The corals were placed in individual Ziploc bags containing a high-salt buffer, which preserves the DNA and allows the samples to be stored at room temperature. In the laboratory, the coral tissue was isolated and purified, and analyzed by Amplified Fragment Length Polymorphism (AFLP), a DNA fingerprinting technique. This technique is based on the polymerase chain reaction (PCR), which requires only a small amount of tissue to amplify the DNA and is a powerful tool for distinguishing between closely related individuals within a species.

Paradise Lost: The Dispersal and Ecology of Coral Reef Fishes Outside their Ranges

*David J BOOTH**

Westbourne Street, Gore Hill, NSW 2065 Australia
David.Booth@uts.edu.au

Settlement of coral reef fishes occurs down the SE coast of Australia, to at least 37°S, well beyond the distribution of coral reefs. Dispersal of these larvae away from the tropics is likely to be a complex function of reproductive patterns, larval dispersal abilities and variation in the East Australian Current. About 50 species of coral reef fishes, most conspicuously butterflyfishes (Chaetodontidae) and damselfishes (Pomacentridae) appear on the New South Wales coast between January and April each year, but few persist over winter. Here, I detail spatial and temporal patterns in settlement of these larvae, post-settlement persistence, and discuss approaches to determining the sources of these larvae. Differences in postlarval duration (PLD) among locations, as well as otolith microchemistry and population genetics, may offer indirect clues regarding the source(s) of larvae. Inter-annual variation in distribution of settlers may be linked to large-scale climatic and oceanographic events, and may provide an index of biological linkage between tropical and temperate waters.

Migration of Demersal Plankton at Double Reef, Guam, in Relation to Lunar Phase and Substrate

*Richard Y CHANG**

UOG Station, Marine Lab, Mangilao, Guam 96923 Guam
aobheil@nwlink.com

In this study, mobility of demersal plankton in relation to substrate and lunar phase (new moon and full moon) was tested. Assemblages were collected from reentry traps that held different substrates: sand, coral rubble, and an artificial substrate. These were deployed at Double Reef, Guam, Mariana Islands. Cyclopoid and harpacticoid copepods were found in significantly different numbers between the full moon and the new moon. Significantly different numbers of cyclopoids, harpacticoids, and ostracods entered the three substrates. A significantly larger proportion of both cyclopoid and harpacticoid copepods resettled in their substrate of origin when given the choice to resettle in either sand or coral rubble. When sand was the only substrate offered, copepods originating from sand found shelter a greater number of times than did copepods originating from coral rubble. These results, combined with behavioral observations, suggest that demersal plankton will discriminate between substrates and that behavioral and morphological characteristics are responsible for the plankton's choice of shelter. Although they are subject to the currents in the water column, the demersal plankton can control their diel settlement, and are thus not truly planktonic. The term "paraplankton" is proposed to describe these organisms.

Spatial Patterns of Endemism in Shallow-water Reef Fishes of the Northwestern Hawaiian Islands

Edward E DEMARTINI, Alan M FRIEDLANDER*

2570 Dole Street United States of America
edward.demartini@noaa.gov

The spatial distribution and magnitude of endemism in shallow-water (less than 18 m depth) reef fish populations of the Northwestern Hawaiian Islands (NWHI) are described based on numerical and biomass densities as well as species presence for all ten emergent reefs, coral cays, and atolls of the archipelago, using a series of in situ diver-observation surveys conducted during September-October 2000-02. Percentage endemism based on biomass and especially numerical densities was strikingly greater than that based on species presence, increased non-linearly with latitude, and was especially pronounced at the three northernmost atolls (Pearl and Hermes, Midway, and Kure) and single coral cay-uplifted bank (Lisianski-Neva Shoal). Endemic reef fishes were appreciably smaller bodied than non-endemics within the NWHI based on observed median as well as documented maximum body lengths. Median length was unrelated to latitude for either group of fishes, though, suggesting that environmental effects such as slower growth due to cooler water temperatures at higher latitudes were not the reason for the observed differences in size. Despite no geographic pattern in average body size (and no relation between latitude and density of older-stage fish), reef fish populations at higher latitudes in the NWHI generally included larger proportions of the smallest size classes of young-of-year (yoy-) sized recruit individuals than lower-latitude NWHI reefs. This pattern held for a number of the most numerically and biomass-dominant species and was especially pronounced for endemics. Seasonal lags in recruitment alone cannot explain the greater proportions of yoy at northern reefs. Possible explanations are discussed, including several mechanisms of differential transport and dispersal as plankton prior to settlement, different settling behaviors of competent larvae, or better growth and survivorship during the first weeks or months of life after planktonic larvae and pelagic juveniles settle onto reefs.

Connectivity in the Hawaiian Archipelago and beyond: Potential Larval Pathways

*June B FIRING**, Ronald HOEKE, Rusty E BRAINARD, Eric FIRING

Kewalo Basin Research Facility, 1125B Ala Moana Blvd, Honolulu, Hawaii United States of America

June.Firing@noaa.gov

In 2001 and 2002, six APEX (Autonomous Profiling Explorer) floats and sixteen SVP (Surface Velocity Program) drifters were deployed along the Northwestern Hawaiian Island (NWHI) ridge to investigate larval dispersion. APEX floats descend at sunset to 100m for 13 hours, profiling water temperature every 2m as they return to the surface. SVPs are drogued to follow water flow at 35m, at which depth previous nighttime surveys for spiny lobster larvae showed maximums. The APEX and SVP tracks show evidence of entrainment in mesoscale eddies encountered near the ridge, turbulent dispersion, and inertial motion moderated by ocean currents; these oceanographic features can provide mechanisms for local recruitment, as well dispersal, of larvae. Four floats moved south/southwest, of which two were swept around Johnston Atoll and then passed north and south of Wake Island. Two SVPs eventually traveled south/southwest, one reaching as far west as the Philippine Sea before moving northward along the coast of Japan in the Kuroshio Current, and then heading east in the Kuroshio Extension, returning to the north of the NWHI. Additional evidence of connectivity comes from 10 years of shipboard acoustic Doppler current profiler data. A total of 105 transects along the NWHI have been analyzed to provide information on spatial and temporal variability of mean currents. The current field is dominated by mesoscale eddy energy with the mean generally characterized by westward surface flow. The long-term mean appears to show the North Hawaiian Ridge Current flowing westward immediately south of Kauai and Nihoa, and suggests an eastward flowing Subtropical Countercurrent during winter to summer, from Maro Reef to Necker Island. These trajectories and circulation patterns have possible implications on larval dispersion and biodiversity in the Central Pacific, while changing water temperatures encountered may affect fecundity of any larvae transported.

Measuring Maximum Sustainable Swimming Speeds of Reef Fish Larvae

*Rebecca FISHER**, Shaun K WILSON

Townsville, Australia 4811 Australia

rebecca.fisher@noaa.gov

We examined the maximum sustainable swimming speed of nine species of late stage tropical reef fish larvae from around Lizard Island, Great Barrier Reef, Australia. Larvae were captured in light traps and were swum in swimming flumes at different experimental swimming speeds (of 5 centimeter per second intervals) continuously for 24 hrs. The proportion of larvae remaining was recorded, and the speed at which greater than 90% of larvae were able to maintain swimming was used to indicate the maximum sustainable swimming speed for each species. These speeds varied among the species examined, with the lethrinid maintaining the fastest sustainable swimming speed (24 centimeters per second), followed by the pomacentrid (10-20 centimeters per second) and the apogonid larvae (8-12 centimeters per second). All species maintained swimming speeds at approximately 50% of their maximum swimming speed or U-crit for 24 hrs, supporting earlier work on laboratory reared pomacentrid larvae. Overall, we found that swimming speed is an important factor when considering the potential for active swimming behavior to influence dispersal patterns, recruitment success and levels of self-recruitment in reef fish larvae, and needs to be carefully considered in models of larval dispersal.

Connectivity among Scleractinian Coral Populations of Two Venezuelan Coral Reefs

Adriana E GARCIA, *Carolina BASTIDAS**

Marine Community Laboratory. Apdo. 89000 Caracas, 1080-A Venezuela
adrigarcia@cantv.net

The study of dispersion strategies is considered a central topic in marine ecological research, especially for those sessile organisms that have larval stages in their life cycles. Understanding the connectivity among scleractinian coral populations might be a difficult task for marine ecologists, due to the diversity of dispersion strategies, life histories and the different factors that influence coral recruitment. The allozyme electrophoresis analysis has been used in genetics research to estimate spatial patterns of genetics structure and potential gene flow among a wide variety of populations of marine organisms. In this paper we will compare the genetic structure and estimate the genetic connectivity within and among populations of two scleractinian coral species (*Montastraea faveolata* and *Porites astreoides*). These two species have a wide distribution in the Caribbean and showed contrasting reproductive strategies. For this, we will study eight populations at three spatial scales: sites, separated by 6Km; localities, separated by <30Km, and areas, separated by <200Km. For each of the populations, a total of 30-35 coral fragments of ca. 20 cm² were collected for each species. The genotypes of individual coral colonies will be determined from electrophoresis analysis of 10 polymorphic allozymes. The gene flow estimations from this project will contribute to understand the connectivity within and across two important Venezuelan reef systems (Morrocoy and Los Roques National Parks). This, in turn, might be an useful baseline to enhance the management strategies for these coral reefs.

Analysis of Fish Habitat in a Coral Moat Using Enlarged Aerial Photograph: Its Application to Anemonefish Ecology

*Akihisa HATTORI**, Miyako KOBAYASHI

2-5-1 Hiratsu, Otsu, Shiga 520-0862 Japan

hattori@sue.shiga-u.ac.jp

In a patchy environment, two or more species that require similar living space can coexist, if they show an interspecific trade-off between dispersal and competitive abilities: a superior disperser can use microhabitats moving between habitats, while a superior competitor occupies single microhabitats. In a coral moat, there are various fish habitats, such as patch reefs and sea grass beds, each of which includes various microhabitats. Many small coral reef fishes inhabit particular microhabitats such as branching corals and dead parts of corals, and they often move between neighboring habitats. Accordingly, the distribution pattern of habitats can be the crucial determinant of a local fish community structure. However, little information is available on the relationship between distribution patterns of habitats and fish community structure in a coral moat, probably because of no suitable techniques of field works in large area involving complicated reef structure. Furthermore, we have no distinct categorization of fish habitat. As a preliminary survey, we applied an enlarged aerial photograph to field works on anemonefish ecology because microhabitats (host anemones) of anemonefish are easily quantified. The study area of four hectare was established on a coral moat of Shiraho reef, Ishigaki Island, Japan. We waterproofed the photograph as a field map, and classified habitats of an anemonefish, *Amphiprion frenatus*, plotting the locations of its hosts. In order to analyze habitat features, water depth and size of each host were measured and the number and standard length of its inhabitant were also recorded. We analyzed the photo image to categorize anemonefish habitats involving anemones. The host anemones inhabited the edge of continuous inner reef flat, the colony of certain species of corals, or structural reefs of dead corals. However, those habitats could be detected by the photo image analysis as a structural object with shade.

Genetic Diversity of the Spiny Lobster, *Panulirus argus*, throughout the Bahamian Archipelago as Revealed by Mitochondrial DNA Sequence Analyses

*Katherine E HOLMES**, *Rob DESALLE*, *Stephen R PALUMBI*,
Daniel R BRUMBAUGH

Central Park West at 79th Street, New York, New York 10024 United States of America

kholmes@amnh.org

The spiny lobster, *Panulirus argus*, is the largest export fishery of The Bahamas and an important resource throughout the Caribbean. The genetic diversity of five populations of spiny lobsters was examined using mitochondrial DNA sequence analyses. Over 200 individuals from the Bahamian islands of Lee Stocking (25), Andros (45), San Salvador, (35), and Bimini (60), as well as from South Caicos Island (60) of the Turks and Caicos were examined at the 16S ribosomal gene and Cytochrome Oxidase I. The data were analyzed using tree-based and population-based methods. Regardless of phylogenetic tree building method, the analyses revealed little geographic pattern among these five sites. Standard population genetic analyses using F_{st} indicates very little, if any, population subdivision. The dynamics of the 16S and COI haplotypes are somewhat different in that 16S has a single major haplotype represented and COI has multiple. The Bimini population, at the western limit of the archipelago and most influenced by currents flowing north between Florida and The Bahamas, may harbor more private haplotype diversity than the other four populations. Analyses of the connectedness of lobster populations in conjunction with similar analyses of populations of other taxa examined as part of the Bahamas Biocomplexity Project will help reveal the degree of connectivity among marine populations and, therefore, help inform resource managers regarding ways to design networks of marine protected areas to help conserve these resources.

A Trail of Stock Enhancement in the Kelp Grouper, *Epinephelus bruneus*, at the Northern Coast of Kyushu, Japan

*Akinobu NAKAZONO**, *Kazuhisa HAMADA*, *Keiichi MUSHIAKE*,
Nishida TAKASHI, *Yasushi HONDOU*

6-10-1 Hakozaki, Higashiku, Fukuoka 812 Japan

nakazono@agr.kyushu-u.ac.jp

The National Center of Stock Enhancement is producing juveniles of *Epinephelus bruneus* artificially, at the Goto Islands, northwestern coast of Kyushu, Japan. The juveniles are produced by spawning of adults in captivity, and they were reared in tanks for nearly one year until they grow to 165 mm (mean) in total length. In July, 2002, 2,500 individuals were released on an artificial reef (80x60 m), near one of the island where no *E. bruneus* were found by underwater observation. The number of juveniles was monitored by diving for two years. Their growth was also monitored by collecting with baited traps. Just after release, the juveniles gathered and hid underneath the rocks near the release point, where a total of nearly 1,300 individuals was counted from the record of an UW video camera. The juveniles dispersed gradually, but nearly 100 tagged individuals were still recognized after 5 months. However, the number decreased as the water temperature fell and only one individual was recognized in January, 2003, probably the rest were hiding deep in the holes. Their growth during the period from June to October was expressed as $Y=0.002X^2+0.0205X+17.602$ ($r^2=0.98$), where Y =total length in mm and X =days after release. As the water temperature rose, the number started to increase again and 33 individuals were observed in July, 2003. These fish came out from holes when pellets were thrown at specific places. A maximum number observed at one specific place was six with a mean at 3 ± 1.54 (SD, $n=11$). It was suggested that they were staying near the release point in small social groups. In October, 2003, the largest individuals were estimated to have grown up to 350 mm TL.

The Structures and Dynamics of Fish Communities in an Okinawan Coral Reef: Effects of Coral Based Habitat Structures at Sites with Rocky and Sandy Sea Bottoms

*Atsushi NANAMI**

Ebidai, Hasaki, Kashima, Ibaraki 314-0421 Japan

nanami@affrc.go.jp

Although there have been many studies on ecological factors responsible for the organization of reef fish communities, most of the studies have focused on isolated habitats. However, findings from isolated habitats cannot necessarily be applied to fish communities in other habitats (e. g., a continuous habitat). In this study, I examined habitat association, spatial distribution, population dynamics, predation pressure and effects of habitat connectivity on abundance and species richness of fishes in two different habitats (continuous habitat and isolated habitat) in an Okinawan coral reef by visual observations and field experiments. Most of the fishes at the isolated habitat exhibited more generalized patterns of microhabitat association because of less coral coverage and diversity. The population densities of fish increased in juvenile settlement periods at both habitats, but the magnitude of seasonal fluctuation in population density was significantly greater at the isolated habitat. The magnitude of aggregation of fishes was also significantly greater at the isolated habitat, especially in the juvenile settlement season. Consequently, the seasonal stability in the species composition of fishes was greater at the continuous habitat than that at the isolated habitat. Our field experiment using artificial reef demonstrated that 1) higher proportion of juveniles moved out from the artificial colonies at continuous habitat and 2) mortality of juvenile by predation was significantly greater at isolated habitat, although no significant differences between the predator abundance at the two habitats. Another field experiment using transplanted coral colonies demonstrated that isolated experimental habitat site attracted significantly greater abundance and species of fishes. The findings suggest that the relative importance of various ecological factors responsible for regulation of the population density of coral reef fishes (e.g., microhabitat association, competition, predation and post-settlement movement) in a continuous habitat and the isolated habitat are different in an Okinawan coral reef.

Defining Interpopulation Connectivity among Three Commercial Grouper (*Mycteroperca bonaci*) Populations on the Campeche Bank Shelf, Yucatan, Mexico

Silvia E PASOS-PINTO, *Renata RIVERA-MADRID*, *Madeleine J H VAN OPPEN*,
*J Ernesto ARIAS-GONZALEZ**

Antigua Carretera a Progreso, km 6. AP 73, Cordemex, Merida, Yucatan.CP 97310 United Mexican States

psilvia@mda.cinvestav.mx

Many commercially-important fish species share a set of life history characteristics that make them particularly susceptible to over-exploitation. These include slow growth and late maturity, high site fidelity, ontogenic changes, seasonal and spawning migrations, complex social structure and sex changes. *Mycteroperca bonaci* is a serranid with all these characteristics. Defining interpopulation connectivity in *Mycteroperca bonaci* is vital to understanding its population dynamic, managing stocks, designing marine protected areas and determining self-recruitment. The large dispersal capacity of marine organisms has frequently been associated with small genetic divergences over vast areas. This is particularly the case in species with high fecundity or very large populations that also have a high dispersal potential of eggs, larvae and adults over large areas. To determine genetic flow between three grouper populations, control region (D-loop) primers from mitochondrial DNA were used and 109 grouper individuals were evaluated from three locations on the Campeche Bank Shelf. The sample areas were delineated based on the fishing areas of the Mexican large vessel fishing fleet operating in the area. The results for DNA amplifications using PCR were analyzed in acrylamide gels with SCCP (single stranded conformation polymorphism), which allows for detection of allelic variation. Preliminary results show both inter- and intra-population polymorphic differences which are being corroborated with sequencing.

Are Recruits within a Massive Recruitment from the Same Origin?

*Karine POTHIN**, *Pascalie CHABANET*, *Raymonde LECOMTE-FINIGER*, *Jean-Pascal QUOD*

15 avenue Rene Cassin, 97490 La Reunion

karinearvam@hotmail.com

In March 2002, an exceptional recruitment of *Epinephelus merra* occurred at La Reunion Island (SW Indian Ocean) coral reefs, following hurricane conditions and a new moon period. This study aims to discriminate the origin of these recruits through the study of their early life history. Otoliths will be used as the indicator of stock identity. The recruits were collected in two sites (St-Leu and St-Paul), 15 km apart. The sagittal otoliths were removed from the recruits and compared using multiple techniques: otolithometry (larval growth and age estimation), morphometry (Fourier descriptor combined with measures of length, width, area and perimeter of otoliths), otolith weight and microchemical composition of otoliths (global composition and stable isotope compositions). Our results show that the weight and the shape of the otoliths (morphometry descriptors) are different between the two sites. The same regional distinctions are found with the characteristics of the larval life: the larval life duration, the age and the length at recruitment, the date of laying, the date of hatching were significantly different between the sites. The observed dissimilarity in *E. merra* otoliths from different sampling sites suggests that stock specific differences do exist between sites, then the samples form two separate groups or cohorts. Furthermore, the ratios of stable isotopes $^{18}O/^{16}O$ and $^{13}C/^{12}C$ in the nuclei otoliths revealed differences between the sites, showing that the recruits were born in different areas. Are these recruits coming from the same island but on different sites, or from different islands? These results arise the question of the connectivity between the relatively isolated islands of the SW Indian Ocean (Reunion, Mauritius, Rodrigues and Madagascar).

The Influence of Habitat Complexity and Monsoon on Reef Fish Communities at Cape Bolinao, Lingayen Gulf, Philippines

*Nguyen QUAN VAN**, *Porfirio M ALINO*

Hai Phong Institute of Oceanography, 246 Da Nang Street, Hai Phong City, Vietnam

nvquan@hio.ac.vn

To understand the effects of habitat complexity in conjunction with monsoonal influences on the structure of reef fish assemblages is still a big gap in the field of reef fish ecology. This study was conducted to contribute in answering these two crucial questions: (1) Which aspects of reef attributes mainly influence the distribution patterns of reef fish communities? (2) How can the monsoon regime relate to the dynamics of reef fish assemblages tropical reef sites? Two marine protected areas (MPAs) were selected in Cape Bolinao, Lingayen Gulf, Philippines. Underwater fish visual census technique was carried out for the assessment of reef fish communities along a 50 m transect line for each monsoon season. Line intercept method for estimating lifeform benthos cover; metal chainlink method for measuring rugosity index. Two way indicator analysis and detrended canonical analysis were applied to explore the grouping pattern between transect sites and evaluate the similarity of their species composition. Correlations between the fish/transect data and environmental gradients were determined using the canonical correspondence analysis. A three way ANOVA was used to test the significant changes of fish assemblages inside and the outside transect sites, between MPAs and during NE and SW monsoons. Based on the results of the study, exposure index, rugosity index and dead coral with algae were considered as the three most important environmental variables influencing the distribution of fish by sites. Live coral cover suggested a strong link with the coral polyp-feeders, while benthos lifeform played an important role in providing shelter for reef fishes in the concept of habitat complexity. Monsoonal changes have interaction effects with other habitat attributes and may influence the behavior of fishes (feeding, spawning and swimming characteristics) that occupy the habitat. Results of this study may contribute to the design, development and management of marine reserves in tropical reefs.

Modelling the Potential of Cyclone Modified Ocean Currents to Enhance Coral Larval Distribution and Increase Connectivity between Geographically Separate Reef Areas

*Ben T RADFORD**, *Terry J DONE*, *Libby HOWITT*, *Kimberly VAN NEIL*

School of Earth and Geographical Sciences, University of Western Australia, Hackett Drive, Crawley 6009 Australia

benrad@segs.uwa.edu.au

We investigated the potential for coral larval distribution between reef areas of the North West Shelf of Australia, an area which is frequently affected by cyclones. We achieved this by modelling coral larval trajectories post spawning between inshore and midshelf reef areas of to determine: i) whether larval transport is likely to occur between inshore and midshelf reefs, ii) if so, how often, and iii) the effects of cyclone modified current and wind patterns on larval transportation and whether they have the potential to enhance the distribution of coral larvae between inshore and midshelf reef areas. We chose to compare two years (1996 and 2001) when cyclones occurred around the time of coral spawning, contrasting this with 2002 when no cyclones were recorded during the immediate spawning period. We simulated the effects of a combination of current and wind patterns on buoyant coral eggs by using the GCOM3D ocean current model (Applied Science Associates Pty). This model couples a three dimensional hydrodynamic current model with surface wind stress to predict surface practical trajectory. Our results suggest that there is wide scale dispersal of larvae between reef areas of the North West Shelf well beyond the parental reefs. Our results also suggest cyclone modified wind and currents patterns have the potential to significantly enhance larval transport by not only increasing the distance larvae travel but by acting to rapidly connect (within one week) inshore areas with midshelf reef areas as in the 2001 larval model and vice versa in 1996. Although cyclonic activity may enhance coral distribution, it is unclear as to the negative impact it may have on coral larval viability. However, genetic evidence also points to the wide scale distribution of coral larvae in the North West Shelf.

Genetic Relationships among Populations of *Acropora cervicornis* at North Mesoamerican Barrier Reef System and Campeche Bank Using Molecular Markers

*Lyn Ohala SANTOS RODRIGUEZ**, *Jesus Ernesto ARIAS GONZALEZ*, *Renata Rivera MADRID*

Km 6 Antigua Carretera a Progreso. Apdo. Postal 73 Cordemex, 97310, Merida Yucatan Mexico

lynohala@yahoo.com.mx

The extensive decline of *Acropora cervicornis* along the areas of the Caribbean has situated this species in a threatened status under the Endangered Species Act. Because of this, it is important to develop research concerning the degree of connectivity among *A. cervicornis* populations. This study evaluates the genetic flow of this species along five systems in the sector of the North Mesoamerican Barrier Reef System and in the Campeche Bank. Two loci were used, one of them is the PaxC intron of the nuclear DNA, and the second one is the intergenic region of the mtDNA of 169 individuals from different populations. This analysis was performed by using denatured PCR products through acrylamide gels tinted with silver nitrate by SSCP (Single Stranded Conformation Polymorphism), which allows detection of allelic variation. Preliminary results show inter population polymorphic differences that are being corroborated with sequencing. However, we have found some signs of intra-population differences in some reefs, nevertheless more studies are required to test them. From these results we will be able to determine whether this species belongs to a single larger population or there are more than one population with a certain level of connectivity. These type of studies are essential to determine the primary zones of larvae production and could be a powerful tool to design specific protected areas to conserve this species.

Reef Connectivity: Historical Genetic Connections among Coral Populations

Tonya L SHEARER, *Mary Alice COFFROTH**

109 Cooke Hall, Buffalo, NY 14260 United States of America

tlnell@buffalo.edu

It has been assumed that marine ecosystems are comprised of “open”, connected communities due to the expectation that abiotic and biotic materials, including invertebrate larvae, move passively and great distances with flowing water currents. Species whose larvae are capable of surviving for long periods in the water column (broadcasters) are expected to exhibit low levels of genetic differentiation between populations due to a greater potential for larval exchange over large distances as currents carry larvae away from the natal population. Using microsatellites, the genetic structure of the broadcasting coral, *Montastraea cavernosa* was assessed at multiple geographic levels to infer dispersal distance and rate of larval exchange among reefs. Samples of adult colonies were collected from several reefs within Bermuda, the Florida Keys including the Dry Tortugas, the Bahamas and the Flower Garden Banks. For *M. cavernosa*, gene flow is restricted across distances greater than 1400 km, but is unrestricted between reefs less than 800 km apart suggesting genetic connections among reefs via larval dispersal, although widespread, is limited at some level. However, dispersal distance is not the only influence on the genetic architecture of this species. High levels of differentiation were observed within a reef were associated with depth and are likely to result from depth-related selective pressures imposed on newly settled recruits. Genetic surveys of adults represent an accumulation of irregular recruitment events that occurred decades to centuries ago and do not reflect the influx of recruits occurring at the present time. In addition, although larvae of this species are apparently capable of traveling hundreds of kilometers, the annual supply of *M. cavernosa* recruits maintaining population sizes is likely to be a mixture of local and foreign recruits.

The Distribution of Pomacentrid Fishes, Hermatypic Corals and Marine Plants in the Moat of Ishigaki Island, Japan and the Detection of Indicator Species for the Evaluation of Coral Reef Ecosystem

*Takuro SHIBUNO**, *Yoshitake TAKADA*, *Yoshimi FUJIOKA*, *Hideo OHBA*, *Kazumasa HASHIMOTO*, *Osamu ABE*

148-446, Fukai-Ohta, Ishigaki Japan

shibunot@affrc.go.jp

The fauna and flora of pomacentrid fishes, hermatypic corals and marine plants at 46 points of Ishigaki Island were investigated by 50m ? 4m belt transect method and 1m ? 1m quadrat method on September, both 2000 and 2001. A total 48 species of pomacentrids, 123 species of hermatypic corals, and 136 species of marine plants were recorded. The number of species and individuals of pomacentrids and the number of species and the percent cover of hermatypic corals were generally lesser in the near shore moat than the offshore and middle of the moat. Multivariate analyses and subsequent analyses (similarity of community structure, clustering and IndVal) were carried out to detect indicator species and environmental gradients by using species abundances data (quantitative data) of pomacentrids, and by using presence-absence data (qualitative data) of pomacentrids, hermatypic corals and marine plants. The first division based on the quantitative data of pomacentrids separated offshore moat-middle of the moat from middle of the moat-near shore moat. Main indicator species were *Stegastes nigricans*, *Pomacentrus moluccensis*, *Cheiloprion labiatus* and *Dascyllus aruanus*. The first division based on qualitative data of pomacentrids, hermatypic corals and marine plants also separated offshore moat-middle of the moat from middle of the moat-near shore moat. Main indicator species were *Pomacentrus bankanensis*, *Plectroglyphidodon lacrymatus* and *Pomacentrus moluccensis*, branching and corymbose type *Acropora* corals, and marine plants that were well growing among the branches of *Acropora* coral. We compare indicator species detected by quantitative data of pomacentrids with ones detected by qualitative data of pomacentrids, hermatypic corals and marine plants, and discuss a capability as indicator species for the evaluation of coral reef ecosystem.

The Development and Use of Species Specific Microsatellite Markers in the Scleractinian Coral *Seriatopora hystrix* and its Associated Symbiotic Dinoflagellates for the Purpose of Studying Population Genetics and Reef Connectivity

*Petra SOUTER**, *Madeleine VAN OPPEN*, *Beth BALLMENT*

141 89 Huddinge, Sweden

petra.souter@sh.se

Defining population boundaries and dispersal patterns of key species is of paramount importance when designing nature reserves. In most species a population is limited by life history characteristics such as reproduction and its ability to disperse, physical conditions of the ecosystem and its provision of biotic and abiotic resources such as food and light. Boundaries between different aquatic ecosystem are more fluid, hence more difficult to define. One determinant of population and ecosystem boundaries are oceanic currents as many sessile marine invertebrates, such as corals, release gametes or larvae into the water column where currents will have a profound effect on the dispersal ability of the species. As coral reefs are commonly the target when designing marine protected areas (MPA-s) finding a way to determine levels of self seeding within reefs, as well as the level of connectivity between reefs is becoming increasingly important as the need to protect this ecosystem intensifies. Population genetic studies provide a powerful tool for determining species boundaries. However, to date the development of reliable molecular markers for scleractinian corals have been hampered by difficulties in obtaining good DNA and more importantly in obtaining DNA that is uncontaminated by the DNA of their symbiotic zooxanthellae. We will present a number of techniques to successfully isolate polymorphic, species-specific microsatellite markers for the scleractinian coral *Seriatopora hystrix* as well as for its associated symbiotic dinoflagellates (zooxanthellae) using material from the Great Barrier Reef, Australia. These markers have been used to provide a very preliminary estimate of the level of reef connectivity in the Zanzibar archipelago, Tanzania, hence have been found to be applicable on a global scale.

Connectivity and Seascape Genetics of Coral Populations

*Craig J STARGER**, *Andrew C BAKER*

MC 5557, 1200 Amsterdam Avenue, New York, NY United States of America

cjs52@columbia.edu

‘Seascape genetics’ describes an approach that incorporates genetic techniques with the biological and oceanographic drivers of dispersal to gain more accurate descriptions and predictions of migration and gene flow in marine populations. Understanding the genetic connectivity of coral populations especially is important for the sustainability of coral reef ecosystems. Although many groups have modeled larval dispersal and others have observed reproduction, settlement, and recruitment in corals, a full-life-cycle approach has rarely been taken, even though many reviewers point to it as the only method that will conclusively answer questions of connectivity. Genetic markers appear to be the best method to follow larvae from fertilization to settlement and into the adult populations. Preliminary data show that hierarchical population genetic analyses have the power to detect the relative importance of many factors that contribute to population structure. When combining these genetic data with oceanographic data, estimates of connectivity will be more powerful and, as a result, more useful to natural resource managers and conservationists.

Nycthemeral and Lunar Variations of Coral Reef Fish Colonization over Uvea Barrier Reef (Wallis and Futuna French Territories, South Pacific)

Laurent WANTIEZ, Pascal HEBERT, Claude CHAUVET*

BP 4477, 98847 Noumea cedex New Caledonia

wantiez@univ-nc.nc

Most studies on coral reef fish colonization describe patterns observed in atolls and high island reefs with a small tidal range, or in the Great Barrier Reef. The present work describes nycthemeral and lunar variations of coral reef fish colonization in a typical West Pacific high island with a mid-size lagoon characterized by an important tidal range (2m) (Uvea). Reef fish colonization was studied using crest nets deployed on the barrier reef flat. Fish larvae were collected by the net during their transfer from the ocean and before their settlement on the reef. Reef fish colonization is known to be nocturnal, which was confirmed by the present study. The number of incoming larvae was significantly higher during night-time (233 ± 58 larvae per night) than during daytime (52 ± 18 larvae per day). Different colonization patterns were observed during night-time and significantly related to moonlit and tide level. The first quarter of the moon phase was characterized by massive arrivals of larvae after moonset (11:30 pm) during the lowering tide. On the opposite, during the last quarter of the moon phase colonization was more abundant before moonrise (2:45 am) during the rising tide. During full and new moon phases the same pattern was observed with two pulses, one at the beginning and one at the end of the night. No colonization was possible between 11 pm and 1 am because water level was over the barrier reef insufficient (low tide). Contrary to what is usually admitted, the highest colonization period was not the new moon phase in Uvea, because the low tide happens during the night. Consequently, larvae colonization was significantly higher during the first and the last quarter of the moon phase. As usually observed, colonization was minimum during full moon phase.

Physiological Response of Shallow Water Corals to Short Term Temperature Fluctuations

*Emily CARRINGTON**, *Brian HELMUTH*, *Kenneth SEBENS*
100 Flagg Road, Kingston RI United States of America
carrington@uri.edu

Environmental stressors can drive patterns of competitive dominance on coral reefs. The long term dominance of the coral, *Acropora cervicornis* in Belize was disrupted by an outbreak of white band disease in the late 1980s. *A. cervicornis* was replaced by *Agaricia tenuifolia*, which dominated the community until 1998, when elevated seawater temperature led to a mass bleaching event. Temperature measurements conducted on this reef show that water temperature can increase by several degrees over periods ranging from hours to days, depending factors such as cloud cover and advection of water masses. The purpose of this study was to characterize the physiological response to increased seawater temperature of three corals common to the shallow reefs of Belize: *A. cervicornis*, *A. tenuifolia*, and *Porites divaricata* and to determine if short-term exposure to thermal stress might explain patterns of dominance in Belize. We used a polarographic oxygen electrode system to quantify rates of light-saturated photosynthesis and dark respiration of coral samples during twenty minute exposures to 27, 29, 31, and 33°C seawater. Increased temperature significantly reduced photosynthesis in *A. cervicornis* only, while dark respiration rates were relatively unchanged among the three species. When subjected to longer term (24 hr) exposures to 33°C seawater, photosynthesis decreased dramatically in *A. cervicornis* and *A. tenuifolia*, but not *P. divaricata*. Two of these species, *A. tenuifolia* and *A. cervicornis* span a depth range of almost intertidal to over 15 m, whereas *Porites divaricata* is limited to depths less than 1 m. The latter species clearly has the ability to withstand higher short term temperatures without great energetic cost, and can thus exploit an additional habitat type. Such differences among species may explain community shifts over longer time periods.

Spatial Distribution of Corals and Fisheries Relation to the Reefs Formation Based on Topography Around Cosrae Island, FSM

*Park HEUNG-SIK**, *Kang RAE SEON*, *Yi SOON-KIL*
P.O.BOX 29, Ansan, Kyonggi-Do 425-600, South Korea
hspark@kordi.re.kr

This study have carried to get the approximate state of the coral reefs and to provide a basic information concerning to quantitative stocks of fisheries such as Trochus, Giant clam, around Cosrae island. The topographical characteristics were divided three types, reef flat, slope and small ravine, approximately. First type have composed to the slope flat type and complicated topography by the clump of brain corals, *Acropora* sp., *Diploastrea* sp., *Montastera* sp. And so on., until 15m depth, and spreaded to deep slope along the deep area. Second type have composed deep slopes than the first type area and formed the small ravine partially Coralline debris and breakages have accumulated on the ravine. Strong downward currents flowed from shallow area to deep area along to the ravine. The corals, *Montastera* sp., showed terrace shape along the slope. Third type also showed similar to second type in topographical shape. Branching type coral, *Porites* sp., and fan coral, *Montipora aequituberulata*, scattered between 8m to 15m depth.

Geomorphic Variation of Coral Reefs in the Ryukyu Islands, Japan

*Chuki HONGO**, *Hajime KAYANNE*
7-3-1 Hongo, Bunkyo-ku, Tokyo Japan
c-hongo@sys.eps.s.u-tokyo.ac.jp

Ryukyu Islands provide the best geographical setting for studying geomorphic variation of coral reefs, because the islands line up along latitudinal environmental gradient from well-developed coral reefs to non coral reef communities. A geomorphic characteristic of coral reefs in the Ryukyu Islands shows distinct variation among islands as well as within one island. The purpose of this study is to determine constraining factors on the geomorphic variation (reef flat width from coastline to reef edge (F), reef basement width from coastline to an inflection point at 50m depth (B) and continuity of coral reef). Geomorphic parameters were measured by bathymetric chart, aerial photograph, boring cores and meteorological data. The ratio of reef flat width over reef basement width (F/B ratio) shows almost the same value in one island. On the other hand, the ratio among islands shows latitudinal variation. A continuity of reef flat differs within one island according to direction of coastline. A well-developed continuous reef fringes the coast facing from north to east, which directions match with prevailing winds. In contrast, undeveloped reefs distribute along the leeward at west coast. The islands situated in latitudes lower than 27°N have the F/B ratio from 0.1 to 0.6, whereas those in higher than 27°N have the ratio less than 0.1. The difference of F/B ratio between the islands higher and lower than 27°N is explained by history of postglacial sea level rise and warming. Formation of coral reefs in the Ryukyu Islands lower than 27°N initiated at 10 kyr B.P. as the SST of the region got favorable. After 10 kyr B.P. the coral reef formation area had expanded to the north accompanying with rising sea level and SST. The reef initiation area did not expand continuously in the Ryukyu Islands.

Topography, Biota, and Sediments on the Northernmost Coral Reef in the Ryukyu Islands

*Emiko IKEDA**, *Yasufumi IRYU*, *Tsutomu YAMADA*, *Kaoru SUGIHARA*, *Hideo OHBA*
Aobayama, Sendai 980-8578, Japan
bleasing@dges.tohoku.ac.jp

The Ryukyu Islands are located at relatively high latitudes within the coral reef province. Although many investigations were conducted on biota and sediments in reefs around the Islands, they were mostly limited to the Central and South Ryukyus. Tane-ga-shima lies in the North Ryukyus, where the northernmost coral reefs in the Ryukyus form. Topographic profiles from shore to reef edge were taken along a ~420 m transect on Hirota coast in Tane-ga-shima. Quadrats (1 x 1 m) were set on transects at 20-m intervals. A total of 19 quadrats were surveyed to clarify distribution of macrobenthos inhabiting the reef. The Hirota reef is divided into three topographic areas according to depth, gradient, surface roughness, dominant macrobenthos, and substrates. These are, from shore to the offshore: shallow lagoon, seaward reef flat, and reef slope. The shallow lagoon comprises a shoreward depression (~160 m wide on the transect) with a sand/gravel bottom, that inclines gently toward offshore, and a seaward patch zone (~70 m). The patches (up to 2 m high) are covered with fleshy algae, coralline algae and hermatypic corals. The seaward reef flat (~190 m) is a flat plane which may be constructed by biogenic carbonates and covered by turf algae with hermatypic corals scattered. The seaward reef flat is not differentiated in Hirota reef. By contrast, the correlative topographic area is differentiated into inner reef flat, reef crest, and outer reef flat in the reefs of the Central and South Ryukyus. Some twenty-two species of hermatypic corals were found on the transect. The coral fauna is dominated by *Turbinaria* spp. and faviids. More than 70 species of algae were collected on the transect. The algal flora was characterized by subtropical and tropical species.

Growth Response of Massive *Porites lutea* Corals, Taken from Different Depths, to Differential Light Treatment

Akihiro IWASE*, Robert VAN WOESIK

Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, 3422 Sesoko, Motobu, Okinawa 905-0227, Japan
k038552@eve.u-ryukyu.ac.jp

Morphology of the massive coral *Porites* colonies vary with depth and their shapes are hemispherical at shallow and encrusting at deep (Nakamori, 1986). This study examined the growth response of the massive coral *Porites lutea* to different light treatments on an open aired aquarium. Growth extension length were measured in the 34 fragments, from a shallow hemispherical colony and a deep flat colony, after a half year culture in the aquarium on 4 different light treatments. Under the highest light treatment, the central section on the fragments of the shallow and deep colony showed greater extension than the edge but the trend was reversed under lowest light treatment. This study examined also projected surface area comparison on a model in software. The model predicted that the projected surface area of a disk is 1.5 to 2 times larger than the same surface area hemisphere. Therefore, their growth response to light could be a response to get more light resource under low light environment.

Sedimentology of Holocene Warm Temperate Limestone at Muroto-Misaki, Shikoku Japan

Yasunobu MAEDA*, Yasufumi IRYU, Hideaki MAEMOKU, Tsutomu YAMADA
 Aobayama, Sendai 980-8578, Japan
y_maeda@dges.tohoku.ac.jp

Sedimentological studies were conducted on Holocene warm temperate limestone that occur along the coast from Muroto-misaki (Cape Muroto) to Meoto-iwa located about 13 km to the north of the cape. Muroto-misaki is a southern tip of the eastern half of Shikoku, southwestern Japan. The Nankai Trough, where the Philippine Sea Plate subducts beneath the Eurasian Plate, is located about 100 km to the southeast of this cape. Muroto-misaki and its environs have been seismically uplifted. Distribution of the limestone is limited to < 10 m in elevation. The limestone is up to 4.4 meter in mean diameter and less than 0.5 m in thickness, and consists mainly of fossilized sessile organisms such as annelids, bryozoans, corals, encrusting foraminifera, and coralline algae. Associated components include barnacles, ostracods, molluscs, echinoids, benthic foraminifera, peyssoneliacean algae, and non-calcareous clasts and grains. Cement is a minor component and found in a semi-closed space between coralline algal crusts and their substrates. The results of point counting technique show that the limestone can be classified into 6 types on the basis of predominant fossilized sessile organisms. The dominant components are: corals and coralline algae in Type I; coralline algae in Type II; coralline algae, annelids and barnacles in Type III; coralline algae and annelids in Type IV; encrusting foraminifera and encrusting bryozoans in Type V; and molluscs in Type VI. Comparison of vertical distribution of the six types with those of modern sessile organisms indicates the highest elevation of Type I at a particular outcrop corresponds to mean low sea level (MLSL) when the limestone formed. Therefore, the Holocene limestone is considered ideal for the analysis of relative sea-level changes.

A Distribution Characteristic of High Latitude Coral Reefs in Ryukyu and Izu-Ogasawara Islands

Tatsuo NAKAI*

2-12-8 Toyotama-kita Nerima-ku, Tokyo, 176-0012, Japan
tatsuo@mud.biglobe.ne.jp

In several islands that are belong to northern part of Ryukyu Islands and Izu - Ogasawara Islands, the author (Nakai, 1990) carried out aerial photo reading and fact-finding, and showed that Geomorphological character in northernmost coral reefs as follows : (1) Continuity of coral reefs becomes bad as higher latitude. (2) As it become high latitude, coral reefs don't develop front of cape, and develop in a small cove (without river inflow) or behind an island. In this report, the author carried out more detailed examination about distribution characteristic of a coral reef in a high latitude area, by comparing with coral reef distribution rate (length of a shoreline of all length / of the shoreline where a coral reef develops) and some conditions; geological and topographical conditions, the situation of an ocean current etc. It's results showed variation of latitude such as the above in generally. However, the coral reef distribution rate of each island showed there was islands where a coral reef did not develop in discontinuity regardless of latitude. These showed what local conditions such as a position of ocean current and volcanic activity influenced severely in addition to a sea surface temperature changing as latitude. It is a characteristic in high-latitude coral reefs that such local conditions influences distribution of a coral reef severely.

Population Dynamics of Hermatypic Coral Communities on Reef Slope and Flat at Shiraho, Ishigaki Island, Southwest Japan

Takashi NAKAMURA*, Toru NAKAMORI

Aoba-ku, Sendai 980-8577, Japan
takachi@dges.tohoku.ac.jp

Spatial distributions of hermatypic coral colonies provide us the most important information on a population dynamics of coral communities, such as growth, death, and invasion rates of the corals. Outlines of the colonies were recorded on reef flat and slope at the Shiraho coral reef, Ishigaki Island in 2002 and 2003 by snorkeling and SCUBA diving with 5 m x 5 m quadrat. Diameter and location in the quadrat of more than 2000 colonies belonging to 92 species were reconstructed in this study on the basis of underwater photograph and sketches. The coral community on the reef slope was represented by encrusting or tabular *Acropora*, *Montipora*, and faviids species, whereas branching *Acropora* and *Montipora*, and massive *Porites* are abundant on the reef flat. Studies on the size distribution of the coral colonies suggests that the number of the colonies in both areas are decreased with their diameter, and that there are three modes of the diameter on the reef slope. These modes are considered to be cohorts of the corals which were settled randomly on hard substrate after the extinction of the coral community due to a bleaching in 1998. The branching corals on the reef flat do not indicate random distribution but has a concentrated pattern, whose density decreases from center of patch to its margin. No mode of the colony diameter can be seen on the community on the reef flat. These facts suggest that branching coral patch increases its size by a rapid growth of the branches after destruction and dispersion of the colonies due to a storm like typhoon. Statistical models for the colony size and distribution pattern of the two communities on the reef slope and flat were made giving appropriate growth, death, and invasion rate.

Northward Advancing of Reef-building Corals Amakusa, Western Kyushu, Japan

*Satoshi NOJIMA**

2231 Tomioka, Reihoku-cho, Amakusa, Kumamoto-ken 863-2507 JAPAN

satoshi@ambl-ku.jp

Amakusa Is. is located at 160 km north from the northern limit of coral reef and is the place where both reef-building corals and macro-algae are observed. The recent seawater ranges from 16 to 28°C normally. However, seawater temperature has been coming up gradually in these 50 years, especially the minimum seawater temperature (MST, the monthly average of seawater temperature in February). In Ushibuka (32°11' N), MIT was recorded to be 12.1°C in February 1963 and most of corals died during the severe winter. MIT has increased gradually after that and the tendency of increase is statistically significant. With increase of MIT, corals gradually recovered under the good conditions for coral growth that prevailed afterwards. The most dominant corals, *Acropora solitaryensis*, have gradually recovered and big colonies over 2m were frequently observed in 1990, and coverage of corals in some areas reached 75%. About 100 species of reef-building coral are observed at present. While, macro-algae have decreased gradually. Tomioka is located at the northern tip of Amakusa (32°31' N), about 40 km north from Ushibuka. Macro-algal beds, which are good fishery grounds for abalone and turban-shells, are abundant. In 1970's, MIT in Tomioka sometimes recorded below 10°C, but MIT has been coming up gradually after that and exceeded 13°C in 1995. *Acropora solitaryensis* has never been seen before 1995, but many juvenile corals appeared in 1999 around Tomioka and grow up gradually under good conditions. While, algal beds are decreasing and disappearing. If MIT is coming up hereafter, the corals cover most of the rocky bottom and macro-algal beds disappeared completely in the near future. The northward advance of corals means not only the enlargement of coral habitat but also drastic change in the structure of the coastal ecosystem in Amakusa.

Uniformity of Reef Width in Ryukyu Islands, Southwest Japan

Mariko ONDA, Nobuyuki HORI*

1-3-26, Chuo, Tsuchiura, Ibaraki Japan

onda_mariko@yahoo.co.jp

Zonation of coral reefs in Ryukyu Islands is well known. The object of this study is to clear the relationship between width of reef flat and lagoon. The study area is Ryukyu Islands, in south-western Japan. Ryukyu Islands are a 1,300 km long island arc including 200 islands which located are from 30°N to 24°N. Almost coral reefs are fringing reefs which formed after the glacial stage. The width of reef flats and lagoons were measured at 200 m intervals of shoreline around twenty-one blockaded islands which using color aerial photographs scaled down to 1: 10,000. The color photographs were taken by the Geographical Survey Institute, the Ministry of Land, Infrastructure and Transport. The reason for using these photographs is the ability to measure at the same scale throughout of the Ryukyu Islands. Well-developed fringing reef exhibits a distinct geomorphic zonation from land to ocean with lagoon, inner reef flat, reef crest, outer reef flat, reef edge, and reef slope. The types of coral reefs are categorized three; flat-lagoon type, flat type and flat-less type. Flat-lagoon type has both a flat and a lagoon. Flat type has a flat lacking a lagoon. Flat-less type has an underwater structure lacking a flat. The average width of reef flat with lagoon is wider than lagoon-less reef flat. This reason is that reef flats of flat-lagoon type could expand seaward and landward, however flat type could expand only seaward. As waves come from ocean-side, it is reasonable to assume that coral which had grown up on reef slope threw landward. The shortness of reef edge width could be effect on strong waves. This is one of the characteristic developments in Ryukyu Islands.

Habitat Enhancement and Coral Fragmentation through Transplantation Process

Dedi SOEDHARMA, Sulistiono SULISTIONO, Istiyanto SAMIDJAN*

Jalan Lingkar Kampus IPB Darmaga Bogor, Indonesia

ds_biola@yahoo.com

The transplantation research collaboration between Bogor Agricultural University with Oceanography Research Center, Indonesian Association of Shells and Corals, and support from the Jakarta Provincial and the Ministry of Forestry. The fragmentation experiment is conducted especially with branching coral of *Acropora* planted on racks made of iron, covered with nets and planted in 5-8 m depth. By the result generally the growth of a new individual is dependent to the species, with the average growth of 0.5-1 cm/month. This experiment are involving undergraduate and graduate student of Bogor Agricultural University. In the next phase of the experiment, transplantation is conducted to massive coral of *Goniastrea* and *Goniaopora* and coral with large polyps such as *Caulastrea*, *Lobophylla*, *Cynarina*, *Plerogyra*, *Blastosoma*, *Euphyllia* and *Cataliphylla*. The later species is limited in amount in nature and have a slow reproduction rate. In order to see the development of their fragmentation, experiment is done in a close system laboratory scale. Gonads observation is conducted to know the reproduction development. Some of the corals species that were transplanted in the laboratory have slow development of gonad growth. In order to see the development of reproduction organs, gonad observation is conducted. Several species of the transplanted corals in the laboratory showed slow progress within the gonad development, due to obstruction in their growth. From the results, it can be concluded that transplantation method can provide acceleration of the damage reef rehabilitation program. On the other hand, the transplantation of large polyp corals requires more research. The Ministry of Fisheries and Marine Affairs and the Ministry of Forestry have adopted the transplantation technique as an element of program-activities in order to develop for rehabilitation and coral trade for export purposes.

Latitudinal Changes in Larger Benthic Foraminiferal Assemblages in Shallow-water Reef Sediments along the Ryukyu Islands

Kaoru SUGIHARA, Naoto MASUNAGA, Kazuhiko FUJITA*

8-19-1. Nanakuma, Jonan-ku, Fukuoka, 814-0180 Japan

sugihara@fukuoka-u.ac.jp

Species diversity of hermatypic corals decreases with increasing latitude, which is correlated to the sea surface temperature (SST). However, little is known about latitudinal changes in species diversity of larger benthic foraminifera, although physiological requirements of these foraminifera are similar to those of hermatypic corals because of their symbiotic relationships with microalgae. In this study, we have examined how the taxonomic composition of larger foraminiferal assemblages in shallow-water reef sediments changes with latitude along the Ryukyu Islands (Ryukyus). Three areas from different latitudes in the Ryukyus were selected to investigate latitudinal changes in larger foraminiferal assemblages: Urasaki (Ishigaki Island, 24°20'N, 124°10'E), Ishiki-hama (Kudaka Island, 26°09'N, 127°54'E) and Hirota (Tane-ga-shima Island, 30°20'N, 131°E). Four sediment samples were taken at three topographic sites (shore, shallow lagoon and reef crest) on the reef flat in each area. Each sediment sample was split until a subsample was 2 g in weight, and the subsample was dry-sieved over 2- and 0.5-mm opening sieves. From a 2-0.5 mm size-fraction of each subsample, all foraminiferal tests were picked, identified and counted. A total of 21, 21 and 9 foraminiferal taxa were identified in Urasaki, Ishiki-hama and Hirota, respectively. *Baculogypsina sphaerulata*, *Neorotalia calcar* and *Amphistegina* spp. were abundant in the three areas. *Calcarina gaudichaudii* and *C. hispida* were common in Urasaki and Ishiki-hama but absent in Hirota. Relative abundances of *B. sphaerulata* and *Amphistegina* spp. tended to increase with increasing latitude. These results clearly indicate that the species diversity of larger foraminifera decreases with latitude along the Ryukyus. By comparing our results with the taxonomic composition of fossil larger foraminiferal assemblages preserved in the Quaternary reef deposits in the Ryukyus, we will be able to reconstruct latitudinal variations in shallow-water depositional environments as well as the SST fluctuations with glacial-interglacial cycles during the Quaternary.

A Bioindicator Species for Dissolved Phosphate in the Florida Keys*Brian D TODD, William K FITT**

Institute of Ecology, University of Georgia, Athens, Georgia 30602 United States of America

fitt@sparrow.ecology.uga.edu

The medusa form of the Rhizostome jellyfish *Cassiopea xamachana* maintains large populations of the symbiotic dinoflagellate *Symbiodinium*. Rates of uptake of dissolved phosphate is inversely related to recent exposure to concentration of phosphate in surrounding seawater. Phosphate uptake is significantly higher in medusae maintained in forereef environments in the Florida Keys, compared to patch reefs closer to shore; lowest rates of phosphate uptake were observed in medusae maintained in mangrove habitats in Florida Bay and in man-made canals. A standard curve was generated, whereby concentrations of dissolved phosphate from reefal habitats can be estimated from uptake rates of phosphate by the medusae.

Late Carboniferous *Palaeoaplysina* Buildups in the Akiyoshi Limestone, and their Paleobiogeographic Significance

*Hideaki MACHIYAMA**

2-15 Natsushima-cho, Yokosuka, 237-0061 Japan

bucci@jamstec.go.jp

Palaeoaplysina, questionably a hydrozoan genus, is an important reef-builder in the Upper Carboniferous to Lower Permian of the Urals, the Canadian Arctic, and western North America. No *Palaeoaplysina* reefs have been found anywhere in the Tethys region, and *Palaeoaplysina* is considered to show a Boreal affinity, judging from associated biota. However, *Palaeoaplysina* buildups have been found from the Akiyoshi Terrane in the western Panthalassa region. In the Akiyoshi Limestone, *Palaeoaplysina*-bearing buildups are found in the Moscovian and the Gzhelian, respectively. The Moscovian *Chaetetes-Palaeoaplysina*-algal buildup consists mainly of *Palaeoaplysina*-bryozoan bafflestone/bindstone, *Chaetetes* framestone, *Solenopora* bindstone/framestone, and *Tubiphytes*-algal bindstone/cementstone, with bio-lithoclastic grainstone/rudstone. This buildup was probably formed in a reef-front environment. This *Palaeoaplysina* is the same specimen reported from the Moscovian and Kasimovian reefs in the Canadian Arctic, as protopalaeoaplysiniid or ancestral *Palaeoaplysina*. The Akiyoshi specimen is smaller than *P. laminaeformis*, and has no pores and protuberance on the upper surface. Therefore, the stratigraphically old Akiyoshi specimen considered to be a new species of *Palaeoaplysina*. The Gzhelian (partly Kasimovian) *Palaeoaplysina*-phyllloid algal buildups consists mainly of *Palaeoaplysina*-algal bafflestone/cementstone, phylloid algal bafflestone/cementstone, *Tubiphytes*-bryozoan bindstone/cementstone, and bryozoan-algal bafflestone/cementstone, with bio-lithoclastic grainstone/rudstone. These buildups were probably formed in a relatively high-energy, open ocean setting near a reef-front zone. *Palaeoaplysina* plays an important role of reef formation in the Akiyoshi Seamounts at that time, because it also occurs from the other limestones in the Akiyoshi Terrane, such as Kasimovian to Artinskian of the Taishaku and the Omi Limestones. Thus, the stratigraphic range of *Palaeoaplysina* is during Moscovian to Artinskian time in the western Panthalassa region. On the other hand, no *Palaeoaplysina* was found from the Late Paleozoic cap limestones of seamounts in the Mino and Chichibu Terranes. This fact suggests that Late Carboniferous to Early Permian reef ecosystem was different within the western Panthalassa region.

The Occurrence of Bleaching and Subsequent Recovery on the High Latitude Reefs of Bermuda

*Samantha J DE PUTRON**, Helen BRYLEWSKA, Alexandra AMAT

Ferry Reach, St Georges, GE 01, Bermuda

sputron@bbsr.edu

Coral bleaching occurred in the summer of 2003 on the outer rim and lagoonal patch reefs of Bermuda (32N, 65W). Surveys were performed at the end of August, when maximum seawater temperatures (SST) had remained for a longer period than typical, and were repeated one month later when SST had decreased. Of the coral colonies surveyed, 21% were bleached at the rim reef and 19% at the lagoonal reefs. Progressive recovery was observed one month later with total bleaching reduced to 13% at both sites. The metabolic consequence of bleaching in Bermuda corals was assessed by comparing the photosynthesis and calcification rate of six *Diploria labyrinthiformis* colonies growing in their natural environment in October 2002, a non-bleaching year, with early September 2003, after *in situ* bleaching had occurred. The bleached corals had photosynthetic capacities two to three times lower, although calcification performances were only slightly reduced. All monitored corals showed zooxanthellae recovery by early November 2003 and photosynthesis returned to a similar, and often greater rate, than the year before. The fire coral, *Millepora alcicornis*, is particularly susceptible to bleaching in Bermuda. The majority of colonies on the rim reefs in August 2003 had bleached, and 35% had suffered recent mortality. The incidence of bleaching decreased one month later, although an increased percentage of the population had died. Bleaching of *M. alcicornis* was significantly lower at the lagoonal reefs, similar to the bleaching spatial patterns recorded for scleractinian species. This greater prevalence of bleaching at the rim compared to lagoonal reefs is concurrent to past observations in Bermuda. Potential mechanisms controlling this site specific variation are discussed, along with a documentation of previous Bermuda bleaching events, and comparisons to the Caribbean.

Ephemeral Macroalgal Blooms on Eastern Tropical Pacific Reefs: Investigating the Roles of Nutrients, Herbivory, and Chemical Defenses by Epiphytic Cyanobacteria

*Peggy FONG**, Tyler B SMITH, Matthew J WARTIAN

621 Young Drive South, Los Angeles, CA, 90095-1606 United States of America

pfong@biology.ucla.edu

In coral reef ecosystems macroalgal blooms are associated with phase-shifts from coral to algal domination. After the 1997-98 ENSO, ephemeral blooms of *Acanthophora spicifera* occurred on reefs in the Eastern Tropical Pacific. We began to investigate several ecological processes that may control their frequency and magnitude. Microcosm and field experiments demonstrated the importance of nutrients in stimulating algal growth and biomass accumulation. In a two-factor experiment phosphorus primarily limited growth while nitrogen was secondarily limiting. A complementary field experiment using slow release fertilizer to enrich algae across 4 reef zones showed that nutrients enhanced algal growth in all locations. In the absence of herbivores, algal biomass increased 10-20% in 4 days without nutrient addition, but 22-30% with nutrients. Several field experiments using tethered algae or caging demonstrated the importance of herbivory in controlling algal biomass accumulation. Herbivory rates varied across reef zones, with the highest rates on the deeper reef slope, lowest on the base, crest and back reef, and intermediate on the reef flat. Further, herbivores grazed preferentially on algae with nutrient-enriched tissues, increasing rates of herbivory by over 50% on algal tissue with high N and P contents. In a caging experiment on the reef flat, algae increased in height by 78% in 6 days within cages and 43% when exposed to herbivores, showing that algae can sustain net biomass accumulation in the presence of natural abundances of herbivores. Finally, the presence of epiphytic cyanobacteria provided *A. spicifera* protection from herbivory; plots of algae with thalli cleaned of epiphytes were reduced 3 fold in cover and by an order of magnitude in average height compared to algae in control plots. These preliminary investigations suggest that all three ecological processes, nutrient enrichment, herbivory, and facilitation by epiphytic cyanobacteria, may influence macroalgal blooms in ETP reefs..

The First Mass Coral Bleaching in Haha-jima Island, at Ogasawara Archipelago in 2003

*Makoto INABA**, Takamichi YAMAMOTO, Kunihisa YAMAGUCHI, Kazuo HORIKOSHI, Sumio YONEYAMA

Miyano-hama-michi, Chichi-jima, Ogasawara, 100-2101 Tokyo Japan

inaba@ogasawara.or.jp

We recognized a mass bleaching of hermatypic corals in Haha-jima Islands, Ogasawara Archipelago at late September 2003. This is the first record in this region. We conduct a survey the coral communities at Oct-Nov. in Haha-jima Islands and estimated the bleaching and mortality rates. Other area, such as Chichi-jima Island and Muko-jima Island were not confirmed the coral bleaching so far. The results in western beaches of mainland and the islands belonging the mainland, coral diversity is about 50 species and coral coverage about 40-60%. Coral species consisted by *Acropora donei*, *Acropora florida*, *Porites* spp., *Goniastrea edwardsi* etc. The bleaching rate is about 70% (coverage) and about 70% (number of colony). The mortality of corals by bleaching is low, except *Acropora donei*, that mortality is 30-50% at Nov. In eastern and northern beaches, 20-40 coral species existed and coral coverages are 25-80%. The bleaching rate is about 15% (coverage) and about 10% (number of colony). The mortality of corals by bleaching is low at Nov. By the analysis on the changes of sea surface temperature (SST) from the satellite data and fixed point data, we recognized that a water column more than 30°C accrued around the Haha-jima Islands in the mid Sep. SST decreased in Nov. through Dec., but the coral bleaching continued except some Poritidae species. This is urgent report, although we continue to monitor the coral bleaching and mortality now.

Widespread but Selective Gorgonian Mortality during a Thermal Event in the Bahamas

*Howard R LASKER**

Dept. of Biological Sci, 635 Hochstetter Hall, University at Buffalo, Buffalo, NY 14260 United States of America

hlasker@buffalo.edu

While considerable attention has been given to coral bleaching and subsequent mortality during periods of high sea surface temperatures, relatively few data are available on the fate of octocorals during such episodes. Here I report on the direct mortality of numerous gorgonian corals during a period of exceptionally high temperatures at a reef near Lee Stocking Island, Bahamas. Between June 1 and June 11, 1998 maximum temperatures measured on the reef at Rainbow patch reef exceeded 30°C and on June 6 reached 33°C. The high temperatures were associated with hypersaline water flowing off the Bahama Banks during ebbing tides and bottom waters were frequently warmer than the top 1-2 m of surface water. Starting on June 6 tissue was observed sloughing from branches of 4 gorgonian species affecting 13% of colonies surveyed on two transects across the reef. Portions of colonies and in some cases entire colonies lost tissue. *Plexaura homomalla* forma *kukenthalii* made up 21% of the gorgonian community and was strongly affected. Thirty eight per cent of the *P. homomalla* forma *kukenthalii* colonies were affected (62% of all affected colonies). Gorgonians on a nearby reef not influenced by the tidal flow off of the banks were unaffected. Events such as that observed, although short lived, may have important effects on the structure of gorgonian communities.

Bleaching of Massive *Porites* at Albion, Mauritius

*Kamla R MOOTHYEN PILLAY**, *Hiroaki TERASHIMA*, *Hiroyuki KAWASAKI*,
Vishwamitra CHINEAH

Present address: Mauritius Oceanography Institute, 4th Floor, France Centre,
Victoria Avenue, Quatre-Bornes, Mauritius
kamlaruby@intnet.mu

Prior to 1998, coral bleaching events in Mauritius had received little attention. However, following the widespread coral bleaching episode of 1998, regular surveys have been conducted to assess and monitor any bleaching response. In April 2001, further bleaching of massive *Porites* (*Porites lutea* and *Porites lobata*) was observed on the outer reef slopes (4-15metres) of Albion, Mauritius. Interestingly other coral taxa on the outer reef slopes as well as the massive *Porites* and other coral taxa in the shallow lagoon (<2metre) remained unbleached. Colonies of *P. lutea* and *P. lobata* were tagged on the outer reef slopes at three depths (5m,10m,15m) for monitoring of the bleaching response over a four-month period. The results showed that percentage bleached area in massive *Porites* did not differ significantly with depth. However, there was a significant decrease in percentage bleached area at all depths with time. The reasons for this species specific bleaching are unclear but we suggest that the observed bleaching response of massive *Porites* at this specific location may be due to past bleaching.

Effect of Macroalgae on Recovery of Coral Reefs in the Gulf of Thailand

Wichanan PHONGSRI, *Thamasak YEEMIN*, *Wasana PHANTEWEE**

Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240 Kingdom of Thailand
phwichanan@hotmail.com

Macroalgae in coral reefs of Thailand have long been studied in several aspects such as taxonomy, morphology, ecology, economic and nutrition. However, a few studies focusing on effects of macroalgae on recovery of coral reefs, especially degradation of coral reefs caused by coral bleaching phenomena. The degradation of coral reef often involves a phase shift from coral to macroalgal dominated reef that macroalgae play a major competitor on coral reef ecosystem and can dominate coral reef. The present study aimed to provide basic information concerning this event that can reduce percent cover, growth, recruitment and survival of coral or increase coral mortality. The pilot study on effects of macroalgae on coral reefs was carried out at four stations: Chalokbankhao Bay, Hinwong Bay, Moug Bay and Sairee beach, of Koh Tao Island, Surat Thani Province. The severe coral bleaching occurred in the Gulf of Thailand in 1998. Percent cover and recruitment of coral were investigated by belt transect method and random quadrat. Distribution and abundance of macroalgae were also recorded. The results clearly showed that densities of juvenile colony of coral at Sairee beach, Chalokbankhao Bay, Hinwong Bay and Moug Bay were 8.80, 8.0, 7.47 and 3.75 colonies/m², respectively. *Lobophora vareigata* (Lamouroux) Womersley and *Turbinaria* spp. were common macroalgae which are found mostly overgrowth on dead corals and dead part of coral colonies. Percent covers of macroalgae on coral reefs at Sairee beach and Chalokbankhao Bay were higher than those at Hinwong Bay and Moug Bay. Increasing of nutrient availability and reduction of grazers such as sea urchins and fishes due to activities of local people played a major role on reef degradation at Koh Tao. The management plan and effective implementation are urgently required to reverse the coral reef degradation trend.

Coral Bleaching in Brazil, Western South Atlantic

Marilia D M OLIVEIRA, *Ruy K P KIKUCHI*, *Zelinda M A N L E A O**, *Leo X C D U T R A*
IGEO/UFBA, Rua Caetano Moura 123, Federacao, Salvador, 40210-340, Bahia
- Brasil Federative Republic of Brazil
mariliad@ufba.br

Since 1993 three events of mass coral bleaching were reported in Brazil, with total recovery of affected corals. The 1997-1998 and 2002-2003 events were monitored along the coast of the State of Bahia, Eastern Brazil. During the former, in north Bahia, three coral species were the most affected: *Agaricia agaricites* with 80% colonies bleached; 60 to 20% of *Mussismilia hispida* colonies were bleached and *Siderastrea stellata* had 45 to 15% colonies affected. In Abrolhos (south Bahia) *Porites branneri* had 80% of its colonies bleached, *M. hispida* 85% affected, *M. hartti* had 75% of the colonies affected and of *P. asteroides* no one healthy colony was seen. During the late event (the 2002-2003 El Nino), reefs in three regions were monitored along the coast of the state: Todos os Santos Bay (north), Tinhare Island (middle) and Abrolhos region (south), where bleaching patterns occurred differently. In Tinhare Island bleaching followed the thermal anomaly, evolving from a background level of 18% colonies affected before the thermal anomaly, to 70% of colonies bleached during the anomaly. *Siderastrea stellata* and *Mussismilia braziliensis* were the most affected species. In Abrolhos a residual bleaching (12% of colonies) was recorded. *Millepora alcicornis* and *Montastrea cavernosa* were the most affected corals. In Todos os Santos Bay a constant frequency of 50% colonies was affected. *Montastrea cavernosa* and *Siderastrea stellata* were the most affected corals. Thermal anomaly associated with El Nino events cause mass bleaching in Brazil. However, in sites where anthropogenic impacts are high, such as in Todos os Santos Bay, it seems that it is only an additional factor. Because no mass mortality has ever been reported, in Brazil, the Western South Atlantic coral fauna can be considered as a resilient fauna.

A Review of Time-Temperature Bleaching Thresholds and the Relationship between Bleaching and Mortality Thresholds

Ray BERKELMANS*

PMB 3, Townsville Q4810 Australia

r.berkelmans@aims.gov.au

Since the 1998 coral bleaching event on the Great Barrier Reef (GBR), a simple series of time-integrated bleaching thresholds has been proposed for GBR reefs based on in-situ temperature data and intensity of bleaching (Berkelmans, 2002). These threshold curves not only defined bleaching thresholds to within narrow thermal limits, but also showed how remarkably sensitive reefs are to bleaching following small increases in either temperature or time at high temperatures. The GBR suffered another major bleaching event four years later (2002). Temperature and survey data obtained during and since this latest event provided an opportunity to re-visit the proposed bleaching thresholds to gauge their accuracy, and for those reefs that also suffered major mortality, also to investigate the relationship between bleaching and mortality thresholds. The results show that the proposed 1998-based bleaching thresholds proved highly robust both in a detailed time-series observation at a local inshore reef and in predicting bleaching at other locations at which temperature loggers were deployed. Mortality levels in some coral species groups (*Acropora spp.*, *Seriatopora hystrix*) exceeded 50% at three locations. A re-construction of time-temperature curves for these locations indicates that (i) for these species groups the mortality threshold is only 0.5 to 1°C above the bleaching threshold and (ii) that the relationship between bleaching and mortality thresholds is constant with respect to temperature above threshold, but not with respect to time above threshold. These results provide both valuable data and a simple approach for modeling efforts aimed at predicting future scenarios for coral reefs and for current early warning systems aimed at monitoring environmental conditions conducive to coral bleaching and mortality.

The Effect of Coral's Metabolism on Temperature Estimated by Continuous Flow Mixing Approach

Hiroyuki FUJIMURA*, Tomihiko HIGUCHI, Kazuyo SHIROMA, Takemitsu ARAKAKI, Tamotsu OOMORI, Hatsuo TAIRA

Chemistry Office, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan

fujimura_h@yahoo.co.jp

For the past several years, large-scale coral bleaching has been observed in many coral reef areas around the world. Since coral bleaching reduces both photosynthetic and calcification activities of corals, large-scale coral bleaching could pose an impact on global carbon cycles. Coral bleaching is considered to be caused mainly by high seawater temperature together with other factors such as strong UV-light and changes in salinity. However, the mechanisms of coral bleaching are not clearly understood. We have designed and conducted experiments using a continuous flow mixing system (CFM system) under well-controlled light and temperature conditions to elucidate the effects of seawater temperature on coral's metabolism and changes in chemical compositions in the seawater around the coral. The CFM system we had used was designed to have a complete mixing and steady supply of fresh seawater. This system allowed us to study effects caused by temperature change on coral's metabolism and changes in uptake or release rates of chemical substances in seawater by separating many environmental parameters (e.g. tide, sunlight, etc.) that otherwise could affect chemical compositions of seawater in actual situations. Coral specimen, *Goniastrea aspera*, was collected from northern shore of Okinawa island, Japan with government permission. pH, dissolved oxygen (DO), alkalinity (Alk), nitrate and nitrite ion ($\text{NO}_3 + \text{NO}_2$), ammonium ion and dissolved organic carbon (DOC) were measured. Metabolism of coral was calculated by analyzing coral's uptake or release rates of those chemical substances such as Alk and DOC in seawater. With our experimental conditions, at 33 °C, coral's photosynthesis and calcification decreased by 27% and 72%, respectively, while release rate of DOC from coral increased by 53%.

Photic Stress and Bleaching in Reef-dwelling Foraminifera: A 20 Year Retrospective

Pamela HALLOCK*, Dana E WILLIAMS, Strawn K TOLER, Elizabeth M FISHER, Helen K TALGE

140 Seventh Ave. S., St. Petersburg, Florida 33701 United States of America

pmuller@marine.usf.edu

Reef-dwelling larger foraminifera share key characteristics with reef-building corals: both groups are prolific producers of calcium carbonate, both groups are physiologically dependent upon algal endosymbionts, and representatives of both groups have suffered bleaching episodes in recent decades. Bleaching symptoms were first observed in foraminifera in the early 1980s in laboratory experiments aimed at determining optimal culture conditions for the most common Caribbean and Indo-Pacific larger species, *Amphistegina gibbosa* and *A. lessonii*. Bleaching was first noted in field specimens collected in the Bahamas in 1988 during a coral post-bleaching survey. Since 1991, bleaching has been observed in populations of *Amphistegina* in all subtropical oceans, with peak bleaching in 1991, 1992 and 1998. *Amphistegina* populations exhibiting chronic, intermediate-intensity bleaching characteristically also show anomalously high incidences of shell breakage, shell deformities, and attack by predators and microorganisms. A key difference between bleaching in corals and foraminifera is that coral bleaching correlates most consistently with elevated sea surface temperatures, while bleaching in *Amphistegina* is associated with photic stress. Throughout the 1990s, bleaching incidences in Florida Keys populations of *A. gibbosa* increased through the spring and peaked near the summer solstice, preceding late summer temperature maxima. Photic stress in laboratory cultures induced visible bleaching that was cytologically indistinguishable from bleaching in specimens freshly collected from the field. Increasing radiant energy by 20 percent above established optimal laboratory conditions by changing fluorescent light sources from white to blue induced chronic bleaching, without affecting rates of shell increase. Thus, while corals that are susceptible to bleaching apparently live near their upper thermal thresholds, *Amphistegina* thrive near their photic thresholds and are particularly sensitive to shorter wavelengths of solar radiation. Recognizing the similarities and differences between these taxonomically very different symbiotic systems may facilitate understanding the global decline of coral reefs.

Physiological Responses of Corallimorpharians (Cnidaria: Anthozoa) to the Synergistic Effect of UV and Temperature Stress

Baraka L KUGURU, Gidon WINTERS*, Sven BEER, Nanette E CHADWICK-FURMAN

P.O.Box 469, Eilat, Israel

barakakuguru@hotmail.com

Corallimorpharians (Cnidaria: Anthozoa) are physiologically resistant to several types of environmental stressors (UV, temperature, nutrients), and are able to overgrow and damage stony corals on disturbed tropical reefs (Chadwick-Furman and Spiegel, 2000, Muhando et al., 2002). Their photosynthetic capacity has never been studied. Warner et al., 1996, show that photosynthetic responses of anthozoans can be used to assess their physiological status when subjected to changes in environmental parameters. In this study, we assessed the photosynthetic capabilities of corallimorpharians using in situ PAM fluorometry and controlled bleaching experiments. Preliminary results for *Rhodactis* (= *Discosoma*) spp. indicate that although these animals grow in extremely shallow environments, they have a high optimal quantum yield of photosystem II (Fv/Fm), equivalent to that measured in corals growing in depths of greater than 20 meters. We will present the results of bleaching experiments, in which several types of corallimorpharians and stony corals are compared in terms of their resistance to stress-induced bleaching. The photosynthetic responses of corallimorpharians to stress may in part explain their ability to survive at the expense of corals on some disturbed Indo-Pacific coral reefs.

Cnidarians: A Biological Model for the Study of Gene Transcription during Hypoxia

Emmanuelle KULHANEK, Didier ZOCCOLA, Cecile SABOURAULT, Eric TAMBUTTE, Sylvie TAMBUTTE, Denis ALLEMAND*
Avenue Saint Martin, MC 98000 Monaco Principality of Monaco
allemand@unice.fr

Cnidarians constitute an important phylum of marine animals, belonging to Radiata and considered as the first Metazoans (Eumetazoans, diploblastic) appeared 600 millions years ago. Their study represents then a high interest for an evolutionary point of view. Moreover, most of the Cnidarians live in symbiosis with intracellular algae, which maintain their photosynthetic capacity, producing high amount of oxygen during the day (until 60 % of O₂ saturation after only 20 minutes of illumination). However, during the night, the respiration rates of the two partners induce a hypoxia state (<1 % O₂). These rapid transitions of the tissular oxygen concentration are usually fatal for most of the animal organisms. In fact, the re-oxygenation of hypoxic tissues involves rapidly cellular damages (cf. the ischemia-reperfusion syndrome in medicine). The high resistance of the Cnidarians to these oxygen transitions, and their simple tissular organisation, allow us to consider these organisms as interesting biological models to investigate the hypoxia-hyperoxia resistance. In order to study the genes involved in the Cnidarian resistance to oxidative stress, we realized a cDNA library by suppression subtracting hybridization (SSH) between the transcripts present during the night and the transcripts present during the day. A microarray, containing 1000 genes obtained from this library, has been produced. The results presented concern the hybridization of the microarray with cDNA populations extracted during the day- and night-time.

Carbonic Anhydrase from Corals

Bill P. LEGGAT*, David YELLOWLEES
Slip Road, St Lucia, Queensland 4175 Australia
b.leggat@marine.uq.edu.au

Photosynthesis by symbiotic zooxanthellae (=Symbiodinium) can provide up to 100% of a corals energy requirements. However for this to occur significant amount of inorganic carbon (Ci) must pass through the coral host to their photosynthetic symbiont. This uptake is facilitated by the enzyme carbonic anhydrase (CA), which catalyses the interconversion of carbon dioxide and bicarbonate. Although it has been known for a number of years that CA plays a central role in Ci uptake, how many isoforms are present and how they function in Ci uptake by corals is still unclear. Here we present the cDNA sequence of 4 different CA isoforms, the most CA cDNA sequences isolated from any invertebrate. Based on sequence analysis three of the isoforms are membrane attached while one is found in the cytosol. How these different isoforms function in Ci uptake and how expression levels change in response to changes in Ci demand by the zooxanthellae is discussed.

Light Stress Effect in Coral Bleaching Phenomenon of Reef Building Coral *Pocillopora verrucosa*

Sophie RICHIER*, Mireille GUILLAUME, Jean Michel COTTALORDA, Pierre-Laurent MERLE, Denis ALLEMAND, Paola FURLA
Faculte des Sciences, Parc Valrose, BP71, 06108 Nice Cedex 02 France, Metropolitan
srichier@unice.fr

Many cnidarians, such as corals, live in symbiosis with photosynthetic Dinoflagellates called zooxanthellae. Mutualistic nutrients exchanges between those two specimens in association lead to the successful colonization of oligotrophic sea waters. Nevertheless, this coral reef ecosystem, one of the most productive of the biosphere, is also one of the most threatened today.

This symbiotic association between corals and zooxanthellae is periodically submitted to a disruptive phenomenon called "coral bleaching". This phenomenon corresponds to the loss of most of the symbiotic zooxanthellae normally found within the coral tissue. Although experiments and observations indicate that coral bleaching results primarily from elevated seawater temperature, UV and oxidative stress remain the main factors interacting in this symbiosis imbalance. In order to determine light stress implication in coral reef bleaching, experiments were performed as part of Auracea Mission 2003 (Daniel Jouvance) to the Glorieuses Island (Western Indian Ocean) in December 2003.

Specimens of *Pocillopora verrucosa* nubbins have been transplanted for five days between deep (20 m depths) and shallow (5 m depths) sea water. Some coral nubbins were collected at J+1, J+2, J+3, J+5 from the two depths. After five days, a loss of pigmentation was observed in the nubbins transplanted from 20 to 5 m depths. Control colonies did not show any bleaching. Biochemical analysis were performed on antioxidant defenses for a better understanding of the enzymatic process that occurred in response to light stress. This work has been performed thanks to Daniel Jouvance Company which organized in collaboration with the Museum National d'Histoire Naturelle of Paris and supported financially the Auracea Mission 2003.

Identifying Determinants of Resistance to High Temperatures: Evidence from a Coral Transplant Experiment

Lance W. SMITH*
Edmondson Hall, University of Hawaii at Manoa, Honolulu, HI 96822 United States of America
lancesmi@hawaii.edu

Coral reef marine protected areas should include coral colonies and habitats that are resistant to high temperatures so that these areas can provide a basis for coral recovery from bleaching events. Identification of determinants of resistance is a critical step in establishing networks of MPAs that are likely to be most robust in the face of continuing climate change. We conducted a coral transplant experiment in Ofu Lagoon, American Samoa, to test for resistance to high temperatures. The lagoon consists of a series of pools that vary in thermal conditions, with temperatures in some pools reaching 35 °C and fluctuating daily by >6 °C. Yet the pools support diverse coral communities, including many species thought to be sensitive to high temperatures such as *Acropora*, *Pocillopora*, and *Millepora* spp. Nubbins of *Pocillopora damicornis* and *Porites cylindrica* were obtained from the deepest pool, dyed with Alizarin red S for measuring growth, and transplanted to the shallowest pool and a pool intermediate in depth, as well as back into the pool of origin. Water temperatures were recorded hourly at the three sites during the one year period, and other water quality and physical characteristics were studied at the three sites. The shallowest site had the highest daily maximum temperatures, the greatest duration of high temperatures, and the greatest daily fluctuations of temperatures of the three study sites. However, transplants of both species had the highest growth rates at the shallowest site, and *P. damicornis* had the highest survival rate at this site. Water motion and dissolved oxygen levels were higher at the shallowest site than the other two transplant sites, suggesting that one or both of these extrinsic factors enhance the resistance of corals to high temperatures.

Growth Response of Caribbean Shallow-water Corals Under UV-Exclusion Experiments*Juan L TORRES**, Roy A ARMSTRONG

PO Box 3210, Lajas, PR 00667 USA Puerto Rico

jltorres@caribe.net

We measured the linear extension rates of the Caribbean shallow-water branching corals *Acropora cervicornis* and *Porites furcata* under excluded ultraviolet radiation (UVR; 280-400nm) in a pristine reef in the southwest coast of Puerto Rico for three consecutive months. Corals were stained with Alizarin Red S just before the beginning of the experiments. Linear extension rates were measured with a vernier caliper from the stain line to the tip of each branch of the colonies. We used a Saran meshes to reduce UVR levels to 4% and Photosynthetically Active Radiation (PAR; 400-700nm) to a 12% of normal intensity levels at sampling depth (2m), and Hyzod Acrylic panels to block 99% of the UVR reaching the corals and 23% PAR. The control colonies were exposed to the normal UVR and PAR levels at sampling depth. Colonies of both species showed significantly lower linear extension rates under the Saran than the control and Hyzod ones. The colonies of *A. cervicornis* grew an average 3% more under 99% excluded UVR, while *P. fucata* grew 12% more under the same treatment. Although the differences are not significant suggest a possible negative effect of the actual levels of UVR reaching shallow-waters on the growth of branching corals. The results are compared and correlated with a possible bleaching event that might have occurred during the course of the experiments, specially in the colonies under the Saran treatment. These colonies showed a decrease in their zooxanthellae/unit area content as well as a decrease in their respective photosynthetic pigments. This reduction results in lesser resources directed towards calcification, which translates into decreased linear extension rates and possibly more fragile skeletons.

The Effect of Temperature on Growth Rate of *Stylophora pistillata* and *Seriatopora hystrix**Ya-Hsuan TUNG**, Tung-Yung FAN, Chang-Feng DAI

No.1, Sec. 4, Roosevelt Road, Taipei, Taiwan 106 Taiwan

r91241219@ntu.edu.tw

The latitudinal range of *Stylophora pistillata* is wider than that of *Seriatopora hystrix*. To investigate the effect of sea temperature on growth rates of these species, coral nubbins were grown in mesocosms at three temperature regimes (20, 25 and 28°C, each 2 replicates). The growth rate was measured at three-week intervals by a buoyant weighing technique. The mean growth rate of *S. pistillata* at 25°C (0.0087 g day⁻¹) was significantly higher than that at 28 (0.0053 g day⁻¹) and 20°C (0.0048 g day⁻¹). The highest mean growth rate of *S. hystrix* was found at 25°C (0.0142 g day⁻¹), intermediate at 28°C (0.0064 g day⁻¹) and the lowest rate at 20°C (0.0043 g day⁻¹). The mean growth rate of *S. pistillata* was significantly lower than that of *S. hystrix* both at 28 and 25°C, but higher than that of *S. hystrix* at 20°C. This suggests that the summer temperature (approximately 28°C) is not optimal for the growth of these two species. The interspecific differences in growth response to temperatures may partly explain the latitudinal distribution of these species.

Influences of Temperature on the Oxygen- and Fluorescence-based Estimates of Photosynthetic Parameters in the Reef Coral *Stylophora pistillata**Tai-Ying WU**, Tung-Yung FAN, Chang-Feng DAI

No.1, Sec. 4, Roosevelt Road, Taipei, Taiwan 106 Taiwan

b87205201@ntu.edu.tw

The effect of temperature on the O₂-based and chlorophyll fluorescence of Photosystem II (PSII)-based parameters of photosynthesis in the reef coral *Stylophora pistillata* was investigated. Coral nubbins were maintained at three different temperature levels (20, 25 and 28°C) for ten days. The electrons transport rates (ETR) and maximum PSII quantum efficiency (F_v/F_m) were measured by diving pulse amplitude modulate (PAM) fluorometry and the rate of O₂ evolution was carried out by oxygen respirometry. The maximum rate of gross photosynthesis (P_{g,max}) and sub-saturation irradiance (I_k) measured by respirometry, photosynthetic efficiency () measured both by respirometry and PAM, as well as F_v/F_m were similar among different temperature treatments. However, the maximum rate of photosynthesis (ETR_{max}) of corals at 25 and 28°C was two times higher than that of corals at 20°C. In addition, the sub-saturation irradiance (I_{k,ETR}) was highest at 28°C, middle at 25°C, and lowest at 20°C. This suggests that fluorescence-based photosynthetic parameters were more temperature sensitive. Furthermore, a similar linear relationship between gross photosynthesis (GP) and ETR was found under irradiances below 400 μ E m⁻²s⁻¹ or GP less than 8 μ mol O₂ m⁻²s⁻¹ at the three temperature treatments. This suggests that diving-PAM may provide a quick and non-invasive way to estimate primary productivity of corals at least under moderate irradiances.

"Spatial Distribution of Calcification and Photosynthesis in the Scleractinian Coral *Galaxea fascicularis*"

Fuad A AL-HORANI*, Tim FERDELMAN, Salim M AL-MOHRABI, Dirk DE BEER

P.O.Box 195, Aqaba 77110 Jordan Hashemite kingdom of Jordan
fal_horani@hotmail.com

The spatial heterogeneity of photosynthesis and calcification of single polyps of the coral *Galaxea fascicularis* was investigated. Photosynthesis was investigated with oxygen microsensors. The highest rates of gross photosynthesis (Pg) were found on the tissue covering the septa, the tentacles and the tissues surrounding the mouth opening of the polyp. Lower rates were found on the tissues of the wall and the coenosarc. Calcification was investigated by radioactive tracers. The incorporation pattern of ⁴⁵Ca and ¹⁴C in the corallites was imaged with use of a Micro-Imager. The μ -images obtained showed that the incorporation of the radioactive tracers coincided with the Pg distribution pattern with the highest incorporation rates found in the corallite septa. Thus, the high growth rate of the septa is supported by the high rates of Pg by the symbiont in the adjacent tissues. The total incorporation rates were higher in light than in dark, however, the distribution pattern of the radioisotope incorporation was not affected by illumination. This further emphasizes the close relation between calcification and photosynthesis.

Biom mineralization in Scleractinian Corals: Calcium Transport and Organic Matrix Synthesis by Calcicoblastic Cell

Denis ALLEMAND*, Severine LOTTO, Sandrine PUVREL, Eric TAMBUTTE, Sylvie TAMBUTTE, Didier ZOCCOLA

Avenue Saint-Martin, MC-98000 MONACO Principality of Monaco
allemmand@centrescientifique.mc

Whereas scleractinian corals are one of the major calcifying groups of organisms in the living world, biom mineralization processes largely remain a biological enigma. Biom mineralization consists of the precipitation of CaCO₃ within an organic matrix. In corals, calcification occurs at the innermost margin of the ectodermal cells of the aboral layers (*i.e.* the calcicoblastic epithelium), consequently, the study of this epithelial layer is of major interest. We present here results concerning calcium transport and synthesis of organic matrix, two essential mechanisms for biom mineralization. Using *Stylophora pistillata* microcolonies as a model, we have demonstrated that a transepithelial pathway takes place in the calcicoblastic cells, whereas calcium crosses the oral layers by a paracellular pathway. This calcium entry into calcicoblastic cells involves a L-type Ca²⁺-channel protein which $\alpha 1$ subunit has been cloned. Concerning Ca²⁺ export from the calcicoblastic cells to the skeleton, we recently cloned a Ca²⁺-ATPase gene. Phylogenetic tree construction showed that this calcium pump is closely related to the PMCA family found in vertebrates. This is the first known example of a Ca²⁺-ATPase from the phylum Cnidaria, and thus, the most distant Ca²⁺-ATPase sequence in animal kingdom described to date. Concerning organic matrix synthesis, we have used antibodies raised against soluble organic matrix extracted from the skeleton of *Stylophora pistillata*. We present direct evidence for the role of calcicoblastic cells in organic matrix synthesis and secretion. Thus we make a contribution to the "organic matrix concept" for calcification which can also be described as a "biologically-controlled process". Furthermore, we present these antibodies as a new tool to identify and isolate calcicoblastic cells in culture which can help to investigate skeleton formation at the cellular level.

Effects of N-form on Nitric Oxide Producing Activities of Zooxanthellae

Takayuki KAMIKI*, Takashi NAKAMURA, Hideo YAMASAKI

Nishihara, Okinawa 903-0213 Japan
kamiki@d1.dion.ne.jp

Corals have adapted to low nutritional environment by establishing symbiotic relationship to dinoflagellates (zooxanthellae) that can assimilate carbon and nitrogen. In nitrogen assimilation, the primary N-form may be served as nitrate or ammonium ions. When nitrate is taken up into the cells, it can be converted to nitrite by nitrate reductase (NR). Nitrite should be subsequently reduced by nitrite reductase (NiR). These enzymes (NR and NiR) are inducible in response to nitrate availability. Recently, the enzyme NR has been found to produce nitric oxide (NO) in addition to the normal product nitrite. NO is a free radical that exhibits versatile functions in vertebrate and invertebrate animals, plants and algae. It has been suggested that NO displays not only beneficial functions but also harmful effects, *i.e.* toxicity of reactive nitrogen species (RNS). The aim of this study was to explore NO producing activity in zooxanthellae grown in different N-forms. *Symbiodinium microadriaticum* (ccmp 829) was used as a model system for this purpose. Zooxanthellae were cultured with either of three types of the media: K-medium, ammonium-based K-medium (ammonium medium), nitrate-based K-medium (nitrate medium). Zooxanthellae grown in the ammonium medium were morphologically distinguished from those in the nitrate medium. In the nitrate medium, most zooxanthellae changed to a motile cell form, whereas the cells grown in the ammonium medium did not show such mobility. Although there was no substantial difference in growth rates at 25°C, we observed significant difference in higher temperatures such as 30 °C. The algae inoculated into the nitrate medium showed normal exponential growth followed by the stationary phase. In contrast, there was a resting period for two weeks prior to such exponential growth in the ammonium medium. NO producing capability along with scavenging activity of zooxanthellae will be reported in terms of nitrogen toxicity in the coral-algae symbiosis.

Seasonal Variation of Nonylphenol and Bisphenol A in Aquatic Environments Using Liquid Chromatography-Electrospray Tandem Mass Spectrometry

Yukio KITADA*, Hodaka KAWAHATA, Atsushi SUZUKI, Tamotsu OOMORI

Japan
y.kitada@aist.go.jp

Examination of Nonylphenol (NP) and bisphenol A (BPA) was conducted in river water and sediment samples collected from Okinawa Island South of Japan. There has been lately an interest in certain chemical compounds released into the environment through human activity, which are capable of disrupting the endocrine system. Alkylphenol polyethoxylate (APnEO) are a major class of non-ionic surfactants used in household and industrial processes. NP, which is generated through APnEO degradation, is the most toxic APnEO and can cause several hazards to aquatic ecosystem. BPA is used in a wide array of plastic products as polycarbonate. Coral reefs are characterized by high biological diversity. Coral reefs are being seriously damaged worldwide. Agriculture, urbanization, pig farming in Okinawa are increasing sediment, sewage, pesticide and antibiotics loads into marine environment. In order to assess the risk of NP and BPA, their presence and fate in the environment must be known. The purpose of this study is to elucidate the distribution of endocrine disrupters (NP and BPA) in aquatic environment and the consequent damage of coral reef around Okinawa Island. Liquid-liquid extraction was adopted for water samples. Water sample (1L) was extracted with dichloromethane. The sediment sample was extracted with acetonitrile. Identification and quantification of NP and BPA were accomplished by liquid chromatography with tandem mass spectrometry (LC-MS-MS) and GC-MS. NP and BPA were present in river water samples (0.13-0.52 and 0.01-0.15 μ g/L) and sediments (6-717 and 0.7-15.7 μ g/kg). Concentrations of NP and BPA near Naha city were higher than that of northern area. NP and BPA were widely distributed in the river sediment. Most of the sampling sites for this study are located within a distance of 2 km in the coral reefs. The results from our survey suggest that NP and BPA pollution has been started in this area.

Genotoxic Effect (Comet Assay) of Increased Water Temperature on Zooxanthellae in a Coral (*Galaxea* sp.) Collected from Polluted Environment, Gulf of Mannar, Southeast Coast of India

*B Muthu RAMAN**, *J Jerald WILSON*

RESEARCH FELLOW, 3/1392, UNIVERSITY FIELD LAB, MIDDLE STREET, PUDHUMADAM-623524, TAMILNADU, INDIA

muthu_mku@yahoo.com

Comet assay is a recent and sensitive method to detect DNA damage as strand breaks. Coral pieces (*Galaxea* sp.) collected from non-polluted area were maintained under laboratory conditions (Flow through system). To study the genotoxic effects of water temperature, coral pieces were exposed to ambient temperature ($28^{\circ}\text{C}\pm 1^{\circ}\text{C}$) and $32^{\circ}\text{C}\pm 1^{\circ}\text{C}$ in separate tanks. From the coral polyps, the symbiotic algal cells were aseptically removed for DNA studies. DNA damage as a measure of DNA integrity in the Algal cells was estimated using the comet assay. The results were compared to assess the genotoxic potential of increased water temperature. **Keywords:** *Comet assay, Genotoxicity, Zooxanthellae, DNA damage, water temperature, Gulf of Mannar**.

Primary Targets of Heat Stress in Reef-building Corals

*Hideo YAMASAKI**

Nishihara, Okinawa 903-0213 Japan

yamasaki@comb.u-ryukyu.ac.jp

Coral bleaching has recently received intensive attentions from the public because the phenomenon is considered to be a significant impact of global warming on biosphere. The most puzzling question on this issue is why corals are bleached by only a few degree of temperature increase. To explain the heat-susceptible mechanism of reef-building corals, a number of hypotheses have been proposed but the mechanism on molecular basis remains unsolved yet. In general, photosynthesis is susceptible to heat stress and impaired by even moderate temperature increases; the phenomenon is primarily attributed to photoinhibition of photosystem II (PSII). Photoinhibition is determined by the balance between the rates of photodamage and protein repair for PSII. Because heat stress could suppress Calvin cycle and may over-reduce the electron transport system, it has been suggested that the reactive oxygen species (ROS), such as singlet oxygen produced in PSII, stimulates the photodamage. We have recently shown that inhibition of PSII protein repair machinery of the zooxanthellae leads to heat-dependent photoinhibition and proposed that bleaching tolerance is ascribed to high rates of repair relative to photodamage, rather than simply photodamage as previously suggested. Here we present a possible involvement of reactive nitrogen species (RNS) in cellular damage caused by heat stress. **References** Yamasaki, H. (2000) Nitrite-dependent nitric oxide production pathway. *Roy. Soc. Lond. Phil. Trans. B*, 355, 1477-1488. Yamasaki, H. and Sakihama, Y. (2001) Nitrate reductase as a producer of nitric oxide in plants: temperature-dependence of the enzymatic active nitrogen formation. *In* PS2001, CSIRO publishing, Collingwood, S21-003. Takahashi, S., Nakamura, S., Sakamizu, M., van Woesik R. and Yamasaki, H. (2004) Repair machinery of symbiotic photosynthesis as the primary target of heat stress for reef-building corals. *Plant Cell Physiol.* in press.

Cell Growth and Calcification Result from Uncoupled Physiological Processes in the Soft Coral *Litophyton arboreum*

*Ernestina TENTORI**, *Denis ALLEMAND*, *Ross SHEPHERD*

The University of Sydney, Sydney NSW 2006, Australia

tinatentori@mail.usyd.edu.au

Cellular growth and calcification were measured in branch tips of the soft coral *Litophyton arboreum* (Cnidaria, Octocorallia, Alcyonacea). We measured cell growth rates as ³H-Thymidine incorporated into tissues, and calcification as ⁴⁵Ca incorporated into sclerites, during 2-hour incubations in labelled seawater. Both parameters were normalized against soft coral protein content and analysed separately as stems and polyps responses. The experiments were run at various times of coral recovery from dissection. Stems and polyps showed their lowest cell growth immediately after injury due to cutting (days 1 to 3), and their highest cell growth during recovery time (days 7 to 49). In all experiments, the cell growth rate of stems was significantly higher than the cell growth rate of polyps. By contrast, no significant difference was detected between calcification rates of stems and polyps of the fully recovered microcolonies (7 to 81 days). This study documents for first time the independent progress of cell growth and calcification mechanisms in tropical corals. This study also demonstrates the contrasting physiological potential between the body regions of soft coral colonies.

Field Measurements of Wave Characteristics and Wave Energy across a Coral Reef Platform

*Robert W BRANDER**, Paul S KENCH, Deirdre HART

School of BEES, University of New South Wales, Sydney, Australia 2052 Australia
rbrander@unsw.edu.au

Spatial and temporal variations in wave characteristics and energy across a coral reef platform at Warraber Island, Torres Strait, Australia were monitored over 3 tidal cycles in July 2001. Measurements of water depth were obtained at 5 locations across a 2.7 km section of the topographically uneven reef flat. Rising and falling tides were characterised by a bimodal energy distribution at short period (0-3 s) and wind (3-8 s) wave frequencies. Higher water levels were dominated by wind waves and greater wave heights. Wave energy at swell (8-20s) and infragravity (> 20 s) frequencies was negligible across the reef platform although evidence of wave groups at higher water levels existed. Reef geometry and changes in water level determine the magnitude of wave energy on the reef platform. Up to 85-95% of incident wave energy was attenuated by a central reef flat depression at high and low tide respectively and strong linear relationships exist between significant wave height (H_s) and water depth (h) at all locations. Both H_s and wave type are strongly depth dependent. Critical reef rim depths required to produce H_s of a given size vary spatially across the reef rim due to variations in reef topography. A distinct depth related threshold exists at which short period and wind wave dominance reverses. Over a 14 day spring-neap tidal cycle, the time of occurrence of wave action diminishes across the reef platform to the shoreline. Larger waves ($H_s > 0.2$ m) occur for only 9 % of time at the outer reef flat and for less than 0.5 % over the remaining reef platform. This implies that under normal wave energy conditions, sediment entrainment and transport on the reef platform are severely constrained and significant change is likely restricted to extreme events.

Comparison between Numerical Simulation of Wind-Wave Distribution and Wavemeter Gauge Measurements in a Semi-enclosed Lagoon

Pascal DOUILLET, Loys SCHMIED, Aymeric JOUON, Ali BEL MADANI, Sylvain OUILLOON*

BP A5, 98848 NOUMEA New Caledonia
ouillon@noumea.ird.nc

In New Caledonia, where open-cast mining plays a significant economic role, the coral reef lagoon ecosystem is strongly dependent on the sediment distribution and dynamics. A study on the influence of anthropogenic and terrigenous inputs has been conducted since 1996 involving in situ measurements, numerical modelling and remote sensing. New Caledonia is surrounded by coral reef lagoons covering a total area of 23,400 km². The study area extended over an area of roughly 2,000 km², and a 500-m grid size is used in the numerical models. In this poster, a part of the modelling system relative to the wave distribution within the lagoon and to its influence on sediment transport is presented. WAVEWATCH III, a public-domain wave model, was used to simulate the wave distribution. The numerical results were compared to wave measurements provided by an Aanderaa WTR9 wave meter gauge. In the wave data processing, a cut-off was automatically taken into account that eliminated the waves with small lengths. If this is generally not a problem in opened sites with sufficiently long waves, this point is very crucial in quasi-enclosed basins such as the southwest lagoon of New Caledonia. In this case, the data outputs can not be considered as actual wave parameters such as the significant wave height. A method was proposed that can easily be generalized to other fetch-limited basins. The wave model was validated from time-series of measurements in the southwest lagoon of New Caledonia under several forcings. A method was developed to model the non-linear wave-current interaction and integrate the wave model to the main hydrodynamical model. It is based on calculations of bed shear stresses due to combined waves and current, which lead to modified erosion and deposition criteria for sediments at the seabed as compared to the purely hydrodynamical calculations.

The Influence of Offshore Water from the Kuroshio Current on High Water Temperature Fluctuations, the Cause of Coral Bleaching, in a Coral Reef Region (Sekisei Lagoon in Okinawa Prefecture, Japan)

*Yasuo FURUSHIMA**, Susumu KANNO, Hiroyuki YAMAMOTO

2-15 Natsushima-cho Yokosuka 237-0061 Japan
furus@jamstec.go.jp

Sekisei lagoon is located in the southern part of the East China Sea, and lies about 1500km south of Tokyo Japan. This lagoon is the largest coral reef region in Japan at about 400 km², (20km long and 20km wide). It is surrounded by six islands including Ishigaki and Iriomote as well as reefs. The Kuroshio Current flows offshore of the lagoon to the west and north. During the worldwide coral bleaching event of 1998 high water temperatures resulted in damage to the coral in Japan's Okinawa Prefecture. As a result Sekisei lagoon suffered damage to about 30% of its corals. This study, based upon long-term variations (from 1989 to 2001), of sea surface temperature (published by Japan Fisheries Information Service Center) and meteorological data, we show the relation between long-term fluctuations of offshore water from the Kuroshio Current and a period of coral bleaching. The distribution of high temperature offshore water (more than 28°C) tended to shift westward in the summer of 1998. It was found that the water in Sekisei lagoon might be warming as an effect of the offshore Kuroshio Current. The disturbance of a typhoon has been considered to be a cause of the coral bleaching in the lagoon. Although this result is correspondent to the coral bleaching of the mainly shallow coral reef region we feel that the effect of the typhoon was relatively weak. We suggest that the high-temperature offshore water, which spread to Sekisei lagoon, was one of the main causes of the coral bleaching.

Coastal Trapping, Sticky Water or the "Coastal Boundary Zone": Does Complex Coastal Topography near Reefs Trap Particles?

*Clifford J HEARN**, William M HAMNER

University of South Florida, USGS , 600 Fourth Street South, St Petersburg, Florida, FL 33701, USA
cjhearn@usgs.gov

Some twenty years ago, Gabriel Csanady in an article in *EOS* discussed the idea of a "coastal boundary zone" which traps particles. The idea is often implicit in discussions of coastal dynamics but still lacks any definitive treatment which relates specific physical processes to observations of particle behaviour near the coast. Hearn, Black, Johnson and Hatcher at the 9th ICERS at Bali summarized the situation for coral reefs in the following terms: "There is a region near to the coast, called by Csanady the coastal boundary zone, and produced by velocity shear, dominance of friction in shallow water, the tendency of topography to produce gyres and eddies, importance of surface waves breaking on coasts and reefs. Modeling such effects requires very fine spatial scales, care with breaking waves, turbulence and the high friction exhibited by coral". Wolanski has also coined the similar term "sticky water" for water effectively "trapped" by high friction on topography complex reefs. In this paper, we show that coastal trapping is associated with non-uniformity in topography or "roughness" and this includes both our traditional perception of roughness as applying to the seabed and roughness in the sense of the irregularity of the coastline. Finally we make some predictions of the width of the coastal trapping zone in terms of this generalized idea of roughness. In a companion paper at this conference, we will examine data which show the importance of coastal trapping and its variability between coastal environments.

Flushing Time and Residence Time in Coral Reef Lagoons: Application to the Southwest Lagoon of New Caledonia

Aymeric JOUON, Pascal DOUILLET, Sylvain QUILLON*, Philippe FRAUNIE
BP A5, 98848 NOUMEA New Caledonia
ouillon@noumea.ird.nc

Applications of transport time scales are pervasive in biological, hydrologic, and geochemical studies. These time scales (flushing time, age, residence time, and water renewal time) are not consistently defined in coastal areas and in particular in coral reef lagoons. New Caledonia, located at 1,500 km east of Australia, is surrounded by coral reef lagoons covering a total area of 23,400 km². From several years, a three-dimensional hydrodynamic model has been developed, calibrated, and validated over an area of roughly 2,000 km² called the southwest lagoon of New Caledonia. In this poster, we present the results of numerical simulations about the different concepts of time scale commonly used to measure the retention of water or scalar quantities transported with water. Different methods as the lagrangian method, the transport of dissolved matter, the age of water masses, and the integral balance of boundary fluxes are used to estimate the different time scales. The influence of different forcings (tide and wind) obtained for the different concepts are compared, and the spatial distribution of residence time is analyzed.

Characteristics of Internal Waves in the Zanpa Sea Area of Okinawa Island, South of Japan

Yasushi KITAMURA*, Eizo NAKAZA, Seikoh TSUKAYAMA, Shak M B RAHAMAN, Kouji TAMASHIRO
1 Senbaru, Nishihara-cho, Okinawa 903-0213 Japan
k998601@tec.u-ryukyu.ac.jp

Comprehensive observations have been conducted in the Zanpa sea of Okinawa Island, south Japan through the deployment of Acoustic Doppler Current Profilers and other necessary sensors. All the sensors were deployed through moored buoys and also mounted on ship for continuous measurements of horizontal current velocity, water temperature, salinity and density. The study area, which is characterized by very well developed coral reefs, is well known as a good fishing area. It is assumed that this areas hydrodynamic environment somehow contributes to making the area more nutritious and ecologically viable for the existence of numerous fisheries and other living organisms there. Observation results show characteristic hydrodynamic features of the study area. The thermocline layer is found at around 60 m below the surface from where water temperature sharply decreases resulting in an increased salinity and dense water body up to the bottom. The M2 tidal component changes the rotational direction of current vectors from clockwise to counterclockwise direction below the thermocline layer. It results when near bottom cold and dense water body from the deeper area is propagated toward this area along a gape of the bathymetry with penetration of internal waves. Zanpa sea area has a very complicated sea bottom topography, coastal configuration and land shelf topography. Getting the eight significant components of harmonic tidal current from raw current data, the characteristics of internal waves are clarified. The characteristic curve analysis of internal wave groups reveals the generating and transmitting mechanisms of the internal waves that mainly control the east-westward current near the sea bottom. These results may contribute to the understanding of currents around the Coral Sea surrounding the Okinawa Islands.

A Numerical Simulation of the Trajectory of Coral Egg and Larvae in the Sekisei Lagoon, Japan

Satoshi NAKADA*, Yasufumi ISHIHARA, Akira HARASHIMA
LOOP-X BLDG., 7F 9-15 KAIGAN 3-CHOME MINATO-KU, TOKYO 108-0022, JAPAN
nakada-s@janus.co.jp

The Sekisei Lagoon surrounded by the Yaeyama archipelago is one of the coral reef areas in Japan. However, it has been partly damaged due to several causes. The transport of coral egg and larvae from the less damaged area would contribute to the recruitment and recovery of the damaged area. Predicting the trajectory from such source areas to recruitment areas based on the modeling of physical circumstances such as the flow and dispersion will help ascertain the protective area and clarify the restoration process of the damaged coral reefs. For this purpose, we examine a flow pattern in summer in the Sekisei Lagoon using a numerical simulation method. The model used in this study is a multi-level hydrostatic model with a two-stepped nesting approach, by which we focus on the flow patterns both of the whole Sekisei Lagoon and the part around Kuroshima, which locates in the southern parts of this lagoon. The model is driven by the averaged wind stress in summer and the M2 tidal component. The results show that the northward current about 10 cm/s, which basically follows the wind direction, dominates along the eastern coast of Kuroshima and a weak flow exists the southeastern side of Kuroshima. We also compare them with the results from a control case where the flow is driven only by tidal force.

Alteration of Colony Morphology in Reef-building Corals by Water Motion

Takashi NAKAMURA*, Hideo YAMASAKI
Nishihara, Okinawa 903-0213, Japan
takasuken@yahoo.co.jp

Reef-building corals spend most of their life as sessile plant-like colony forms, except for the planktonic larval stage and solitary species. As similar to terrestrial plants, there is a wide variety in colony shape and morphology. Although most colony morphologies are determined genetically, some of them seem to change in response to surrounding environment. Field studies have shown that variation in colony shape may correspond to environmental gradients, such as irradiance and water motion. Until recently, however, there are few laboratory studies to demonstrate such morphological changes induced by a single environmental factor. Here we show the effects of unidirectional water flow on colony growth and its morphology over one year period. For this, *Stylophora pistillata* and *Pocillopora damicornis* were placed onto experimental flow flumes settle in the tanks. Flow-treated colonies of *P. damicornis* grew faster than low water-flow treated control and showed shorter branches or buds which subsequently fused each other and eventually formed thick and compact colonies. In contrast, colonies placed in a low water-flow produced spiny branches elongating horizontally and showed fine colony morphology. Basically, similar results were obtained in *S. pistillata*. We observed that water flow velocity strongly affected colony morphology, growth rate and mortality. The results suggest that flow-limitation reduces colony growth, and alter the colony morphology in *S. pistillata* and *P. damicornis*.

Field Study of Coral Mining on Turtle Island of Bali

*Satoquo SEINO**, Takaaki UDA, Osamu ONAKA, Masumi SERIZAWA, Toshiro SAN-NAMI
Japan
fwid6176@mb.infoweb.ne.jp

Protection of coral reef has been widely discussed regarding green house effect, since it has an ability to absorb carbon dioxide. However, in developing countries, activities accelerating extermination of coral reef have been conducting, driving gradual destruction of coral reef. Examples are a large-scale excavation to get construction materials, land reclamation using such materials and coral mining by local people to earn their daily bread. Coral mining causes not only loss of eco-system on coral reef, but also causes erosion due to the increase in wave action through the increase of water depth. This study aims at investigation of these issues through field observation and hearings from the local fishermen who was trying to carry out coral mining, taking Turtle Island of Bali in Indonesia as an example. Field studies were conducted in September 1999, September 2000 and August 2001. Coral mining had been prohibited by law since 1973, but in fact it has been carried out with composure in this area. At present, it is still continuing. Fundamental causes of continuation of coral mining are that there is no choice for local people to earn their daily bread except coral mining, because of deterioration of fishing ground, and that governmental activity such as legislature has few effect, because Custom Village, being a strong organization of local people, is superior to the regional government to determine their activities and they do not sufficiently understand the effect of meaning of coral mining. Coral mining and resulting beach erosion on Bali relates to not only engineering problem, but also they deeply depend on fundamental problems related to social and economical backgrounds. In order to solve these problems, not only a scientific approach, but also further reform of awareness of the local people and realistic suggestions for life and their actions are required.

Numerical Current Simulation in a Fringing-type Coral Reef: A Case Study at Ishigaki Island, Okinawa

*Hitoshi TAMURA**, Kazuo NADAOKA, Enrico C PARINGIT
2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552 Japan
tamura@wv.mei.titech.ac.jp

The Ishigaki Island is located at the southern-most end of the Ryukyu Islands of Japan, and is encompassed by well-developed fringing reefs. For detailed and quantitative understanding of coral reef environments and their evolution, we conducted hydrodynamic and biological field surveys at Shiraho reef located southeast of the Ishigaki Island. Generally fringing reefs are so shallow that the local topographic effects may significantly influence the flow circulation pattern. As a typical cross sectional feature of the Shiraho reef, the reef crest is exposed to the air during low tide. Besides, at some locations along the reef crest, there exist channels, which connect the reef area and the outer sea and hence may govern the water exchange between them. These complicated features of the reef topography, especially the exposure of the reef crests during low tide, and of corresponding hydrodynamic situation make field measurement of currents and related quantities difficult. In this study, we have applied a quasi-3D shallow water turbulence model (SDS-Q3D model) developed by Nadaoka and Tamura (2001) for investigating the characteristics of the currents in the reef area and local topography effects on them. One of the most important points to be implemented in the computational method is the introduction of a scheme for properly treating the exposure of the reef crests into the air during the low tide. For this purpose, we have applied a moving boundary scheme to SDS-Q3D model. Another crucial point is how to specify the bathymetry of the reef area, because there exists no available data for the reef area due to its shallowness. In this study, we have applied a method developed recently by Paringit and Nadaoka (2002), in which the bathymetry in and near a reef area may be inversely estimated with remotely sensed image data (Ikonos).

Evidence for Coastal Trapping and Conjectures on Processes and Ecology

William M HAMNER, *Patrick L COLIN**, Clifford J HEARN
621 Charles E. Young Drive South, Box 951606, Los Angeles, CA 90095-1606
United States of America
hamner@biology.ucla.edu

In a companion paper at this conference, Hearn and Hamner have discussed the basic idea of coastal trapping and the not new, but historically ignored, Csanady concept of the coastal boundary zone. We elaborate on those ideas by considering specific data relevant to several coastlines of different "roughness" including the topographic complexity of coral reefs. Data demonstrating the existence, and extent, of very near-shore coastal trapping are presented for five datasets (our own and from Wolanski and Spagnol, 2000) of drogues released near shore at two coral reefs, one oceanic island, and one continental shore line. These data suggest that coastal trapping occurs primarily under particular combinations of long-shore oscillatory tidal flow, shore-line roughness, and modest winds, abetted by buoyancy. We discuss the chemical and biological significance of such trapping for spawning, survivorship and recruitment of coral reef fish and invertebrates. Emphasis is given to ontogenetic changes in larval behaviour within the complex three dimensional flow regimens of a highly localized coastal boundary zones. We note that factors which enhance the flow of materials and energy onto coral reefs may simultaneously hinder dispersal and/or recruitment of coral reef fish and invertebrate larvae. Fringing reefs, barrier reefs, and coral atolls have distinctive topographies, bathymetry and meso-scale hydrodynamics. Patterns of coastal trapping in each of these environments present different biological challenges for long-term population maintenance.

AGRRA Benthic Assessment of Coral Reefs Around the Cuban Archipelago(1999-2001)

*Pedro M ALCOLADO**, Robert N GINSBURG, Sergio GONZALEZ-FERRER, Phillip A KRAMER, Elena DE LA GUARDIA, Judith C LANG, Vladimir KOSMININ, Erdwin A HERNANDEZ, Hansel CABALLERO, Miguel HERNANDEZ

Ave. Ira, No. 18406, Rpto. Flores, Playa, Ciudad de La Habana, Cuba

alcolado@ama.cu, pmalcolado@yahoo.es

A rapid ecological benthic coral reef assessment, using the AGRRA Protocol, was carried out at the Golfo de Batabano (SW Cuba), Archipiélago Jardines de la Reina (SE), Maria la Gorda (W end) and Archipiélago Sabana-Camaguey (N-center of Cuba) in 1999-2001 (140 sites; 1,100 km). Region-wide impacts (i.e., coral diseases being the major cause of the declines of acroporids and other corals, and the Caribbean-wide die-off of *Diadema antillarum*) rather than direct anthropogenic impacts were the main causes of reef decline. Most of reefs displayed moderate to high old coral mortality, mainly at the reef crests where *Acropora palmata* was severely affected by disease. Recent mortality was very low virtually everywhere. The main apparent cause of coral decline in the Archipiélago Sabana-Camaguey was outcompetition by fleshy algae because of scarcity of *Diadema* and some land-based eutrophication, while in the southern reefs the main cause seems to be coral disease. Most biological indicators suggest general improvement of reef crest condition on the eastern margin of the Golfo de Batabano, toward the north of the Golfo de Cazonos, where two healthy almost pristine reef crests were assessed. Although not sampled, a small very healthy crest was also observed north of Cayo Caballones in the Archipiélago Jardines de la Reina. In both cases waters were no oceanic but inshore and apparently more productive than in the remaining crests. In the average, better benthic conditions were found at the Golfo de Batabano and Maria la Gorda. According to the fish assessment team, the best fish community condition was observed in the protected area of the Archipiélago Jardines de la Reina. Lateral expansion of living tissue on dead *Acropora palmata*, called resheeting, was widespread both south and north of Cuba, giving good expectancies of fast recovery if no further mortality events take place.

Sea Urchin Population Dynamics on Kuwait Reefs

*Shaker HALHAZEEM**

School of Ocean Sciences, Manai Bridge, Anglesey, North Wales, U.K. LL59 5EY United Kingdom of Great Britain and Northern Ireland

salhazeem@yahoo.com

Studies on the coral reefs ecosystems and their ecology will provide a baseline for monitoring the marine environment of Kuwait, allowing development of management plans for marine protection and conservation. High densities of sea urchins *Echinometra mathaei* have been observed (5 to 100 urchins per square meter) on fringing reefs of islands. To examine the effect of no urchins on coral reefs *Echinometra mathaei* were excluded experimentally by using 2 X 3 m cages. The southern island coral reefs were monitored quarterly using video to calculate benthic percentage cover and anthropogenic and natural environmental (ex. temperatures) impacts were measured by deducting changes over time. Kubbar island reef is the most visited reef, being closest to land with easy access from harbour, making it a vulnerable location. Um Almaradem island reef is less visited, as it is distant from the shore (about 65 km). Qaru island reef is the farthest reef from any access site, and therefore is visited the least of the reef islands. In average of (43 ± 6) boats have been seine at Kubbar island reef, (22 ± 8) at Umm Almaradem island reef and (4 ± 2) at Qaru island reef on calm weather days (n= 17). These results suggest that it is an indicator of sea urchins population due to human impact; over-fishing, boat anchor damage and sand movement causing higher turbidity and killing corals also removing new coral recruits by sand smothering. High densities of sea urchins and its grazing activities might result in high mortality of recruits of coral and other sessile invertebrates. Therefore, the ideal solution for our reefs is to reserve these reef islands and to be controlled as Marine Park.

Biological Monitoring of Coral Communities in Tung Ping Chau Marine Park, Hong Kong Sar, China

*Put ANG JR.**, M M CHOI, T W TAM, L S CHOI

Shatin, NT, Hong Kong SAR, China

put-ang@cuhk.edu.hk

A biological monitoring program was carried out in Tung Ping Chau Marine Park from September 2002 to October 2003 and data collected were compared with historical data obtained in 1999 to evaluate any changes in coral cover and species diversity since the designation of Tung Ping Chau as a marine park in November 2001. Permanent transects and quadrats were set up within the core areas in A Ma Wan (AMW) and A Ye Wan (AYW) since 1996. These transects and quadrats were resurveyed in this present study. Generally, there was no significant change in the coral community structure in AYW and AMW during the last four years from 1999 to 2003. However, percentage cover of corals appears to be increasing faster, at 9% in AMW from 37.5% in 1999 to 46.15% in 2003 than in AYW (at 2%) from 15.5 % in 1999 to 17.14% in 2003. There were changes in the ranking in dominance of some coral species from 1999 to 2003 but the dominant species remained the same. These are *Platygyra acuta*, *Pavona decussata*, *Porites lutea*, *Leptastrea purpurea* and *Goniopora lobata* in AMW and *Platygyra acuta*, *Platygyra carnosus*, *Leptastrea purpurea* and *Favites flexuosa* in AYW. A total of 61 coral species have been reported from Tung Ping Chau Marine Park and 44 of these are located within the permanent transects. No major environmental disturbances (e.g. typhoon, high water temperature) appear to seriously affect the overall coral community structure in Tung Ping Chau in the last four years so the coral communities are stable and healthy. However, recent increase in the number of visitors, especially skin and SCUBA divers, to the marine park could impose some pressure on these coral communities so monitoring for changes in coral abundance and diversity must continue to be carried out in the future.

Assessment of Benthic Communities of Three Sectors of Fringing Reefs near El-qusier (Egypt), with Emphasis on Sedimentation Patterns and Scleractinian Coral Assemblages

Holger ANLAUF, *Goetz B REINICKE**

Katharinenberg 14/20, 18439 Stralsund Federal Republic of Germany

Goetz.Reinicke@meeresmuseum.de

The coastal fringing reefs along the Egyptian Red Sea coast face increasing impact from various anthropogenic activities, diving tourism being among the most prominent. Benthic communities of three sectors of a fringing reef region south of El-Qusier were assessed in Sept./Oct. 2002. The status of those communities was monitored using a quantitative, non-invasive protocol. Categories of living benthic fauna and flora, bare coral rock, broken coral colonies, corals rubble and algae coverage and environmental conditions such as weather, wave exposition and turbidity were recorded. Proportions of broken coral colonies (BCC) and coral rubble (CR) of Scleractinian coverage were determined to apply the Coral Damage Index (CDI, Jameson et al. 1999). The northern Torfa Lassall (TL) sector showed low sedimentation rates, moderate exposure to waves and lowest values of CR and BCC. Highest values for CR and BCC were recorded for the intermediate sector Torfa Lassall Goubli inside (TLGi), along with maximum sedimentation. Southern sectors of the fringing reef TLG inside and outside (TLGo) showed a rise in BCC and CR between 3-5m to 20m depth for TLGi, and between 10-30m depth at TLGo along with increased sedimentation. High sedimentation rates at TLGi were observed to result from predominant southerly alongshore currents and rip-currents transporting great amounts of sediment from the lagoon areas to the outside reef. Quantity of mobilised sediment loads depends on wind direction, wave action and bathing hotel guests. By comparison of coral assemblages in the three sectors, sedimentation patterns appear to cause a gradual shift in benthic community composition towards fast-growing, well recovering and sedimentation-resistant corals, e.g. *Seriatopora hystrix* for TLGi. While at TLG reefs wave-action as a physical impact factor is negligible in depths below 10m, also damage by snorklers and SCUBA-divers has to be considered as a major driving force of coral community degradation.

Methodological Gaps in Molecular Biology Works in Anthozoa

Juan E CAMACHO-LONDONO, Alberto ACOSTA*, Manuel RUIZ-GARCIA
Carrera 7 No 43-82 Republic of Colombia
quicapu@yahoo.com

At scientific method level methodologies should be repeatable to determine if the results are product of the design. Methodologies standardization and evaluation requires knowing each stage of the same ones, this allows to identify how a determined change at the methodology affects it and allows to settle down if the results are inside the study justification. The objective of this work was to evaluate methodologies applied in molecular biology studies of anthozoans to determine the viability of population genetics use in Colombian Caribbean reef species, with an eye toward the management and conservation of reef ecosystem. The evaluation of the methodologies was carried out through the standardization of protocols (sample collection, DNA extraction and PCR) to use 11 molecular markers in two species of zoanthids of *Palythoa* genus. The difficulty to reproduce published methodologies was due to that in a more than 50% of articles is not clarity in materials and methods description. It was evidenced that: 1) informative gaps are constant in most published works and bibliographical references generate a tautological process of references consults and information loss; 2) the information obtained with the collection design and by the organism knowledge are important for the biological interpretation of genetic results; 3) it doesn't exist the appropriate application of statistics in populations' genetics studies, most of statistical applied are for species of strictly sexual reproduction; and 4) the results of the published studies are outside of the social sphere in which they are justified; the application of the results is not inside the frame of coral reefs conservation and management. Finally, the potential use of model reef species in population genetic studies has settled down starting from the methodological collage obtained in the standardization process.

A Coral Reef before and after Protection: A Case Study at the Flower Garden Banks, Northwest Gulf of Mexico

Ken J P DESLARZES*, William F PRECHT, Richard B ARONSON,
Martha L ROBBART, Gregory S BOLAND, George P SCHMAHL,
Emma L HICKERSON, Thaddeus MURDOCH
550 East 15th Street, Plano TX 75074 United States of America
kdeslarzes@geo-marine.com

Although remote (190 km offshore), the Flower Garden Banks are well-known commercial and recreational fishing grounds, and are located in an area rich with hydrocarbon resources. The possible impacts on coral reefs of the Flower Gardens by the exploration and development of natural gas and oil, (and related industrial activities) MOTIVATED the implementation of protective measures. The anchoring of large ships on the reefs and increased recreational activities further prompted protective legislation. Since 1973 oil and gas exploration and production have been prohibited within a "No Activity Zone" immediately surrounding the reefs and limited within a "4-Mile Shunting Zone" around the banks. In 1992, the Flower Garden Banks became a National Marine Sanctuary, thus prohibiting such direct impacts as mechanical injury to the seafloor (anchoring), commercial and spear fishing, and discharges of pollutants. The effectiveness of the protective measures is partially assessed through the periodic and systematic monitoring of coral reef populations. Although the biota at the Flower Gardens was first examined in 1956, repetitive monitoring of coral and fish populations did not begin until 1988 and 1996, respectively. Here we assess reef ecosystem changes at the Flower Gardens in the absence of direct human impacts by comparing coral populations before (1988-1991) and after (2002-2003) the 1992 sanctuary designation, and by using data from fish censuses. Since 1996, there has been an increase in the abundance and size of fishes belonging to higher trophic levels (e.g., groupers). At the same time, coral populations have been largely sheltered from localized impacts (e.g., anchor damage) but have been affected by regional impacts (e.g., Diadema die-off, coral bleaching, coral DISEASES, hurricanes, and river runoff). Coral population levels have remained largely unchanged since the 1988-1991 baseline, despite the complex interactions of small- and large-scale impacting factors.

Todos Os Santos Bay Coral Reefs, Eastern Brazil, Revisited after 40 Years

Leo X C DUTRA, Ruy K P KIKUCHI*, Zelinda M A N LEAO
Centre for Ecological Economics and Water Policy Research (CEEWPR)
University of New England Armidale NSW 2351 Australia
lximenes@pobox.une.edu.au

The Todos os Santos Bay (TSB) is the second larger bay in Brazil. With an area of 1000 km², warm and shallow waters, it offers optimum conditions for growth of well-developed coral reefs. The French Biologist J. Laborel, in Calypso's journey to Brazilian waters in the early 60's, identified the hydrocoral *Millepora alcicornis*, the corals *Montastrea cavernosa*, *Mussismilia braziliensis*, *Siderastrea stellata* and *Meandrina braziliensis* as the dominant organisms in those reefs. *Millepora nitida*, *Porites branneri*, *Favia grandidieri*, *Mussismilia hispida*, *M. hartii* and *Stephanocoenia michelini* were also found in the bay. Besides, the octocorals *Plexaurella dichotoma*, *Muriceopsis sulphurea* and *Phyllogorgia dilatata* were also abundant. A quantitative assessment of TSB reefs applying a video-transect technique began in November 2002 and has shown that, nowadays, *Montastrea cavernosa* and *Zoanthus sociatus* are the dominant organisms, covering reef tops. *Mussismilia hispida* and *Siderastrea stellata* are also present though not abundant. Laborel has already pointed out, also, that the TSB waters were subjected to high levels of turbidity. Urban development in the bay surroundings increased deforestation and sedimentation rates during these decades. A petrochemical complex (1978) and a cement plant (1954) should have been contributing for reef decline due to their chemical and muddy waste discharges into the bay. Dynamite fishing is a practice that, although prohibited, occurs frequently. Efficient management is urgent for minimizing the impacts to the reef ecosystem in the Bay of Todos os Santos.

Diversity and Abundance of Coral Reef Fishes off Former Military Ranges at Culebra and Vieques, Puerto Rico

David J EVANS, Robert NAWOJCHIK, Ken J P DESLARZES*
550 East 15th St., Plano, Texas United States of America
devans@geo-marine.com

The effect of military activities on reef fishes at Vieques and Culebra is largely unknown. Military forces used target ranges at these islands from 1941 through 2003 and 1901 through 1975, respectively. The perception of the general public is of widespread damage to nearshore marine ecosystems, including fisheries resources, although scientific studies have not shown this. This study examines the relative health of reef fish populations around both islands. Study sites were chosen to reflect varying degrees of military and civilian impact. The parameters that were examined (as proxies for "health") included species richness (i.e., the number of species), abundance (i.e., the number of individuals of each species), and body length (minimum, maximum, and average). Data were collected by scuba divers using both stationary and roving census techniques. Despite difficulties in categorizing "impacted" versus "non-impacted" sites, statistical analyses make it evident that those sites closest to the bombing ranges were no worse than other sites, and in some cases supported more diverse and/or abundant fish populations. Some researchers have suggested that military ownership and operations have in effect conferred on nearshore areas a degree of protection from negative civilian activities. Because of the transfer of the military lands located on Culebra and Vieques to civilian control, it is imperative that alternative management plans (with associated enforcement) be implemented and enforced as soon as possible to avoid overexploitation of the fisheries resources of these islands. Also, because of the important economic and nutritional value of fishes to local fishermen and other residents, it is crucial to provide accurate and non-biased information. The overall effect of the military presence at these Puerto Rican islands has left reefs with relatively healthy fish populations in contrast to reefs found around other parts of Puerto Rico and exploited areas of the Caribbean.

Coral Reef Evaluation in the National Marine Park Costa Occidental of Imujeres Island, Punta Cancun and Punta Nizuc, Mexico

*Miguel A GARCIA**, Roberto IBARRA, Susana A PATINO

Boluverbard Kukulcan K.m 4.8 Z.H. Cancun, Quintana Roo, Mexico

magarcia@conanp.gob.mx

The Mexican Caribbean potential is fundamental based in the used of the costal zone. Beaches and coral reefs are the base of fisheries and recreatives activities. The description of the marine communities help to identify the actual conditions and the conservation level of these places. This studies are useful to design manage alternatives giving elements for an adequate administration of this area. In the same way are useful to identify and select the site of high priorities of conservation or sites that are under an overfishing, and tourism pressure this activities damage the natural process of the coral reef. The objectives are based in the evaluation of the biological conditions of the coral reefs, with a technique that was comparable in regional scale and give a quick and opportunity information in the precise time. In 2001 the National Marine Park made an evaluation in 21 reefs, in each reef made transects of 20 m length to evaluate the coral escleractins coverage, algal coverage, gorgonaceo density and transects of 50 m length for reef fish.

Comparative Analisis of Chain vs Video Transect Methodologies for Quantitative Surveys of Benthic Community at Isla de Vieques, Puerto Rico

Jorge R GARCIA-SAIS, *Rocio P GARCIA-URUENA**, Roberto CASTRO

P. O Box 908, Lajas PR 00667 Puerto Rico

renigar@caribe.net

This work represents a quantitative and qualitative baseline survey of the sessile-benthic communities associated with coral reef habitats in areas outside the U. S. shooting range in Isla de Vieques, Puerto Rico. Quantitative assessments of sessile-benthic reef communities were performed by application of the Chain Transect Method as described in the CARICOMP protocol and the video-transect technique. Both methods were used simultaneously during sampling events in February and May 2001. A total of 11 reefs were surveyed around Vieques and five replicate transects permanently established for monitoring at each reef. Twenty-seven species of scleractinian corals were recorded by the video-transect method. The dominant species in terms of coverage were *Montastraea annularis*, *Colpophyllia natans* and *M. cavernosa*. Thirty-three species were registered with the chain transect method and the dominant species were *M. annularis*, *Dendrogyra cylindrus* and *C. natans*. Mean substrate cover by coral, sponges and coralline and turf algae were very similar except in two reefs while gorgonian and fleshy algae were higher with the video technique. Abiotic substrate cover was higher with the chain method. Hydrozoans, zoanths, ascidians and coralline algae were present in such low abundance that the comparison between methods was not meaningful. The video transect method provided more information because of the relatively larger reef area sampled. Substrate cover by gorgonians and fleshy algae were consistently higher with the video transect technique. The chain transects method provided a 3-dimensional perspective of the reef that includes holes, gaps and reef overhangs not visible by the video method.

Diving for the Environment. 2002-2005: Mediterranean Underwater Biodiversity Project

*Stefano GOFFREDO**, Antonio ORLANDI, Patrizia NERI, Maria SCOLA GAGLIARDI,

Angela VELARDI, Sofia E KASFIKI, Corrado PICCINETTI, Francesco ZACCANTI

Via F. Selmi 3, I-40126 Bologna, Italy

sgoff@tin.it

Biodiversity has a great ecological value as an indicator of environmental health and ecosystem functional capacity. Monitoring is the first step towards the balanced management of natural resources. The University of Bologna launched in 2002 "Diving for the Environment. 2002-2005: Mediterranean Underwater Biodiversity Project" with the aim to obtain data on the state of the marine biodiversity along the Italian coasts, with the collaboration of recreational scuba divers. Divers were asked to signal on report schedules the presence in the explored areas of 61 taxa (4 vegetals, including seaweeds and a seagrass, and 57 animals, both vertebrates and invertebrates). This research is patronaged by the Italian Ministry of the Environment and supported by ASTOI (Association of Italian Tour Operators), ADISUB (Association of Italian Scuba Diving Agency: IDEA, PADI, SNSI, SSI) and the magazine Quark. During the year of 2002, 1006 divers have registered 3721 report schedules, corresponding to 2705 diving hours. Data indicate that the insular stations present better conditions with respect to the continental ones; furthermore the continental coasts of Ligurian Sea show a more degraded situation than the northern Tyrrhenian Sea ones. These results are in agreement with those obtained by other monitoring methods (chemical and physical analysis). The most important limit in the collaboration with scuba divers is the difficulty to obtain a survey effort uniformly distributed on a geographical large scale. The main advantage is the considerable amount of data obtained in a short time, with a significant limitation of the costs for the Academy. We retain that the recreational diving can be useful for monitoring marine environments and that this project may be used as model for marine biodiversity monitoring and citizen environmental education, exportable in other countries and/or other biomes.

Three Low-cost Tools for Reef Monitoring and Risk Assessment: Distinguishing Local from Global Stresses

*Pamela HALLOCK**, Barbara H LIDZ, Elizabeth CARNAHAN,

Camille DANIELS, Ana M HOARE

140 Seventh Avenue South, St. Petersburg, FL 33701 United States of America

pmuller@marine.usf.edu

Three proxy indicators have been developed to assess reef condition on time scales suitable for resource or risk assessment. The FORAM Index is a single-metric index that can be used to determine if environmental conditions support mixotrophy (algal symbiosis) as a dominant trophic mode for benthic communities on the scale of years. This index is based on assemblages of foraminiferal shells within the sediments. High index values indicate low nutrient environments that support mixotrophy, intermediate values indicate relatively abundant food resources, and low values indicate more acute stressors, including chemical pollutants. Fluctuating values indicate changing conditions. The SEDCON Index, which is based upon reef sediment constituents and the same ecological concepts as the FORAM Index, can also be applied in resource assessment. Sediment constituents reflect condition of reef ecosystems, on the scale of years to decades, relative to community structure and bioerosion. The Amphi Index, based upon densities and visual assessments of *Amphistegina* populations, is designed to be a low-cost risk-assessment tool. These protists, which are circumtropical in distribution, are sensitive to environmental conditions over days to weeks, and provide a method to quickly distinguish between water quality (local) and photooxidative (global) stresses. Low abundances on reef rubble, and little or no bleaching, indicate unsuitable local conditions. Abundances of *Amphistegina* relative to bleaching prevalence and intensity indicate presence and degree of photooxidative stress. Risk assessments based on the combined use of in situ measurements and low-cost bioindicators can provide resource managers with essential information to decide when more costly chemical or molecular procedures are needed to determine local sources of stress. Such information can facilitate management actions to protect or restore reef resources.

Changes in Trophic Community Structure of Shore Fishes at an Industrial Site in the Gulf of Aqaba, Red Sea

Maroof A KHALAF, Marc KOCHZIUS*

PO Box 195, Aqaba Hashemite kingdom of Jordan

khalaf56@hotmail.com

The semi-enclosed Gulf of Aqaba is under high pressure by urban and industrial pollution, shipping and port activities as well as tourism. Off the Jordanian Red Sea coast, the trophic community structure of shore fishes was determined on coral reefs in front of an industrial area (disturbed), in a marine reserve and site without industry or port activities (undisturbed), as well as in a seagrass-dominated bay. Planktivores were the most abundant feeding guild on coral reefs as well as in the seagrass-dominated bay. The relative abundance of feeding guilds other than planktivores seems to be strongly influenced by the benthic habitat. Multivariate analysis clearly separated disturbed from undisturbed sites, whereas univariate measures, such as species richness, diversity and evenness did not reveal any negative impact of disturbance. The disturbance of the coral reefs led to changes in the fish community through the reduction of total fish abundance by 50%, increased total abundance of herbivorous and detritivorous fishes, decreased total abundance of invertebrate and fish-feeders, and increased relative abundance of planktivorous fishes.

Conservation Status Index for Caribbean Coral Reefs: An Initial Proposal

Adrian MALDONADO*, Jorge A HERRERA, Francisco A COMIN

645 Diagonal Av., Barcelona Kingdom of Spain

adrian_mg@yahoo.com

Over the years, the natural resources of the coral reefs have been used by men for different purposes, mainly for tourism, fishing and research. However in the last three decades these human activities have changed and increased so much that all around the world there is degradation in those ecosystems. The Caribbean Sea is not an exception and the corals have experienced a long-term region-wide decline, from 50% to 10% hard coral cover in three decades. Considering this, is evident the importance to develop new approaches to evaluate the conservation status of this ecosystems. In this paper the development of the individual components of this index is briefly described. We integrate water quality, benthic community, fish community and aesthetic metrics, into a multimetric index, based on published data from studies realized across the Caribbean Sea. We also outline an approach to the acquisition and an easy and effective transfer of integrated, multidisciplinary, environmental information from scientist to non-expert end-users.

Population Estructure and Growth of the Sea Fan Gorgonia *Ventalina* in the Santa Marta Area, Colombian Caribbean, 15 Years after a Mass Mortality Event

Nelson A MANRIQUE, Jaime GARZON-FERREIRA, Sonia BEJARANO*

Harbor society of Santa Marta Republic of Colombia

gorgonia@invemar.org.co

The initiative to conduct this study arose from the lack of information about the current situation of the sea fan Gorgonia ventalina (Linnaeus, 1758) 15 years after its wide-ranging mass mortality event occurred throughout the entire Caribbean sea, including the Santa Marta area and Tayrona National Park (Colombian Caribbean). The study was carried out by the Coral Reefs Research Group the Institute of Marine and Coastal Research (INVEMAR), at Santa Marta (Colombian). Between March and December 2003 we assessed the current status of sea fan populations in twenty stations, seven of which were surveyed also sixteen years ago. We used band transects (30 x 2m) to determine density of living colonies and skeletons and size composition of the population. We are also carrying out a pursuit of sixty colonies inhabiting four contrasting coral formations to estimate growth rates. Sampling and analysis is about to be completed on December 2003, and main the results will be the scope of the paper. After sixteen years of the mortality event, population densities are significantly lower (0.09 col/m²) than those recorded then, even finding remnants of very dense former populations, which are currently conformed by large death skeletons. Considering that currently living populations are mainly constituted by colonies of 1 to 40 cm in height, it seems likely that a probable recovering process is taking place. Nevertheless, density and structure of populations occurring two decades ago have not been achieved.

Status of Caribbean Coral Reefs of Panama Surveyed in the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program

Juan L MATE*, Judith C LANG, Robert GINSBURG, Arcadio CASTILLO

Unit 0948, APO AA 34002-0948 United States of America

matej@naos.si.edu

Eleven scientists and assistants participated in an AGRRA Program that evaluated the condition of 81 coral reefs on the Caribbean coast of Panama during June 12-27, 2002. Thirty reef crests (RC), 25 front reefs (FR) and seven back reefs (BR) were surveyed at Kuna Yala (KY), eastern Panama. Twelve RC and seven BR were surveyed at Bocas del Toro (BDT), western Panama. Mean live stony coral cover for Caribbean Panama was 37.5 ± 1.5%. Coral cover at Kuna Yala (38.5 ± 1.5%) was slightly larger than at Bocas del Toro (34 ± 4%). In general mean live coral cover was higher in reef crests (40.8%) than in other habitats (32.1%, p>0.046). A Tukey test revealed coral cover differences only between KY-RC and BDT-BR (p>0.048). Mean total partial colony mortality at Bocas del Toro was 10.3 ± 0.6 and at Kuna Yala was 12.8 ± 0.6. Relative abundances of algal functional groups on reefs were: macroalgae (31 ± 2%); turfs (45.5 ± 2%); and crustose coralline algae (20.5 ± 2%). Caribbean Panama mean fish density was 27.9 ± 1.7 fish 100 m² transect and fish biomass was 3125 ± 29.5 g 100 m² transect. The results of the Caribbean Panama AGRRA assessment indicate that reef corals in Panama are currently among the healthiest in the Caribbean in terms of relatively high live stony coral cover and low total partial coral mortality, especially in shallow water. Nevertheless, they among the least healthy in terms of fish density and fish biomass. The paucity of large herbivores (*Diadema antillarum* and herbivorous fishes), and the overall high relative abundances of macroalgae and algal turfs, are indications that many of these reefs as a whole are less robust than when first investigated nearly four decades ago.

Detection and Monitoring of Alien Marine Species in a Tropical Coral Reef: The Need for a Standard Methodology

*Imene MELIANE**, David OBURA, Hewitt CHAD, Clive WILKINSON

Rue Mauverney 28, 1196 Gland Swiss Confederation

imene.meliane@iucn.org

Invasion of reef communities by alien species is one of the least understood threats to coral reefs, but one that will occur increasingly with growing levels of commercial shipping and small boat recreation. The development of effective management strategies addressing the threat of future incursions relies on an underlying knowledge base of the current state of introductions and is dependent on pest incursions being detected at an early stage of an invasion. Research and monitoring efforts are essential to provide early warning of arrivals of alien species, and to equip managers with a better understanding of the impacts of alien species on reef ecosystems. Many countries of the Indian Ocean currently have coral reef monitoring programmes that focus on MPAs, fishing threats and coral bleaching. These programmes will be improved by the addition of protocols for detecting and monitoring alien species. This paper describes survey methodologies and strategies to establish baselines and document current and future impacts of alien species on coral reefs of Mahe Island, Seychelles. The sampling methodologies are designed to increase the likelihood of detection of rare introduced species presence in a reef community, with the aim of providing a standard for survey of alien species in coral reefs that would allow comparing data within and between countries. The proposed protocol builds on existent methods for monitoring coral reef environments with modifications in the spatial sampling design and replication necessary to detect non-indigenous marine species. Sampling sites are prioritised according to the potential inoculation pressure and sampling methods are selected to ensure comprehensive coverage of habitats.

Coral Reefs of the Natural Reserve of the Glorieuses Islands, Mozambique Channel, Western Indian Ocean

*Jean P QUOD**, L BIGOT, J BLANCHOT, P CHABANET, P DURVILLE, B WENDLING

14, rue du stade de l'Est, Sainte Clotilde, Reunion

jpquod.arvam@wanadoo.fr

Located north of the Mozambique Channel, the Glorieuses archipelago is part of the five scattered coral islands called "Iles Eparses" (French overseas territories) which are natural reserves. In November 2002, a scientific expedition was carried out to survey coral reefs, as part of the IFRECOR action plan (Initiative Francaise pour les Recifs Coralliens). Objectives were to: (i) map the coral shallow marine ecosystems, (ii) monitor the health of coral reefs according to the GCRMN protocols, with special focus to the 1998 coral bleaching, (iii) study benthic, fish and planktonic communities, etc, (iv) and finally provide help for decision making regarding management and conservation issues for these remote islands. Sampling of coral and fish communities were conducted by visual census techniques, for both intertidal and subtidal depths. Results are the following: 1- Mapping was based on the ISS raster photographs followed by sea-truthing the shallow marine habitats, 2-Planktonic community was dominated by the Picoplanktonic fraction (77% of the total), *Synechococcus* was the most significant cellular group and contributed for more than 50 % to the chlorophyll concentration of the picoplankton, 3-Shallow benthic communities are dominated by macroalgae (mainly *Halimeda spp.*) and sub-massive corals, associated with large sandy areas. On South Western reef slopes of Grande Glorieuse, very interesting coral reef typologies are founded between 8 and 25 meters deep, 4-Fish communities are characterized by a high species richness (332 species/57 families) and a high biomass of top predators (up to 214 g/m²). From this expedition, it appears that Glorieuses are an exceptional reference site for coral studies as they are a remote and human protected area.

Line and Video Transect Surveys of Apo and Bantayan Reefs, Philippines: A Comparative Study of Protected and Non-protected Coral Reefs

*Jb TANANGONAN**, Aya MASUIKE

3327-204 Nakamachi, Nara 631-8505 JAPAN

jbtago@nara.kindai.ac.jp

Replicate transect surveys of coral reefs were made in 2002 and 2003 at the sanctuary of Apo Island Marine Protected Area and offshore of Bantayan Beach near Dumaguete City, Negros Oriental, Philippines. The marine sanctuary southeast of Apo Island, initiated by Silliman University since 1982, has been designated a "no-take" zone prohibiting extractive activities of any kind. Three line transect surveys in 2002 and three video transects in 2003 were made within the sanctuary area with GPS coordinates 09°19.799N and 123°18.755E. The marine waters off Bantayan Beach are fished by local residents generally using nets and cages, and also utilized for recreational purposes such as swimming and diving by both local and non-local residents. The coral reef site with GPS coordinates 09°04.421N and 123°16.225E were surveyed with three line transects in 2002 and three video transects in 2003. The length of one line transect was 20m while the video transect was 50m. The result of the line transect surveys in 2002 showed that average live coral cover in Apo Island is 64.5% while Bantayan has 49.3%. For the video transect in 2003, the point count showed that Apo Island has 68.8% live coral cover and Bantayan 49.9%. After its legislation as a marine protected area in 1986, live coral cover in Apo Island has continued to increase only to decrease near 50% in 2000 due to coral bleaching caused by the 1997-98 El Nino. The results of these surveys indicate the effectiveness of designating marine protected areas to prevent further degradation of coral reefs.

Long-term Variation of Coral Reef Fish Community and Habitat in the South Lagoon Marine Park of New Caledonia

*Laurent WANTIEZ**

BP 4477, 98847 noumea cedex New Caledonia

wantiez@univ-nc.nc

In 1989, the authorities of the Southern Province of New Caledonia created the South Lagoon Marine Park. Reef fish communities were sampled in five islands of the Park before they were declared permanent marine reserves, and in control sites. A long-term monitoring survey of these five islands began in 1994, with a sampling every four years. Other protected and unprotected sites were added to the sampling design since 1994 and the data gathered were extended to the habitat in 1998. In 2002, overall species richness, density and biomass were significantly higher in the marine protected areas than in the unprotected reefs. However, density and biomass estimates were higher in these unprotected reefs than they were in the marine reserves before protection, suggesting significant interaction between reefs. Since 1990 species richness of butterflyfish and commercial species was relatively stable but density and biomass were significantly lower before protection. Since 1994, marine reserve effects lasted in times where enforcement was effective, and natural temporal variations were observed. Density and biomass were higher in 1994 and 2002 during La Nina or transitory environmental conditions, and lower in 1998 during a strong El Nino condition. Changes in habitat characteristics were recorded between 1998 and 2002. Live coral cover decreased and were replaced by dead corals and algae, mainly branching *Acropora* eaten by crown-of-thorns. Anthropogenic effects were also observed. One branching *Acropora* formation was nearly completely destroyed in 1998 after the construction of an embankment (1.2% cover) and slowly recovers with recruitment of encrusting corals (15.1% cover in 2002). After 10 years of research in the South Lagoon Marine Park, a new development was proposed in 2004 on the study of the interactions between protected and unprotected reefs.

Sources of Mortality Affecting *Acropora* spp. Populations in the Florida Keys (USA)

*Dana E WILLIAMS**, *Margaret W MILLER*

SEFSC 75 Virginia Beach Drive, Miami FL 33149 USA

dana.williams@noaa.gov

Caribbean Acroporid species have faced extreme declines since the 1970s, which has resulted in local to regional extirpation and led to their identification as candidates for endangered species listing. Population level recovery will depend on re-colonization by juveniles or fragments, which are particularly vulnerable to threats such as predation and disease. Photo-monitoring of juvenile *Acropora cervicornis* and *A. palmata* colonies was undertaken to determine the progression and fate of various conditions on the growth and survivorship of recruits. Both healthy colonies and those displaying signs of recent predation were selected haphazardly among several sites in the Florida Keys (USA). Colonies were tagged, photographed and measured for size and condition, then reassessed every 3 to 4 months. Results of this ongoing monitoring suggest that among *A. cervicornis*, predation by the gastropod *Coralliophila abbreviata* decreases growth and live cover substantially more than the polychaete *Hermodice carunculata* however, preliminary incidence data suggest that *H. carunculata* affects far more colonies among the sites sampled. Similar effects of *C. abbreviata* were seen among *A. palmata* juveniles.

Status and Coral Reef Monitoring in Kaledupa Islands, South East Sulawesi, Indonesia

*Suharsono**, *Giyanto, Budiyanto AGUS*

Jl Pasir putih No 1 Ancol Timur. Jakarta. Indonesia

shar@indo.net.id

Eight permanent transects sites were set on reef slope in the Wakotobi Islands. These permanent transects were monitored using LIT technique to detect change between 2002 & 2003. The permanent transect were set in the 1, 3 and 10 m depth (50 meter long, 3 replicates). The data showed that mean coral cover varied from 14.70 & 76.58%. The differences between sites can be attributed to physical water condition and related to the development stage of nearby population. Mean hard live coral cover at eight sites showed only slightly decrease (47.21 & 46.78%) from 2002 & 2003, but was not statistically significant. The decrease in mean coral cover was compensated by increase of the death coral cover (4.59 & 8.77%). Algal, soft coral, sponges and other fauna cover were slightly decrease but was not statistically significant.

A Bleaching Event Survey in 2002 All around an Insular Coral Reef Ecosystem : Moorea, French Polynesia

Yannick CHANCERELLE, Sebastien POUJADE, Didier LEQUEUX, Bernard SALVAT*

BP 1013, MOOREA, FRENCH POLYNESIA French Polynesia
criobe@mail.pf

Since 1991 Moorea CRIOBE research center monitoring programs surveyed annually fixed stations of some tens to hundreds square meters (transects and belts methods) on the north west Tiahura sector of Moorea as well as on thirteen other outer reef slope islands all over French polynesia. Precise data but on small space scale needed to be enlarged by another method in order to assess any disturbances at the scale of insular coral reef ecosystem. A new method called photo tow survey has been implemented all around Moorea which is triangular shaped : off and parallel to the barrier reef front, at 9 m depth on the outer slope, photos 19 sq.m were taken each 300 m along the 100 km all around Moorea, except faced to the 13 passes. Each shot was exploited on screen by observation of 20 points in order to determine the percentage of total coral cover and the percentage of those bleached. All data have been incorporated into a GIS with GPS reference points. Data from the 280 photos pooled by tens, indicate the variability of the coral cover and of the bleaching even which occurred in April May 2002. The coral cover percentage vary from 20 to 56% with a mean of 40% (most important on the north coast, less important on the east and west coast). The bleaching (percentage of beach coral cover related to the total coral cover) occurred all around the island and vary from 6 to 35% indicating a modest bleaching event not as important at the two last ones (1991 and 1994). The bleaching is more important, over 15%, on the north east part of the island. These results are discussed according to hydrodynamics and to the variability of coral genus dominances more or less sensitive to bleaching.

The Use of Videography as a Rapid Assessment Monitoring Tool in the Caribbean

Marcia M CHEVANNES CREARY, Peter WILSON-KELLY*, Sean GREEN, Leslie WALLING

13 Gibraltar Camp Way , Mona, Kingston 7, Jamaica
marcia.creary@uwimona.edu.jm

The coral reef monitoring protocol used in the The Caribbean: Planning for Adaptation to Climate Change (CPACC) project to monitor coral reefs in three pilot countries in the region employed high-resolution digital video cameras fitted with a wide-angle lens and underwater housing. Images from the videotapes were processed and analyzed to identify species and determine percentage cover of the higher functional taxonomic groups. The use of underwater videography has the advantages of providing permanent photographic records with the possibility of re-analysis. Time spent in the water is reduced and data collection is not dependent on coral reef experts. These advantages make it an effective rapid assessment tool in the Caribbean. In addition to monitoring studies carried out by CPACC in the Bahamas, Belize and Jamaica the underwater videography has been used in Jamaica as an assessment and management tool by The National Environment Planning Agency. A few examples include a rapid assessments along the northeast coast of Jamaica to assist in the resolution of conflict between fishermen and hotel operators, assessment of the status of the reef environment in the vicinity of the proposed expansion of a marine attraction for permitting purposes and an evaluation of the health of transplanted corals to check compliance with EIA guidelines after the widening of a ships' channel. Countries of the Caribbean have limited human capacity to devote to coastal ecosystem monitoring and assessment but nevertheless need quality data to inform management decisions. Videography is a versatile monitoring technique that can provide part of the solution to this problem.

Rapid Ecological Assessments: Creating Teams for Coral Reef Resource Management

David A GULKO*

1151 Punchbowl Street, Rm 330, Honolulu, Hawaii 96813 United States of America
david.a.gulko@hawaii.gov

Although Rapid Ecological Assessments (REAs) have for a while been a coral reef scientist's tool of choice for assessing remote coral reef ecosystems, only recently have REAs started to be refined for use by coral reef resource managers from an investigative perspective. In general, response to short-term anthropogenic impacts often occurs through assessments by either single agencies or individuals, often without an adequate evaluation of ecological damage, and without an eye towards mitigation and restoration of the affected reef resources. Rarely is restitution sought, damage mitigated, or parties held responsible; in part, because the legal standard for evidence surpasses the ability, time, or resources, of field personnel to make a compelling case. Following models created for remote area multi-agency REAs, Hawaii has recently started to use REA teams for investigating events and impacts affecting coral reefs. The strength of such teams rest upon their unique composition of resource management field personnel and expertise, on-site assistance of academic coral reef ecologists and researchers, and specialized training and equipment. This talk will review the requirements for fielding field personnel with different expertise trained to function efficiently together to investigate coral reef ecosystems in an extremely timely manner. It will highlight the advantages of pooling limited resources and expertise in a coordinated fashion in order to better minimize the impacts, implement more effective and timely mitigative strategies, and collect the necessary data and evidence in a legal manner to allow resource trustees to both recoup the costs of such investigations, hold parties responsible for the environmental damage they cause, and allow for better management of natural resources. It will use recent examples of multi-agency investigations conducted in Hawaii and provide guidance on techniques and team make-up; in addition to highlighting various barriers to implementation.

Chemical Defense of the Exotic Coral *Stereonephthya* aff. *curvata* (Alcyonacea, Octocorallia) at Brazilian Marine Reserve

Bruno G LAGES, Beatriz G FLEURY*, Carlos Eduardo L FERREIRA, Renato C PEREIRA

Dept. de Biologia Marinha, Universidade Federal Fluminense, C.P. 100.644, 24.001-970, Niteroi, RJ, Brazil
bgfleury@uol.com.br

Biological invasions can dramatically alter community composition and ecosystem function. Soft corals are known to produce an array of secondary metabolites, which can play important roles in the complex behavioral and ecological interactions among marine organisms. The species of alcyonacean coral *S. aff. curvata* from the Indo-Pacific region was detected in Arraial do Cabo Marine Reserve, eight years ago, in a shallow embayment. This work evaluated *in situ* the invading potential of this exotic coral through the study of the action of its secondary metabolites as allelopathic and defense agents. Crude organic extracts isolated from *S. aff. curvata* were incorporated into artificial food to assess defensive properties against a natural assemblage of generalist fishes. Otherwise, allelopathic action was evaluated in space competition by transplanted and replicated experiments with direct contact with local coral *Phyllogorgia dilatata*. The results showed that the non-polar extract (hexane) from the *S. aff. curvata* acts as chemical defense against potential consumers and caused contact necrosis on the endemic gorgonian *P. dilatata*. Both strategies of expansion and/or perpetuation for this exotic species emphasize its strong potential for invasion. This species may be a threat for the integrity of local communities in the marine reserve.

Rapid Assessment of Seahorse Densities and Associated Habitats in the Philippines

*Aileen P. MAYPA**, *Melita A. SAMOILYS*, *Denise M. MCCORRY*, *Amanda C. J. VINCENT*

222 First St. Happy Valley, Guadalupe, Cebu City 6000 Republic of the Philippines

aimaypa@yahoo.com

Ecological assessments of fish populations and associated habitats are integral to management. Using a rapid assessment team comprised of trained fishers, we assessed wild seahorse densities and associated habitats in 475 transects across six provinces in the Philippines, covering a total area of 118750 m². Six community types associated with seahorses were identified and characterized using a multivariate analysis: (A) seagrass/algae, (B1) seagrass, >60% cover, (B2) seagrass, < 60% cover, (C1) *Sargassum*, (C2) *Sargassum* mixed with other algae and dead coral and (D) hard coral. Four species of seahorses (genus *Hippocampus*) were recorded. We found *H. comes* and *H. barbouri* in sufficient numbers to allow statistical analysis, whereas we sighted only one each of *H. kuda* and *H. spinosissimus*. Our surveys revealed *H. comes* as the most abundant and widespread species, with *H. barbouri* recorded only from Palawan. Seahorse densities in all surveyed sites were extremely low (0 to 1.35 ± 0.34 individuals per 250 m²) but *H. comes* density was highest in the coral community D (0.33 ± 0.06 individuals per 250 m²; 2.5 times higher than in other community types). Such very low densities are compatible with our hypothesis that wild seahorse populations in the Philippines are heavily exploited and subjected to habitat loss. Interviews with fishers on perceived long-term catch rates suggested a sharp decline in seahorse catch and catch per unit effort from 1970 to 2000, which supports the low densities observed in our surveys. This study also illustrates the difficulty of assessing depleted wild fish populations without baseline data.

Impact from Anthropogenic Processes that Affect Two near Shore Coral Reefs Located in Matara and Weligama Southern Sri Lanka

*Fairoz MOHAMED**, *Cumaranatunga RUCHIRA*, *Amarasinghe BANDU*

Department of Fisheries Biology, University of Ruhuna, Matara, Sri Lanka

fairoz@fish.ruh.ac.lk

Two near shore fringing reef lagoons located at Polhena (Matara) and Weligama of Southern Sri Lanka were surveyed from August 1999 to December 2001, to assess the possible impacts due to anthropogenic activities. Anthropogenic activities at Polhena reef lagoon (PRL) are recreational activities and ornamental fish collection. At Weligama Reef Lagoon (WRL) anchorage of fishing boats and ornamental fish collection was observed. Live coral cover percentage at WRL (31.04±13.7) is significantly higher than at PRL (18.39±10.69). Dominant live coral species recorded at WRL is *Acropora formosa* (25.3 %) and at PRL was *Podabacia crustacea* (4.25 %) an opportunistic coral growing on dead *Acropora*. Visitors who come to PRL for swimming and bathing cause a major impact to coral recovery. According to the observations an average of 577 visitors day⁻¹ are engaged in different activities harmful to the young corals. Ornamental fish capture using destructive techniques and gears is presently under operation at PRL and WRL. Average number of persons engaged in it were 2 day⁻¹ at PRL and 5 day⁻¹ at WRL. Within the WRL fishing boats are anchored, using it as a natural harbor causing severe damage to the reef. This also causes an impact on the vegetative propagation of broken fragments of *Acropora formosa*. According to census 56 fishing boats are operating from Weligama and 38 boats day⁻¹ are frequently anchored in an area of 0.036 Km² on the WRL. Recovering percentage of the *Acropora formosa* branches and fragments were determined at the boat anchoring site and at other sites, which are not used for anchorage and it shows that boat anchorage is having a direct impact on the recovery of *Acropora formosa* (11.2 ± 2.4 and 35.8 ± 8.4 respectively). A proper management plan and enforcement of law is essential to rescue this fragile ecosystem.

Integrated Coral Ecosystem Mapping and Monitoring to Support Ecological Assessments

*Mark M. MONACO**, *Matt S. KENDALL*, *Tim A. BATTISTA*, *John D. CHRISTENSEN*, *Russell C. CALLENDER*, *Alan M. FRIEDLANDER*

1305 East West Highway Silver, N/SC11, Silver Spring, Maryland 20910 United States of America

mark.monaco@noaa.gov

NOAA/NCCOS' Center for Coastal Monitoring and Assessments in partnership with state and territory partners, have been conducting biogeographic research and monitoring of tropical marine ecosystems to define, characterize and assess the status of coral reef ecosystems throughout the US Caribbean and Pacific. The work is underway in areas where NOAA/NOS has developed high-resolution digital benthic habitat maps derived from remote sensing imagery in the US Virgin Islands, Puerto Rico, the Northwestern Hawaiian and main Hawaiian Islands, and the US Pacific Territories. The GIS-based maps are classified into approximately 27 levels of habitat type (e.g., seagrass, patch reef) and these habitats are organized in space by cross-shelf zones (e.g. backreef). The maps enable a companion living marine resource monitoring component to be conducted within the coral reef ecosystems surrounding US islands. Species occurrence, abundance, size, and trophic ecology based on random stratified sampling of the digital habitats maps are surveyed to provide base line data for several applications, including documenting changes in reef fish populations due to natural or anthropogenic events. The integrated mapping and monitoring studies across Caribbean and Pacific coral ecosystems enables defining species habitat utilization patterns under various management regimes and ecological comparisons between ocean basins. Biogeographic products include species distribution maps depicting the probability of encountering species based on their habitat affinities and maps of ecological indices. This work was designed to support many users including the National Park Service in assessing short-term ecological impacts from hurricanes, the US Caribbean Fisheries Management Council in defining essential fish habitats, and Puerto Rico in defining biologically relevant marine protected area boundaries. In the Pacific, the digital habitat maps are supporting research cruises to characterize coral reef ecosystems and the selection of monitoring sites to address management needs, such as the efficacy of marine protected areas and rapid ecological assessments.

Development of a Blast Fishing Detection System

*George H. WOODMAN**, *Simon C. WILSON*, *Vincent LI*, *Reinhard RENNEBERG*

18 Sun King Terrace, Sai Kung, KLN Hong Kong

george@otolith.com.hk

Blast fishing has been widely reported in the literature in recent years and has been identified as a major threat to reefs in many parts of the world. Resource managers face a number of key problems relating to the best available approach to resolve issues relating to this form of destructive fishing. These include: the expense and ineffectiveness of surveillance and the enforcement of existing blast fishing regulations, the provision of evidence to secure convictions for the use of explosives rather than the lighter offence of possession of illegally caught fish, the difficulty of determining the ecological impact of blasting on large scales due to the lack of spatial and temporal information about the incidence of blasting and finally the problem of objectively measuring the success of management approaches that seek to control blasting. We describe a blast detection system based on hydrophones that is capable of determining the direction of travel of a blast wave with a precision of less than 0.2 degrees. The system's software filters reject background noise so that its sensitivity can be increased to allow detection of individual fish bomb blasts at ranges of tens of kilometers. During field testing in Sabah, Malaysia in July 2002, seventeen blasts were detected over an 11-day period using an array of three hydrophones located near to a boat jetty and a shallow reef. Over 4000 noise events, mostly caused by nearby alpheid (snapping) shrimp and boat engines were successfully rejected by the filters. The deployment of a network of directionally-sensitive, systems based on this technology has the potential to give real-time warnings of fish blasting events and their precise location to fishery enforcement agencies, managers and researchers. Work is underway to develop an affordable prototype.

Basic Information for Sustainable Use of a Sea Urchin, *Diadema setosum* from Coral Communities in the Gulf of Thailand*Jamrearn BUARUANG**, *Thamasak YEEMIN*Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok, 10240 Kingdom of Thailand
jamrearn@hotmail.com

Ecological data of *D. setosum* are very important for coral reef management because the sea urchin often plays major roles in controlling macroalgal populations and organizes structures of shallow subtidal communities. The present study on *Diadema setosum* from coral communities at Khang Khao Island, Chonburi Province, and Samet Island, Rayong Province, in the Gulf of Thailand was carried out during July, 2000 to September, 2002. Averages of recruit densities of *D. setosum* in January, July, October, 2001 and September, 2002 at Khang Khao Island were 2.33 ± 0.41 (mean \pm SE), 2.31 ± 0.56 , 2.60 ± 0.70 and 3.13 ± 0.78 individuals/m², respectively. While those at Samet Island in July, September, 2000 and April, July, 2001 were 0.45 ± 0.001 , 0.42 ± 0.005 and 0.44 ± 0.003 , 0.49 ± 0.004 individuals/m², respectively. Recruits of *D. setosum* at Khang Khao Island were observed mainly on three types of substrate, i.e. dead coral, live coral and hard substrate (fragments of rock). Sea urchin recruits found in the field on dead coral were higher than those on hard substrate and live coral, respectively. The recruitment in September, 2002 was higher compared to the previous years. Means of recruit density of *D. setosum* on dead coral, live coral and hard substrate in September, 2002 were 4.33 ± 0.76 (mean \pm SE), 1.67 ± 0.42 and 3.40 ± 1.16 individuals/m², respectively. The experimental settlement devices were also deployed at coral and sandy zones of Khang Khao Island. Densities of newly settled urchin found on the sandy zone were higher than those on the coral zone. The periods of high newly settled *D. setosum* were during July to October, 2001 and June to September, 2002. The present study not only shows implications for coral reef management but also provides important basic data for commercial cultivation of *D. setosum* in the future.

Resource Use Study in the Republic of Palau*Ann KITALONG**Box 1696, Koror, Palau 96940 Republic of Palau
kitalong@palaunet.com

A resource use study in the Republic of Palau was commissioned by the Office of Environmental Response and Coordination for the National Biodiversity Strategic Action Plan. Interviews with 35 key informants by The Environment, In., and a nation-wide survey of over 357 community members by the Palau Conservation Society were incorporated into this study. The perceptions of the informants and community were as follows: Traditional agroforestry was sustainable but threatened by sea level rise, droughts, fires, pests, and market fluctuations. Resource use within managed areas was sustainable. Offshore tuna, pelagic fish, medium sized parrotfish and surgeonfish and trochus were being sustainably harvested. Unsustainably harvested inshore fisheries resources included most reef fish, especially the humphead wrass and bump head parrotfish, and invertebrates such as giant clams, sea urchins, sea cucumbers, and crabs. Dredging, mangrove filling, over harvesting, deforestation, fires, quarrying and unplanned development attributed to the decline in these resources. Threats to marine resources included sea level rise and rising sea temperatures. All resources could be used sustainably that were not. There was potential for sustainable resource use through agroforestry, ecotourism, aquaculture, and mineral production. Benefits were reinvested in resource management through the tuna fishery fees, aquaculture, national surveillance and the Rock Island Permit System but these benefits were insufficient. The key beneficiaries were the local residents. Ways to promote sustainable development included capacity building, information collection, coordinated efforts, mutual support, and funding. Knowledge gaps included the following: sustainable harvest levels of marine species; population size and distribution of endangered or threatened species; financial benefits from fisheries and tourism; non-commercial inshore fisheries production; land use changes over time; point sources and measurable impacts of pollution; land use planning, and potential production and markets for resources.

Human-Camel Relationships in Coral Reef and Mangrove Ecosystems: Resource Patch Accessibility and Availability in the Coastal Zones of the Arid Tropics*Hiroshi NAWATA**Crescent Shugakuin 517, Mukaihata-cho 53, Ichijoji, Sakyo-ku, Kyoto 606-8126 Japan
nawatahiroshi@hotmail.com

I analyzed resource patch accessibility and availability in the coastal zones of the arid tropics, focusing on human-camel relationships among the Beja on the Sudanese Red Sea coast. Firstly, I made schematic overviews that show physical environment, biological environment, and livestock grazing zones on a three-dimensional figure. Secondly, I threw light on a role of one-humped camels with an outline of resource patch accessibility and availability, by constructing a relation web among human beings, livestock, coral reefs (physical environment), and resource patches (biological environment). As a result, I clarified that resource patch accessibility and availability are determined by camels' intervention so that its overexploitation in the coastal zones of the arid tropics has been limited consequently.

Activity Patterns, Habitat-use and Survivorship of Hatchery-reared *Trochus niloticus**Davelyn S PASTOR**, *Marie Antonette JUINIO-MENEZ*Roces Avenue, University of the Philippines, Diliman, Quezon City 1101 Republic of the Philippines
davelyn75@yahoo.com

The gastropod *Trochus niloticus* or topshell is an important reef organism in the tropical Pacific and a valuable source of foreign exchange where trochus fishery exists. The relative ease in gathering adult topshells has led to overfishing of this important resource and one of the management options considered to enhance wild populations is the reseeded of hatchery-reared *T. niloticus* juveniles. However, some of the problems encountered in many invertebrate stock enhancement programs are high mortality of reseeded stocks, fitness of the released organism and suitability of habitats. We studied the activity patterns and habitat-use of hatchery-reared juvenile *T. niloticus* to different substrate types, its behavioral responses to predation and survivorship in its natural environment. Initial results indicate diel pattern of hiding and foraging behaviors, refuge-seeking behavior in the presence of habitat or structure and the preference to a particular substrate. These aspects on the ecology of the topshell is largely undocumented and results from this study can give insights to future reseeded program of *Trochus* in terms of increasing survivorship.

Reef Associated Molluscs of Gulf of Mannar Marine Biosphere Reserve, Southeast Coast of India: Diversity, Threats and Management PracticesDeepak V SAMUEL, *Jamila PATTERSON**44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India
deepp_ocean@yahoo.com

The Gulf of Mannar Biosphere Reserve is unique in possessing 21 coral islands (one submerged) with rich diversity of flora and fauna. The islands are divided into 4 groups namely, (1) Mandapam group (2) Keelakarai group (3) Vembar group and (4) Tuticorin group. Molluscs were surveyed by SCUBA diving, trash of trawl nets, bottom set gill nets, push nets, shell shops and shells washed ashore. The survey revealed a total of 5 species of polyplacophorans, 174 species of bivalves, 271 species of gastropods, 5 species of scaphopods and 16 species of cephalopods. A poor diversity of the molluscs was recorded from the Tuticorin group of while comparing with other island groups. Coral mining and other destructive fishing practices have caused serious habitat destruction to the molluscan fauna. The recorded molluscan fauna were divided in to three categories as reef dwelling molluscs, molluscs that dwell near the reef areas or sea grass beds and endemic molluscs. The reef-associated molluscs were dominated by the gastropods *Drupa margariticola*, *Cypraea arabica*, *C. pallida*, *C. erronea*, *C. vitellus*, *Haliotis varia*, *Conus textile*, *C. coromandelicus*, *Lambis scorpius* and *Trochus radiatus*. For bivalves, *Septifer bilocularis*, *Barbatia amygdalumtostum*, *Mimachlamys sanguinea*, *Cardium setosum*, *Vasticardium assimile* and *Pteria chinensis* were recorded. Endemic species like *Harpulina lapponica* and *Mitra* sp. are also characteristic only to the Gulf of Mannar region. *Lambis lambis* was the most dominant species among gastropods found abundant through out the biosphere reserve. Certain gastropods like the sacred chank (*Xancus pyrum*) and Pileare shell (*Cymatium pileare*) are exploited in large quantities for their traditional sacred usage. Ministry of Environment and Forests, Govt. of India has imposed a ban on exploitation of vulnerable and threatened species of mollusks. Conservation and management strategies including alternative livelihood programmes are now being explained to the fisher folk through awareness programmes and camps.

An Evaluation of the Live Rock Fishery and its Consequences*Samasoni SAUNI**, Mecki KRONEN, Aliti VUNISEA, Lilian Fay SAUNI

B.P. D5 98848 Noumea Cedex New Caledonia

SamasoniS@spc.int

Coral and reef fish communities were investigated in Muaivuso qoliqoli, Fiji Islands, for localized ecological effects of the live rock fishery. The socio-economic benefits derived from this growing fishery and trade is also weighed against the perceived disruption of the reef ecosystem. The study found significant differences in habitat health between target and non-targeted biotopes of live rock extraction areas. Conversely, the study found no significant impact of such an operation on the overall reef fish communities, except for species-specific impacts on coralline algae feeders. Socio-economic implications of this fishery/trade suggest short-term cash benefits enjoyed by just a few participating households. The ecological and socio-economic results suggest that the adverse effects of the live rock fishery can be monitored for sustainable extraction, thus, minimizing the potential impacts leading to unbalanced ecological and socio-economic structures at the community level.

Geodatabase for Recreational Fishing Effort in Coral Reef AreasSteven H WONG, *Sandra L AGUILAR**, David W CARTER75 VIRGINIA BEACH DRIVE, MIAMI, FL 33149 United States of America
steven.wong@noaa.gov

U. S. NOAA Fisheries collects, manages, and analyzes long-term fisheries-dependent data sets to support ecosystem-based fisheries research and management. It is becoming increasingly important to investigate the spatial distributions of fishing effort in coral reef areas to improve scientific research on fisheries stock assessments, relationships between biological species and their environment, and evaluation of socioeconomic implications. The task of mapping the fisheries-dependent data sets is very difficult because (1) the lack of geographic coordinates as part of the data sets, (2) the coarse spatial resolutions of fisheries statistical grids. Using a subset of the U. S. Marine Recreational Fishing Statistical Survey (MRFSS), the authors demonstrate how we can map recreational fishing locations in coral reef areas by extracting spatial data from certain variables provided by anglers, such as distance from shore and fishing mode (e. g., types of boats). We will also show how we can refine the spatial resolutions of these fishing locations by using data from vessel travel information, and species-habitat associations. In addition, the authors will present ideas and samples of useful spatial queries on the fisheries-dependent data in combination with other data sets such census of human population, habitat maps of coral reef areas, and fisheries-independent surveys (e.g., aerial surveys of vessel activities). The objective of these queries is to evaluate the socioeconomic impact of fishing and fisheries management in the study areas.

Spatial Distribution and Natural Stocks of Black-lip Pearl Oyster, *Pinctada margaritifera* in Chuuk Lagoon, Federated State of Micronesia*Soon Kil YI**, Heung-Sik PARK, Ki-Sik WON

P.O.BOX 29, Ansan, Kyonggi-Do 425-600, South Korea

skyi@kordi.re.kr

The purpose of this study was to understand the spatial distribution of blacklip pearl oyster, *Pinctada margaritifera*, in Chuuk Lagoon, Federated States of Micronesia. Twenty six stations were selected along the coast of major islands and a series of underwater observations was done at each station by scuba divers. Based on the multi-dimensional scaling, bottom habitats of the study area were classified into four habitats such as Porite lutea dominated, dead coral bed, Porite nigrescens dominated and coralline sand bottom area. The spatial distribution of the oyster seemed to be closely related to habitat types, however no difference in shell size was observed among habitats. The overall means (n=236) of shell length and total weight of the oyster were 124 mm and 286.4 gWWt, respectively. The mean density of the oyster was 0.3 inds./100m² and the stock size of the oyster which can be directly put to pearling industry was estimated to 367,000 individuals

Alliances for Marine and Coastal Conservation in the Abrolhos Region, Brazil

Guilherme F DUTRA, Timothy B WERNER, Rodrigo L MOURA*

Rua das Palmeiras, 451 Caravelas BA 45900-000 BRAZIL

g.dutra@conservation.org.br

The Southwestern Atlantic bears unique coral reef communities, with high endemism levels and distinctive reef structures. The greatest biodiversity in this entire region is found on the Abrolhos Bank, off the southern coast of Bahia State. Abrolhos represents one of the most spectacular examples of coral reef growth in turbid waters, but is highly threatened by sedimentation, overfishing, urban development, and several industrial activities that are steadily increasing in its coastal zone. In 1996, Conservation International responded to the imperative to conserve this region by establishing a regional conservation program, based on a partnership with the Federal Environmental Agency (IBAMA) and other key stakeholders such as fishing communities, local NGOs, donors and scientists. This alliance focused chiefly on the establishment and implementation of a mosaic of coastal and marine protected areas, including three main units: (1) a National Marine Park comprising two separate blocks, totaling 88,249 ha; (2) a state-designated Protected Area (APA) covering coral reefs and mangroves, with 346,000 ha; (3) an Extractive Reserve managed by a council with majority of traditional fishermen, with 89,525 ha. In this paper, we describe the different responses of each management regime adopted in the region. Parallel conservation efforts with cellulose and shipping companies, as well as with the oil and gas industry, are also described. Overall, the Abrolhos project developed and implemented a conservation strategy focused on multiple-use, but also incorporating several no-take areas. Despite the major emphasis given on marine protected areas, control of land-based sources of threat to coral reefs is also a key issue to protect Abrolhos' unique marine biodiversity

A Performance Assessment Framework for Marine Conservation Reserves in Western Australia

Timothy GRUBBA*, John LLOYD, Chris SIMPSON, Andrew HILL, Kevin BANCROFT

47 Henry St, Fremantle, Western Australia, 6160 Australia

tim@calm.wa.gov.au

Western Australia has a system of eight existing marine conservation reserves (MCRs) with another 60+ areas identified as candidates for reservation. The MCR system is being established to preserve representative and special marine ecosystems and to ensure that the various uses of MCRs are managed in an equitable, integrated and sustainable manner. Of the existing MCRs, three (Rowley Shoals, Ningaloo, and Shark Bay marine parks) encompass significant coral reef systems. The Western Australian MCR system is vested in the Marine Parks and Reserves Authority (MPRA) and managed by the Department of Conservation and Land Management (CALM). The management of MCRs follows an outcome based performance assessment framework based on a pressure state response model. Under this framework, management plans for each MCR identify overall strategic management objectives and clear objectives for each identified ecological and social value. For ecological values and specified passive social values, management targets, desired trends, and performance measures for each value are also specified. The management plans also identify current and potential pressures and management strategies/actions that can be implemented to avoid or mitigate those pressures, or remediate the impacts of past pressures. The overall effectiveness of management is assessed against management targets of the key ecological and passive social values referred to as key performance indicators (KPIs) (identified by a risk assessment using a value-threat-knowledge framework). The KPIs reflect the management targets for the highest conservation (from biodiversity and ecosystem integrity perspectives) and social value priorities. The KPIs are a core component of CALM and MPRA audits. To facilitate auditing a report card has been developed which assesses the key ecological and social components of the MCR, the MCR as a whole, and the Western Australian MCR system. The report cards link to state of the environment reporting at a State, National and International level.

Atlantic *Acropora* Status Review and Potential Listing under the US Endangered Species Act

Jennifer A JACUKIEWICZ, Stephania BOLDEN*

9721 Executive Center Drive N, Suite 102, St. Petersburg, FL 33702 United States of America

jennifer.jacukiewicz@noaa.gov

In 1999, the National Marine Fisheries Service (NOAA Fisheries) determined that elkhorn coral (*Acropora palmata*) and staghorn coral (*A. cervicornis*) were candidates for listing under the U.S. Endangered Species Act (ESA). The ESA directs NOAA Fisheries to make determinations on the listing of a species solely on the basis of the best scientific and commercial data available after conducting a review of the status of the species. An Atlantic *Acropora* biological review team (BRT), comprised of species experts, has been convened to review the status of the two species and prepare a written report (status review). The status review will help guide future listing decisions by investigating the following threats: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; (E) other natural or manmade factors affecting its continued existence. Since the two species' range is Caribbean wide, NOAA fisheries will evaluate implications of listing both in the U.S. and foreign countries. Preliminary results of the status review are discussed.

Sustainable Management of Coral Reefs in Cu Lao Cham Islands, Quang Nam Province, Vietnam

Nguyen V LONG*, Vo S TUAN, Hoang X BEN, Phan K HOANG

01 Cau Da st., Nha Trang city Socialist Republic of Viet Nam

nvanlong@dng.vnn.vn

Cu Lao Cham is recognised as an important area in terms of biodiversity and fisheries in Vietnam. With high diversity of habitats, marine organisms (128 species of reef-building corals, 178 species of reef-associated fishes, 122 species of macro-algae, 84 species of molluscs, 12 species of echinoderms and 4 species of crustaceans) and the importance of fishing grounds, Cu Lao Cham is proposed as a Marine Protected Area in Vietnam. Comparisons of the data collected between 2003 and 1994 indicate that some coral reefs have remained in good condition and others have deteriorated. The trend of change in live coral cover between 1994 and 2003 at 5 reefs was a very little. However, signals of degradation of coral reefs have been recorded at some reefs due to dynamites, poisons, bleaching, sedimentation and crown of thorn starfish. Interviewed information and recent data have shown that reef and non-reef fisheries have been declined due to overexploitation and habitat destruction. Cu Lao Cham islands located nearby Hoi An ancient town and Da Nang City are identified as one of the most important areas in the development strategy of Quang Nam Province. Unsustainable development and management plans will cause many problems to the environment around the area. Marine habitats and resources are under increasing pressure and subject to increasing damage from a wide range of human and natural impacts. Based on available data and information, the report will evaluate effectiveness of recent management and propose sustainable management strategies for coral reefs in this area. (The surveys were supported by WWF(1994) and Total Foundation (2002-2003))

Beach Erosion of Candi Dasa Coast on Bali Island Triggered by Excess Coral Mining

*Takaaki UDA**, Yutaka OSUGA, Susumu ONAKA, Masumi SERIZAWA, Toshiro SAN-NAMI

1-6-4 Taito, Taito, Tokyo Japan

uda@pwrc.or.jp

There are world-famous coastal resorts on Bali Island. Especially, they concentrate on the southern part, but there are some small-scale, scenic resorts in the eastern part. Candi Dasa is one of those with coral reef. Recently beach erosion has become severe on this coast, resulting in unavoidable construction of seawall. This leads to devastation of natural reef coast. This study is aimed at investigating the erosion caused by coral mining, taking Candi Dasa coast as an example. On September 1999, field observation was carried out. In July 2001, aerial photographs were taken from a helicopter to investigate the mining. On August 2002, second field observation was carried out as well as the analysis of sea-bottom sounding data to estimate the causes of the beach erosion. An aerial photograph shows that shoreward of reef edge, a natural reef is not left behind, and considerably deep seabed covered with fine materials extends up to the shoreline, implying the formation of excavation holes by excess coral mining. It was carried out from the vicinity of the reef edge, except the reef edge itself. As a countermeasure against beach erosion, seawall and groins were built, but seawall was severely damaged. Coastal utilization of sandy beach became impossible in front of the hotels. After coral mining, coral sand, which was originally to be transported shoreward, was trapped by the artificial holes, resulting in the decrease of sand supply to the shore. The balance between westward longshore sand supply and shoreward sand transport was lost, leaving the beach erosion from the eastern coast. Now coral mining is prohibited by law, but still small-scale mining has been carried out by local people. The experience of Candi Dasa coast tells us that once the balance of coral reef is lost, the recovery work needs an extraordinarily high cost.

Algal Biomass in Relation to Depth and Proximity to Marine Parks at Leeward and Windward Sites in Little Cayman, Cayman Islands

*Vania R COELHO**, *Carrie MANFRINO*, *William KING*, *Desaree WILLIAMS*
50 Acacia Avenue, San Rafael, CA, USA, 94901-2298 United States of America
vcoelho@dominican.edu

The marine parks of Little Cayman are no-take zones, thus expected to have greater fish abundance, and consequently greater herbivore pressure, than non-protected areas. In this study, we analyzed algae biomass as an indirect way of inferring the effectiveness of the parks. We compared deeper water regions (10-15 m) inside and outside marine parks, as well as areas enclosed in shallow lagoons (1 m) near and far from protected zones at leeward and windward sides of the island. Three 10 m line transects were positioned randomly at each site. The algae enclosed by quadrants of 0.0625 m², placed every other meter in the transects, were collected and stored in labeled plastic bags. The samples were later rinsed in freshwater for faunal removal, then dried and weighted. We used Mann-Whitney tests to compare the data statistically. In both leeward and windward areas, the shallow water sites had more total algae biomass and more upright (articulated) calcareous algae than deeper water sites. Lagoon areas on the windward side of the island had more upright calcareous algae than the ones on the leeward side. In the deeper leeward areas, total algae biomass and upright calcareous algae abundance was greater in the non-park region. The leeward lagoon site farther from the protected zone also had more upright calcareous algae than the shallow area closer to the park. No clear pattern was observed at windward areas regarding marine park protection. Our data suggests that the protection of the marine park on the leeward side of the island may be more effective than on the windward side. The fact that the latter park is about half the size of the former one could possibly account for these differences. However, further studies will be necessary to better understand the underlying reasons for these differences.

Coral Point Count with Excel Extensions (CPCE): A Windows-based Program for the Analysis of Coral and Substrate Coverage Using the Random Point Count Method

*Kevin E KOHLER**
8000 North Ocean Drive, Dania Beach, Florida 33004 United States of America
kevin@nsu.nova.edu

With large-scale impacts on coral reefs worldwide, increased efficiency and integration of monitoring efforts is required and photographic and video-methods are frequently used to optimize diver time. The random point count method is commonly used on frame-grabbed video or still images to estimate the community statistics of benthos. Underwater photographic frames are overlaid by a matrix of randomly generated points, and the fauna/flora species or substrate type lying beneath each point is identified. To be statistically unbiased, it is desirable to obtain a different set of random points on each image. The data for each frame is stored and the accumulated data of several frames are combined and saved as a transect dataset. The transect datasets are then statistically analyzed to give quantitative measurements over the area of interest. CPCE is a standalone Windows-based program which automates the random point count method. CPCE is designed specifically to speed analyses and includes features such as automatic frame-image sequencing, single-click species/substrate labeling, auto-advancement of data point focus, zoom in/out, zoom hold, and specification of random point number and frame border location. Additional customization options include user-specified coral/substrate codes and data point shape, size, and color. A significant feature of CPCE is the ability to automatically generate analysis spreadsheets in Microsoft Excel™ based upon the supplied species/substrate codes. Multiple frames can be combined into a single transect datasheet containing header information, statistical parameters of each species/substrate type (relative abundance, mean and standard deviation), and the calculation of the Shannon-Weaver diversity index for each species.

Benthic Habitat Characterization in the Tortugas Ecological Reserve

*Gregory A PINIAK**, *Christine M ADDISON*, *Mark S FONSECA*
USGS Pacific Science Center, 400 Natural Bridges Drive, Santa Cruz, CA 95060 United States of America
gpiniak@usgs.gov

The implementation of the no-take Tortugas Ecological Reserve in July 2001 provided an opportunity to study the recovery of the ecosystem from the physical impact and consumptive use associated with human activity. To document this change, we established 30 permanent sampling stations, evenly distributed among three strata: the newly established Tortugas Ecological Reserve, Dry Tortugas National Park (first protected in 1935), and unprotected reference sites. The overall project is designed to inventory benthic habitats and fish communities at the deep reef-sand flat interface (60-110 ft). This poster describes the baseline benthic community composition of the hardbottom and soft-bottom habitats as determined from video transects. Preliminary results from 2001 indicate that coral cover was similar in all three strata. The national park had lower macroalgal cover in the sand flat, likely due to higher levels of herbivory.

The Measure for Coral Preservation of the Okinawa Electric Power Company Limited

Tsutomu YOGI, *Hitoshi MIYAZATO**
2-1,5-Choume,makiminato,Urasoe Okinawa Japan
kankyo@okiden.co.jp

In power plants, sea water is taken in for cooling of power generation equipment, and it discharges as thermal wastewater. As a drainage system of thermal wastewater, there are a surface-discharged system and an underwater-discharged system. In two of our thermal power plants (Gushikawa and Kin), in order to reduce the influence of thermal wastewater to the coral and other living things, the underwater-discharge system is employed so that the diffusion range of thermal wastewater may become small as much as possible. In this poster session, we will present a diffusion phenomenon of thermal wastewater and the reduction of influences to living things, such as coral, by means of the underwater-discharge system through the results of a diffusion prediction simulation and the monitoring before and after operation. In addition, we will also present the measure for coral plantation in the front ocean space of a power plant which our company is carrying out.

Fish Communities Following the Recovery of Coral Reefs from Blast Fishing Practices in Kepulauan Seribu, Indonesia

*Unggul AKTANI**, Matthias WOLFF, Andreas KUNZMANN

Jl. Lingkar Akademik, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia
aktani@indo.net.id

Kepulauan Seribu is an archipelago of 110 small islands in the southwest Java Sea. The archipelago is currently used for traditional fishing area, tourism, sand mining, off shore oil exploration, sailing, and conservation. The major problem in Kepulauan Seribu was blast fishing since the 1970s, which had caused extensive coral destruction. Blast fishing stopped since 1995. Six islands were chosen, each with three permanent transects on the northeast parts of each island, covering three management zones: Sanctuary Zone, Intensive Utilization Zone, and Traditional Utilization Zone. From October 2000 until August 2001, underwater visual censuses were carried out within 45 day-intervals. The fish transects were 50x5m. Within the fish transects, underwater sequential photographs were taken (50x1m) to assess benthic groups and coral reef coverage. Hard coral coverage was 43, 29, 25, 20, 18 and 7% in Genteng, Pandan, Melinjo, Bira, Opak and Putri, respectively. Dead corals were the dominant cover in all islands surveyed (range: 52 to 83%). The long-lasting impact of blast fishing on the substrate was reflected by the presence of extensive fields of dead coral rubble (range: 31 to 59%). In contrast to the zoning allocation, the percent hard coral cover in the Sanctuary Zone was lowest and percent cover of dead coral was highest. The highest cover of hard coral was found in the Intensive Utilization Zone. A total of 119 fish species belonging to 25 families (32863 fishes) were determined. Pomacentridae was the most abundant family, followed by Labridae. Planktivore and omnivore fish were the two most abundant trophic groups. The composition of the fish community changed seasonally according to the alteration of west and east monsoon. The fish community was more related to the presence of benthic groups and life form categories than to the coverage of hard corals.

Fish Communities Following the Recovery of Coral Reefs from Blast Fishing Practices in Kepulauan Seribu, Indonesia

Oscar M DELGADILLO, Jackeline CORREA, Camilo B GARCIA, Sonia BEJARANO*
 22B street, No. 63-24, Interior 5, Apartment 403, Bogota, Colombia
imagovy@yahoo.com

In Morrosquillo Gulf the little arts technical character and diversity utilization, make that fishermen have a limited extractive activity to coastal waters resulting in overfishing process. For these reasons, it installed two benthic artificial reefs (ARs) to improve the fishing for the artisanal fishermen community. Catch and effort data were recorded during august 2001 to august 2002 to each landing from ARs on randomly chosen in seven days each month, and the number, weight and standard length of catch species were collected for the fishermen that use hook and line. A total of 39 species were registered. In Punta de Piedra (PP) AR were caught 19 species and 146,725 kg, and in Tolu (T) AR 36 species and 1467,56 kg, with common 16 species. The common species were *Caranx crysos*, *Sphyrna guachancho*, *Scomberomorus brasiliensis* and *Lutjanus synagris*. The differences found among ARs were consequence of greatest effort in T, due that this AR was more near to cost. The mean catch per unit effort (CPUE) was 0,40 kg/hour and 0,42 kg/hour in PP and T respectively. These values were founded up of minimum range reported in the zone for the same art. The two-factor analysis of variance showed that there was no significant difference in CPUE among sites and days. The similarity analysis mediated in study weeks in each ARs, showed that the assemblages had homology for the same factors, due to the similar characteristics of design and ambient factors influence at both sites. Apparently, the catch stability reflected that the ARs were regulated near of his load capacity like a balance among the ambient disturbance degree and the specialization advantages of the species. Finally, the ARs fulfilled the proposed objectives, creating a fishing effective area and can serve like a conservation tool if fishing activities are not permitted.

Nautilus pompilius - Large Scale Mark/Recapture Studies

*Andrew J DUNSTAN**

Princes Wharf, Port Douglas, QLD, Australia
info@undersea.com.au

Nautilus inhabit the tropical Indo Pacific region and have been studied in the field through mark recapture, in-situ photography, telemetry and associated laboratory/aquarium experiments. Two species of *Nautilus*, *N. pompilius* and *N. stenomphalus*, have been found on the outer slope of the Northern Great Barrier Reef. This study presents data on a wild population of *Nautilus pompilius* at Osprey Reef, an isolated Coral Sea reef. *N. pompilius* at Osprey Reef are smaller (mean diameter 130mm) than the same species at other Indo Pacific sampling locations (133mm to 220mm mean diameter).

Between July 1997 and January 2004, 1305 *N. pompilius* were captured, marked, measured and released with a 17% recapture rate. Recapture rate has increased, as predicted, with increased capture number, giving confidence in the tagging method and viability of released animals. Recaptures occurred from one week to 30 months from initial capture with multiple recaptures occurring for some individuals. Immature individuals comprise 15% of recaptured animals, from which it has been possible to estimate wild growth rates. Mark/recapture models used give a reliable overall population estimate for this remote and isolated Coral Sea reef.

Ultrasonic telemetry will be used to identify home range and further quantify population estimates. In-situ deep sea cameras will be used to assess capture methods, population structure and juvenile presence. *Nautilus* have decreased in a number of Indo Pacific locations where they are harvested for the shell trade. Management implications and fisheries recommendations may be extrapolated from this study in the future to sustainably manage *Nautilus* populations.

Assessment of the Vulnerability of Reef Fish Spawning Aggregations to Overexploitation

*Helen J HENDRY**, Andrea MANICA, Andrew BALMFORD

Downing Street, Cambridge, CB2 3EJ, UK United Kingdom of Great Britain and Northern Ireland
hjhendry@yahoo.com

Many commercially important species of coral reef fishes aggregate in large numbers at specific locations, times and moon phases to spawn. Such behaviour has led to growing concern that these species may be particularly vulnerable to overexploitation since fishermen have exceptional opportunities to efficiently take large catches from spatially and temporally predictable spawning aggregations. However, to some extent, this vulnerability of spawning aggregations to fishing pressure has been assumed rather than quantitatively proven with little attention given to assessing whether species forming spawning aggregations actually suffer greater impacts of over-fishing. A literature review and quantitative analysis have been carried out to investigate what evidence there is for the targeting and vulnerability of spawning aggregations to overexploitation. Limited published data show that in the Caribbean many grouper fisheries have traditionally been based around spawning aggregations, while scattered information from the Indo-pacific provide more fragmentary and sometimes contradictory evidence. A phylogenetically controlled analysis shows that species that form spawning aggregations are at greater risk of extinction than non aggregating species, but that this could be driven partly by the prevalence of large bodied species of aggregating fish. A case study of artisanal fisheries in Borneo provides little evidence to support the theory that live reef fishermen in this region specifically target spawning aggregations. Overall I show there is some evidence that spawning aggregating behaviour renders species of reef fish more vulnerable to overexploitation however I emphasize the importance of considering other factors such as body size when planning to protect exploited species. Spawning aggregations are important for reef fish management, both in terms of capturing them within networks of reserves interconnected by larval dispersal and as a monitoring tool for widely dispersed populations that are otherwise difficult to access.

Comprehensive Census of Commercial Fishers of the United States Virgin Islands

*Barbara KOJIS**, Roger UWATE

6291 Estate Nazareth, Red Hook, St. Thomas, US Virgin Islands 00802 Virgin Islands of the United States

bkojis@vitecom.net

A comprehensive census of the registered commercial fishers of the US Virgin Islands (USVI) was conducted in 2003. Over 300 fishermen were interviewed to determine target species, method of fishing and other fishing demographics. The fisheries of St Thomas (STT) are dominated by trap fishers catching mainly reef fish (35%) and lobsters fishing (14%) an average 2.6 times per week for an average 8 hours per trip. The fishers of St. Croix (STX) are more likely to use methods to catch pelagic and deep water snappers fishing an average 3.5 times per week averaging 6.6 hours per trip. The St. Thomas fishermen have been fishing longer (mean 25.4 years) compared with St. Croix fishers (21.6 yrs). The STT fishers are slightly younger and slightly better educated than STX fishers. Efforts of the Caribbean Fisheries Management Council and the USVI Division of Fish and Wildlife to manage USVI fisheries will be discussed.

Habitat Selection of Post-recruited Wedgespot Damselfish *Pomacentrus cuneatus* on Coral Reefs at Khangkhao Islands, Chonburi Province, Thailand

*Kampee PATISAYNA**

Department of Marine Science, Chulalongkorn University, Bangkok, Thailand

kampee_p@hotmail.com

Habitat selection pattern for recruitment of wedgespot damselfish, *Pomacentrus cuneatus* in coral reefs at Khangkhao Islands, Chonburi Province, Thailand, was investigated during April 2002 to May 2003. Sampling periods were scheduled monthly during dawn and dusk except for the months of May and June 2002, that samplings were conducted twice each month. The highest recruitment of wedgespot damselfish, *P. cuneatus* occurred at reef slope in station B at dawn in early May 2002 of 3.7 ± 1.2 individuals/4 m². Habitat heterogeneity at station B reflected the higher proportions of rubbles and dead corals with algae coverage than station A. This served as food source for the fish. The recruitment pattern of wedgespot damselfish *P. cuneatus* in this study followed the Recruitment Limitation Model. Juvenile abundance, habitat selection and predation governed the recruitment pattern. Habitat selections in wedgespot damselfish juveniles and adults in post-recruitment in the coral reefs at Khangkhao Islands were significantly different between the two stations. At station A the north and leeward, both phase of wedgespot damselfish were common among the massive corals at the reef flat and the reef slope. While at station B the southeast and windward, the wedgespot damselfish juveniles preferred the rubbles at reef slope. However the adults were common among the massive corals. Habitat heterogeneity at the two stations determined the habitat selection pattern in this fish. Factors determining the habitat selection of wedgespot damselfish juveniles were as followed: 1) Habitat composition in reefs were different between stations 2) Abundance of wedgespot damselfish adults maybe posed as the intra-competition with wedgespot damselfish juveniles on space and food source. 3) Abundance of predators on juveniles posed as threat so the juveniles seek for more complex habitats as refuges.

Reef Associated Ornamental Fishes of Gulf of Mannar Marine Biosphere Reserve, Southeast Coast of India - Diversity, Fishery, Threat and Management Strategies

*Jamila PATTERSON**, Deepak V SAMUEL, Dan WILHELMSSON

44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India

jamilapat@hotmail.com

Gulf of Mannar Marine Biosphere is predominately a coral reef ecosystem, which includes 21 islands surrounded by fringing and patchy reefs. 51 species of reef fishes and 14 species of invertebrates are exploited in large quantities in Gulf of Mannar (GOM) to supply the aquarium market. Some species in demand are the Clownfishes (*Amphiprion sebae*), Angelfishes (*Pomacanthus* sp.), Long-nose butterflyfish (*Forcipiger flavissimus*) and the Clown triggerfish (*Balistoides conspicillum*), and invertebrates like tubeworms (*Serpulid* sp.), anemones (*Heteractis crispa*), hermit crabs (*Birgus* sp., *Clibanarius* sp.), starfishes (*Pentaceraster regulus*, *P. affinis*, *P. indicus*, *Proteroaaster linckii*) and brittle stars (*Ophiocoma* sp.). From GOM, annually around Rs. 5 lakhs (US\$ 11,100) worth of marine ornamental fish and invertebrates are being exported to Sri Lanka alone, and about Rs. 3 lakhs (US\$ 6,675) worth are sold within India. The representatives of the order Syngnathiformes (inclusive of sea horses, and pipe fishes) were exploited to the maximum for their medicinal value and as an aphrodisiac. The Ministry of Environment and Forests of Govt. of India now put sea horses, *Hippocampus kuda*, *H. kellogi*, *H. hippocampus* and *H. trimaculatus* under the banned list. Sudden demand for Clown fish, *Amphiprion sebae* and mat anemones (*Stichodactyla haddoni*, *S. meretensii* and *S. gigantea*) led to indiscriminate exploitation during 2002. Traditional destructive fishing practices cause a permanent scar on the reefs in the region. Awareness programmes through public aquaria in the northern part of GOM have now brought out a radical change among fisher folk. The marine ornamental outlets in northern part of GOM also train fishermen about sustainable fishing without any damage to the reef ecosystems, operation of eco-friendly traps and avoidance of nets in the reef area.

Habitat Associations and Recruitment Patterns of Reef Fish in Balayan Bay, Batangas, and Puerto Galera, Oriental Mindoro, Philippines

*Badi R SAMANIEGO**

25 Junction, Los Banos, 4030 Laguna, Philippines

badisama@yahoo.com

A total of 15 reef sites in Balayan Bay and Puerto Galera were examined to explore and describe variations in patterns of distribution, composition, abundances, species richness, habitat preferences and recruitment patterns of juvenile reef fishes. Habitats were characterized at various scales, including sampling sites, degrees of embayment, reef zones, and habitat complexity and biological diversity. Linear regression, Two-way Indicator Species Analysis (TWINSPAN) and Canonical Coefficient Analysis (CCA) were used to explore the community patterns in juvenile fish. The results of the study show that the effects of sites, degrees of embayment and reef zones were important factors that influenced habitat selectivity and patterns of recruitment of juvenile fish in the area. Habitat attributes such as complexity, percentage cover of abiotics, hard coral, and algae also play an important role on the distribution of juvenile fish but the associations were confounded by the effects of sites. On finer scales of analyses, habitat attributes such as percentage cover of various benthic lifeform categories predicted poorly the abundances and compositions of juvenile fish. At this level, the number of samples considered in the study maybe very small to detect appreciable patterns. Overall, the data show that juvenile reef fish in Balayan Bay and Puerto Galera have particular habitat preferences and that reef types in a site (site effects), reef zones, embayment degrees and various categories of lifeform influence patterns of recruitment of fish. The information generated by this study is useful in selecting site for the establishment of marine reserves. The importance of a wide range of habitat types is underscored as potential settlement habitats of juvenile fish. The protection of habitats of juvenile fish will increase the potential success of protecting the adult stocks of fish in marine protected areas.

Abundance of Coral Reef Fish Larvae and their Relation with Environmental Factor around Khangkhao Island and Vicinity

*Nipat SOMKLEEB**, *Nittharatana PAPHAVASIT*

Department of Biology, Ramkhamhaeng University, Huamark, Bangkok, Bangkok Kingdom of Thailand
somkleebn@hotmail.com

Identification and distribution of fish larvae at Khangkhao Island, inner Gulf of Thailand, were carried out during June 2001 to September 2002. Sampling period were scheduled bimonthly with day and night samplings. Twelve were monitored around the island according to the reef conditions and distance from shore. Salinity, temperature and dissolved oxygen were recorded in situ. Only 6 families of fish larvae were recorded in coral reef area with dominant group in the family Pomacentridae. Fish larvae that occurred in coral reef area were most abundant during October 2001 and September 2002. Abundance of fish larvae in this group showed no significant correlation to the environmental factors. From vicinity water around this island, fish larvae of 43 families were recorded. The dominant group was family Gobiidae. Fish larvae in the family Apogonidae, Carangidae, Cynoglossidae and Nemipteridae were next in terms of abundance. Fish larvae in this group were most abundant in September 2002. The lowest abundance were recorded in March 2002. Their abundances showed significant correlations with salinity.

Evidence of Increasing Fish Biomass Outside Marine Reserves in the Central Philippines

*Brian L. STOCKWELL**

Silliman University, Dumaguete City, 6200 Republic of the Philippines
brian_stockwell@hotmail.com

Marine reserves are seen as one of the most effective management tools available to alleviate important problems facing the marine environment, particularly overfishing (Russ, et al, 2003). Major objectives in using marine reserves to manage coral reef fisheries are the protection of a critical spawning stock biomass to ensure recruitment supply and adult spill over to neighboring fished areas. The few studies that have addressed the issues of fisheries enhancement through recruitment and adult spill over have focused on a single site through time (Russ, 2002). The goals of the study are to determine (1) the relationship between target fish biomass and years of protection for reserves and non-reserve sites within the central Philippines (2) determine the effect coral cover has on target fish biomass both within and outside marine reserves. The linear regression analysis of target fish biomass and years of protection inside and outside the reserves was significant ($r^2 = 0.85$ for reserves, and $r^2 = 0.78$), while for target fish biomass and hard coral cover inside and outside the reserves the analyses were not significant. A two-way ANOVA revealed hard coral cover was similar between reserves and their non-reserves sites, but percent cover increased with years of protection. The increase in target fish biomass outside the reserve could be the result of (1) adult spillover (2) recruitment spill over and (3) the reduction in destructive fishing gears such as blasting and fine mesh nets. The non-significant effect of hard coral cover on target fish biomass may be a result of protection overshadowing its effect. Also considering the slower growth rates of corals it is possible that maximum effect may not occur till after 10 to 13 years (age of oldest reserves in study).

Reef Fish Assemblages in Tung Ping Chau Marine Park: Before and after Protection

*Man Cheong TAM**

Shatin, N.T., Hong Kong SAR Hong Kong
cheongx2@hotmail.com

Tung Ping Chau Marine Park was designated in November 2001. Within this Park, fishing is banned in two core areas [A Ma Wan (AMW) and A Ye Wan (AYW)], but is allowed in two other sites. This study compared the reef fish assemblages in summer 2003 in these four sites with four other sites outside this Marine Park that are subjected to different fishing pressures, and temporal variation in reef fish assemblages in AYW before and after protection. Both species density and biomass MDS plots indicated a spatial grouping of samples among sites. In cluster analysis, as confirmed by ANOSIM, samples from AYW and AMW formed two groups at ~ 65% similarity level with density data and at ~ 55% level with biomass data. SIMPER analysis indicated that fishery target species like *Siganus canaliculatus*, *Mugil cephalus cephalus* and *Cephalopholis boenak* were typifying groups from protected sites. Both mean fish density and biomass were significantly different among sites (Kruskal Wallis test, $p < 0.05$). Mean fish density was highest in AMW (4.63 individual m⁻²) and mean fish biomass was highest in AYW (101.10 g m⁻²). MDS plot generated using temporal species density data from 14 seasons (summer 1998 to winter 2003) indicated seasonal grouping with mean density being lowest in winter 98 (0.29 individual m⁻²) and highest in summer 03 (2.91 individual m⁻²). SIMPER analysis found that species typifying seasonal groups were different. The top three species that differentiated samples of 98/99 (pre-protection) from that of 02/03 (post-protection) were *Neopomacentrus bankieri*, *Siganus canaliculatus* and *Upeneus vittatus*. Cluster analysis and ANOSIM showed seasons and protection to be factors controlling groupings. Two way ANOVA indicated that both season and year had significant effects ($p < 0.05$) on mean density and species richness, and the interaction term was significant for mean species richness.

Fish Communities of Nearshore Rocky and Coral Reefs of the Pilbara and Kimberley Regions of Western Australia

*Michael J. TRAVERS**, *Ian I. POTTER*, *Stephen S. NEWMAN*

Murdoch Drive, Murdoch, Western Australia, 6150 Australia
mtravers@murdoch.edu.au

Fishes associated with rocky and coral reefs were sampled in shallow (ca 12 m) and deep waters (ca 22 m) using fish traps at seven locations during the day and night along ca 3,000 km of coastline in north-western Australia. The samples collectively contained 132 species, representing 67 genera and 36 families, with those obtained during the day and night separately yielding 112 and 100 species, respectively. The Serranidae, Lutjanidae, Lethrinidae and Carangidae were represented in the catches taken by trapping over reefs by 15, 14, 11 and 9 species respectively and these families collectively contributed 88.1 and 91.6% to the catches in this habitat during the day and night, respectively.

Gilutongan Marine Sanctuary, Cebu, Central Philippines: Its Biophysical and Socio-Economic Outcomes

*Rizaller CAMOLO**

Banilad, Cebu, Philippines

rcamolo@hotmail.com

In the Philippines, many local governments recognizes marine protected areas as an effective approach in addressing habitat losses and decline in reef fishery production and simultaneously generating revenues from tourism. This study evaluates the outcomes and benefits of Gilutongan Marine Sanctuary (Cebu, Central Philippine). Biophysical impact was based on the 6-year biannual monitoring, whereas, economic benefits was based on revenue generated and number of tourist visiting the MPA. Bi-annual biophysical monitoring from 1998 – 2003 showed a significant changes benthic community and reef fish population. Live hard coral cover has increased both the core and buffer zone to 25-31% from the baseline. Of the 13 families of reef fishes, abundance and size class population have significantly increased. Tourist arrival and revenue generated rapidly increased over the first 3-year of protection and gradually decreased. Other outcomes includes vital lessons learned in the process to include: (a) that clarifying goals, a clear process, and the involvement among co-managers and partners in the management process for MPAs should be prioritized early planning process; (b) that formulation and adoption of a MPA management plan is important to determine the framework for agencies and other partners to work effectively together, (c) that zoning of activities within the MPA can minimize tourism impacts and focus protection efforts on the most valuable resource areas, (d) that multi-sectoral monitoring of MPAs is a good means for providing feedback to MPA co-managers, and (e) that tourism may be an asset of a MPA to generate funds for its operation and to provide indirect economic benefits to communities.

Pattern in the Co-occurrence of Fishes Inhabiting the Coral Reefs of Bonaire, Netherlands Antilles: Implications for Planning Networks of Marine Reserves

Peter JAUSTER, Brice X SEMMENS, Kimberly BARBER*

1080 Shennecossett Rd., Groton, Connecticut 06340 United States of America
auster@uconn.edu

We analyzed species associations in Bonaire Marine Park using fish diversity and abundance surveys conducted by recreational divers between 1995-2001. Divers collected data through the REEF (Reef Environmental Education Foundation) Fish Survey Project; our analysis only used data from surveyors classified as "expert" by REEF. Surveys consisted of random timed swims within particular habitat and depth bins. Surveyors listed all positively identified fish species and their associated abundances along a categorical scale. We computed Bray-Curtis similarity coefficients for all species pairs for the top 100 most commonly sighted species. Hierarchical agglomerative clustering and non-metric multidimensional scaling (MDS) of the matrix of similarity coefficients were used to quantify species associations. Cluster analysis identified three groups of species. MDS results showed species groups occupied distinct regions across a continuous gradient in two-dimensional space, but did not form distinct and separate groups. While two groups occurred within statistically similar depth categories, the third group was in significantly deeper water. While each group contained a full range of trophic guilds, the deeper group contained fewer species in the herbivore guild. These results suggest that species interactions, and/or species-habitat relationships, even at the scale of roving diver surveys (0.5-1 km in length), may be important behavioral attributes mediating the local structure of fish assemblages on coral reefs. Research needs to be directed at the subject of behavioral mediation of local diversity. Further, such interactions should be considered when planning networks of marine reserves (e.g., include wide depth ranges and insure significant abundances of all trophic guilds within a network of sites).

Standardization of Heterologous Molecular Marker Protocols in Zoanthids (Cnidaria: Hexacorallia)

Juan E CAMACHO-LONDONO, Alberto ACOSTA, Manuel RUIZ-GARCIA*

Carrera 7 No 43-82 Republic of Colombia

quicapu@yahoo.com

Coral reef ecosystem management in Colombian Caribbean has been centered in communitys structure studies of scleractinian corals without considering population genetics information defined as high-priority for conservation. Investigation in Colombia has serious restrictions of manipulation and collection in spite of the fact that has gotten lost 33% of coral reef. This implies to look for model species to be used in evaluation of molecular marker functioning and of existent sampling methodologies; those species have to be important in the structure and dynamics of reefs ecosystems, and with any restriction for their collection. The objective of this study was to standardize protocols for the use of five nuclear molecular markers (three microsatellites and two rITS) that are available for scleractinian corals and gorgonids, in two zoanthid species (*Palythoa caribaeorum* and *Palythoa mammillosa*). Collection and preservation protocol of samples, DNA extraction protocol and PCR protocols, were standardized. It was found that *Palythoa caribaeorum* is polymorphic for all five markers and *P. mammillosa* is polymorphic for three of them; it means that the markers have potential informative utility for population genetics or systematic works. DNA extraction protocol was achieved using bone extraction buffers used in forensic science, this protocol showed to be useful to extract DNA from the zoanthids species and of three scleractinian using tissue without isolating it from the inorganic matrix. Chelex100 extraction was performed too for rapid DNA extraction. PCR amplifications of seven additional nuclear markers (five ISSR, one rIGS and one rITS) were obtained in *P. caribaeorum*. According to results, *Palythoa caribaeorum* is more appropriate than *P. mammillosa* to be used as model for genetic studies because *P. caribaeorum* amplified for all markers, it has a larger distribution range -horizontal and bathymetric-, and there are information about its biology and ecology.

Bio-Physical and Socio-Cultural Basis for Medium-scale MPA Designs - The Samoa Experience

*David A FISK**

PO Box 2149, Apia, Samoa Independent State of Western Samoa

davefisk@ipasifika.net

Bio-Physical attributes and socio-cultural aspects of two medium scale MPA project areas in Samoa were used to provide critical input into the design and establishment of multiple use MPA's. The scale of the projects covered approximately 10-20km of coastline in both cases, and included major coral reef, offshore island, seagrass and mangrove habitats. Ten to 12 contiguous villages incorporating two politically acknowledged Districts, were involved in both cases and defined the geographical limits of the projects. Broad scale surveys of all habitats were conducted along with extensive consultation sessions where local knowledge and perceptions were integral to the recommended MPA design. Physical features that proved to be critical included local physiognomic features that carried local names and references to the physical features of a site, circulation patterns in lagoons, estuaries, and near-shore habitats, physical heterogeneity, and relative depth profiles. Biological features of most influence included current viable populations of economic, subsistence, and non-economic sessile invertebrate populations. Also, the concentration points for edible fish species, along with well known spawning and feeding aggregation sites, and juvenile fish aggregation areas. The social considerations included acknowledging the extremes of acceptability of No-Take sites at a village scale, the natural competition between participating villages, and the presence of previously established and often non-functioning No-take areas from other projects. The final MPA design was a compromise with some better than expected outcomes and some less than expected outcomes, but the scale of operation of the projects meant that despite some 'losses' and 'gains', the overall final outcome was potentially viable in achieving the objectives of enhancing sustainable fisheries and protecting biodiversity.

Conservation, Connectivity, and MPA Design in the Hawaiian Islands

*Helen E FOX**, *Martin P BUCHERT*, *Cedric CHAVANNE*, *Pierre FLAMENT*
 PO Box 1346 Kane'ohe HI 96744 United States of America
hfox@hawaii.edu

Well-designed networks of no-take reserves within Marine Protected Areas (MPAs) may provide stability against ecological disasters and aid in long-term fisheries management by serving as genetic reservoirs of biodiversity and sources of recruits for re-colonizing damaged or depleted areas. Better knowledge of currents and larval dispersal is critical to understanding how reef populations are connected. Connectivity can be difficult to assess due to variability in these factors. However, data from an existing long-term oceanographic database makes it feasible to evaluate these large-scale complex processes. We will present analysis of a large dataset of surface drifting buoys (356 WOCE/SVP surface drifters that have been deployed in or passed through the central North Pacific between 1989-1999). We are developing a frequency distribution of the Lagrangian flow (movement of water masses and therefore relatively passive larvae within those water masses) between the islands in different seasons and oceanic regimes. The resulting data, combined with existing information on peak spawning events and larval duration for a number of economically and ecologically important reef species, will generate predictions of population connectivity that can be tested with molecular genetics in the future. As a complementary approach, we are developing a connectivity index to predict potential levels of connectivity under different hypothetical MPA plans for the Hawaiian islands, using the reserve system selection tool MARXAN and assuming a bimodal distribution of dispersal supported by several recent studies.

An Economic Valuation of Coral Reefs in the Wider Caribbean Region

*Suzanne L GARRETT**
 4600 Rickenbacker Cswy., Miami FL 33149 United States of America
sgarrett@rsmas.miami.edu

Over the last two decades, coral reefs in the Caribbean have been subjected to many stressors, both natural and anthropogenic, leading to degradation of a vital resource. Since reefs provide many functions and have many economic uses, the region will be greatly affected if its coral reefs are lost. In order to encourage further support for reef management and conservation efforts, a region-wide economic valuation of coral reefs was performed, addressing contributions from industries such as fishing and tourism, as well as natural functions, ie, coastal protection. A method using selected countries to represent geopolitical groups within the region was devised, and a value for reefs in the region was estimated. Social benefits such as employment and fish protein consumption were included. Given the social and economic importance of Caribbean reefs, a more diverse "portfolio" of management strategies and funding mechanisms is encouraged. More cohesive regional coordination is also recommended.

Coral Reefs of the Woody Island in South China Sea

*Huang HUI**, *Huang XIAOPING*, *Wang DAOLU*, *Huang LIANGMIN*,
Zou RENLIN, *Dong ZHIJUN*, *Li XIUBAO*
 South China Sea Institute of Oceanology, The Chinese Academy of Sciences,
 Guangzhou P.R. China 510301 People's Republic of China
huanghui@sccsio.ac.cn

The Woody Island, one of the largest islands in South China Sea, covers a square of 1.8km². According to the geographical orientation, four fixed surveying and drawing sections were set up (I:west, II:north, III:east, IV:south) in the Woody Island. The cover degree of living corals, the composition and size of the community were surveyed in August, 2002. The cover degree for the four fixed surveying and drawing sections was 52.6% (I), 93.4% (II), 76.8% (III), 80.2% (IV) respectively. The dominated species was *Acropora humilis* (Dana) in I section, *Montipora foliosa* (Pallas) in II section, *Acropora formosa* (Dana) in III section and *Acropora millepora* (Ehrenberg) in IV section. Based on the data of our investigation, 25 species of the hermatypic coral were found in shallow water areas. With a view to the serious condition of the coral reef and impacts of human activities in the Woody Island, the necessity and possibility for building up the marine protection reserve of the Woody Island coral reef was brought forward in the article.

Developing a System of Effectively Managed Marine Sanctuaries in the Philippines: A National Network Strategy

*Margarita N LAVIDES**, *Isidore ANCOG*, *Socrates BANZUELA*, *Marivic PAJARO*
 4F Fil-Garcia Tower Kalayaan cor. Mayaman Sts. Diliman, Quezon City, Philippines
lavides@yahoo.com

Over the past two decades, establishment and management of marine protected areas (MPAs) has become a popular fishery and coastal management technique in the Philippines. There may be well over 600 established MPAs in the Philippines with only 18% of them functional. Meanwhile, community based MPA managers, numbering about 150 representing about 87 community based MPAs in the Philippines, mostly fisherfolks and village-level local government units, gathered together in 1999 to form a national alliance and called themselves PAMANA Ka Sa Pilipinas Inc. Sixteen months after its formation, strengthening of PAMANA fell within the framework and implementation of Haribon Foundation's project called Building a National Community of Local Coastal Resource Managers (BNC-LCRM) aka PAMANA Project. That is, aiming for a strengthened national network of MPA like PAMANA thru capacity building, participatory research and policy advocacy can lead to the development of an effectively managed marine sanctuaries. After its 2nd and 3rd National Assemblies in 2001 and 2003, it has a new set of elected officers and has set the policy and organizational agenda that is presently charting the organization's activities. At present, PAMANA is active in creating a more conducive policy environment related to fishery and MPA management and coastal management in general. Policy advocacy carrying national and local issues are being conducted both at the national and local levels at the same time creating opportunities for PAMANA ecosystem based/baywide organizing and networking activities. On the other hand, participatory research and trainings are being done primarily with the use of participatory marine sanctuary monitoring tools as part of membership development services. Significant lessons has been building up since PAMANA's conception, currently numbering about 122 member sites, and that include areas such as national alliance building, policy advocacy, participatory marine sanctuary monitoring and training and MPA management.

Impact of a Marine Fishing Reserve on the Abundance and Demography of the Red Hind Grouper *Epinephelus guttatus* in Culebra Island, Puerto Rico

*Maria Del Mar LOPEZ-RIVERA**, *Alberto SABAT*

Department of Biology, UPR, P.O. Box 23360 San Juan, Puerto Rico 00931
Puerto Rico

mdmlopez@aol.com

The Luis Pena Channel Marine Fishing Reserve (LPCMFR) in Culebra, Puerto Rico was established in 1999 to mitigate the exploitation of local over-fished stocks, protect important coral reef and sea-grass communities, and to provide socio-economic benefits to local base communities. For this study we used the commercially exploited red hind grouper *Epinephelus guttatus* as a target species to determine if the LPCMFR is effective in enhancing the abundance and survivorship of this species. A mark-recapture study was used to estimate: stock abundance, size structure, growth rate and possible spillover of *E. guttatus* in three sites inside and three sites outside the LPCMFR. Between October 2002 and December 2003, sixty fishing events were conducted at the six study sites for a total capture of 418 red hinds (227 inside, 191 outside). A total recapture rate of 25.4% was obtained. Two of the three sites inside the reserve show the highest estimates of red hind abundance. The remaining site inside the reserve plus one site outside exhibit the lowest abundances, while the other two sites outside show intermediate abundances. Mean average size of the red hinds inside was significantly higher than those captured outside. No significant differences in growth rates were observed among the six sites. Red hinds exhibited high site fidelity, for all the recaptures were made at the site of initial capture. The greater abundance and average size of red hinds inside the LPCMFR shows a positive effect of the reserve in decreasing fishing mortality. However the high site fidelity exhibited by red hinds precludes a possible benefit of spillover.

Estimation of Entrainment Potential in Philippine Coastal Waters

*Marites M MAGNO**, *Cesar L VILLANOY*

Velasquez St., College of Science, University of the Philippines, 1101 Diliman,
Quezon City Republic of the Philippines

magnom@upmsi.ph

Wake features and eddies are recirculation zones in coastal waters which can potentially entrain larvae and other suspended particles. These features play a significant role in larval recruitment process since the scale and patterns of larval dispersal are often influenced by local coastal ocean dynamics. The presence of islands and coastline irregularities (i.e., headlands) obstructs normal flow of water thereby causing flow separations in the lee of the islands or turbulent secondary circulation past a headland. The resulting secondary circulation is a function of the shape of the island or coastline and the speed of water, mainly tidal current, moving through or past an obstruction. In this study we assumed that a more complex coastline configuration and stronger water flow would have a greater potential to produce entrainment features. This condition would make a coastal area highly suitable for marine protection because of its potential to promote local recruitment of fish and corals. In order to assess the validity of this assumption, the areas where both conditions (high tidal velocity and coastline rugosity) exist were mapped by deriving tidal velocities from a two dimensional tide model and an assessment of coastline complexity around Philippine coastal waters. Initial results show some agreement on the presence of reefs in areas with high rugosity which are further supported by available satellite images. Characteristic distances between areas of entrainment and tidal advection scales can give some insights into spatial scales, which may be used in developing networks of marine protected areas (MPA).

Biodiversity Information Sharing System for Protected Areas

*Imelda C PANGGA**

3rd floor ERDB Bldg., College, Laguna Philippines

melpangga@arcbc.org

The ASEAN Regional Centre for Biodiversity Conservation is a network of institutions designed to strengthen biodiversity conservation in the ASEAN. The Centre is located in Los Banos, Philippines and linked to focal agencies working on conservation of biodiversity among the ASEAN Member Countries. It started operation in 1999 and jointly funded by European Union and the ASEAN. ARCBC currently manages and maintains metadatabase consisting of protected areas and species of flora and fauna of the ASEAN and biodiversity institutions, experts and training resources data. The ARCBC metadatabase is accessible through a website (www.arcbc.org). ARCBC developed a state-of-the-art data management system that is easily transferable to its NBRUs or biodiversity focal agencies in each ASEAN country. The database is web-ready and could be used as an effective database platform suitable to the needs of the NBRUs and the ARCBC. ARCBC developed the following software products for making on-line databases: 1. ABISS Web-database module – Full biodiversity data search and retrieval engine on any number or type of items stored in the database. It has a mapping feature which can show a map of a region showing point data from the database with any number of zoom levels. Individual points can be queried to have access to the underlying data (e.g. distribution of species) 2. GenSQL –data transfer utility which uses Borland Database Engine (installed with it) 3. Remote Datapump- enables the transfer of data tables between two different databases, or to update data from another table in a remote or local server (web-based) 4. BISS Editor –provides easy access to records and datasets in a SQL database

The website shows the searchable database of plant, butterfly, amphibia, bird, reptile, freshwater fish. On-line species data includes 2396 birds, 945 mammals, 655 amphibians, 1995 freshwater fish, 1652 reptiles, 33411 plants. The database for plants is linked to the website of Leiden Herbarium, amphibians database is linked to the American Museum of Natural History, mammals database is linked to the Smithsonian Institutions website, and the Freshwater fish databases is linked to the Fishbase website. A total of 1518 protected areas are currently on-line. All these software products were made out of free softwares and given for free to NBRUs. Even maintenance use is free of charge. They were made out of free softwares and were made available to the NBRUs to be used in managing their country data sets. The BISS is also applicable in databasing of coral reef areas and marine protected areas.

Case Study: Planning a Marine Protected Areas System with Community and Scientific Knowledge

*Valeria PIZARRO**, *June Marie MOW*

School of Biology, Ridley building, University of Newcastle, Newcastle upon Tyne, Tyne & Wear, NE1 7RU, UK United Kingdom of Great Britain and Northern Ireland

Valeria.Pizarro@ncl.ac.uk

A Marine Protected Area (MPA) system has been planned during the last four years, by CORALINA, the Corporation for the Sustainable Development of the Archipelago of San Andres, Old Providence and Santa Catalina, Colombia, with funds from the Global Environmental Facility (GEF) of the World Bank. The main objective of the MPA system is to conserve and ensure the sustainable use of the marine resources. Like the majority of the MPA systems around the world, scientific research has been developed and used to design and locate the different MPA zones (i. e., no-take, no-entry, artisanal fishing, special use and general use) around the islands and reef complexes. What makes this MPA special is the use of traditional (community) knowledge and the involvement of stakeholders during all the stages of the project. Land-based threats, especially around San Andres Island, and overfishing are the main problems faced by the Archipelago. Because of a lack of governmental control on artisanal and industrial fishing, environmental awareness programs have been carried out within the community. Community participation gave tools to identify and protect potential spawning aggregation sites around the two most populated islands (San Andres and Old Providence), and it also encouraged the community's involvement in enforcement programmes. Basic data gaps were filled during scientific and technical expeditions. Incorporating reliable science with community knowledge and support has resulted in the design of an MPA system that is expected to cope with both conservation and sustainable aims. Local community and government are responsible for the success of the MPA system. Future changes in the shape and location of each zone can be made when scientific, economic and social assessments justify them.

Worldwide Cruise Line's Caribbean Cruise Board Game*Clive A RAMSDEN**

3, a, Torrens Street, Angel, London, EC1V 1NQ U.K. United Kingdom of Great Britain and Northern Ireland

cliveramsden@worldwidecruiseline.com

This new Board Game celebrates and educates players about the people and islands of the Caribbean, especially the wonderful light and sunshine which makes the beautiful blue Caribbean Sea such an excellent home for some of the most eye-catchingly beautiful creatures on this planet, both above the sea in the rainforests, and below the waves in the crystal-clear turquoise waters. This Game also educates players about the indigenous peoples of this magical region who are brought up to live in harmony with nature and to respect all living things. WorldWide Cruise Line's Caribbean Cruise has a stylized map of the Caribbean as the Gameboard; ten different sail boats, cruise ships, converted freighters or sailing clippers as choices for Game pieces; a scorecard of over 150 different Caribbean Island destinations; and most importantly, almost 400 Ship Cards and Island Cards which educate anyone playing this game about the history, art, literature, beaches, shopping, food, ecology, snorkling trails, scuba dive sites, reefs and conservation associations of this region. Ship and Island Cards highlight, for example, Los Roques National Park, John Pennekamp Coral Reef State Park, Coki Point Observatory, Hol Chan Marine Reserve, the Exuma Cays Land and Sea Park, Garden Key, the Bay Islands Conservation Association, Belize's Barrier Reef and tell of the star corals, orange cup corals, azure vase sponges, elkhorn and clover corals who share the aquamarine waters and it's fringing and barrier reefs with blue doctorfish, hovering trumpetfish, purple parrotfish, wrasses, seahorses, triggerfish, as well as manta rays, sting rays, sharks and barracuda. As the designer of this Game, I believe that people need to communicate with one another across the generations, and there is a need to educate and help make people aware of Nature's simplicity and generosity and the inter-relationship between all that exists in creation.

Sustaining Marine Protected Areas through Continued Monitoring and Evaluation: The MPA Report Guide and Rating System*Alan T WHITE, Anna B MENESES*, Ming OVENDEN, Sheryll TESCH*

3rd Floor, PDI Condominium, Banilad, Cebu City Republic of the Philippines

ccef@mozcom.com

In the 1980s, Philippine researchers started to document dwindling fish catches and reef destruction and began to promote marine protected areas (MPAs) to protect coastal reef habitats and to enhance reef fisheries. Now in 2003, the country is promoting integrated coastal management that includes MPAs as a key strategy. Data sets beginning in 1984 in 12 study sites representing the first MPAs designated have been monitored to the present using the same methods that are now adopted in the Philippines as the standard protocol for coral reef monitoring. Yearly expeditions since 1992 have documented the overall status within and around the identified MPA areas. Now, approximately 50 sites have been monitored using the same methods since the late 1990s that are contained in the MPA Database of the Coastal Conservation and Education Foundation. This database highlights trends and clearly shows the methods used to collect and analyze the data. The MPA Report Guide and Rating System is a tool used to extract information on: MPA basic description; general status; management rating system; biophysical data; human activities and natural disturbances; and community perception. Benefits derived from the MPA Guide are improved management of individual sites through feedback to management groups, increased awareness of the problems and solutions surrounding MPA management and a view of improvement that encourages more and better MPAs in the country. Also, more MPAs are collecting user fees reflecting the willingness to pay of foreign and local visitors for recreation in the MPA.

Advanced Energy System for Coral Reef Society

*Tohru KATO**, Hajime KAYANNE, Ken NOZAKI, Ken KATO, Kenji OTANI, Miki YOSHIHARA, Akira NEGISHI

AIST-2, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568 Japan

to-kato@aist.go.jp

According to the energy analysis of typical fishermen of coral reef islands, most of the consumed energy is fuel for boats mainly on fishery use. We propose an advanced total energy system to meet the future coral reef society in consideration of influence to give to coral reef islands area of sea level rise with global warming. The advanced total energy system proposed is to produce synthetic fuel such as GTL(gas to liquid: that is synthetic gasoline and gas oil) and DME(dimethylether) which are applicable to the boats, and to inject by-produced carbon dioxide which is produced from the synthetic fuel production process to limestone layer under the coral reef area. It is surmised that the raw materials of synthetic fuel is coal from Australia and hydrogen from renewable energy system construct on the reef.

Satellite-based Typology of Atoll Islands, Environmental Controls, and Human Settlement

*Hiroya YAMANO**, Hiroto YAMAZAKI, Hiromune YOKOKI, Toru YAMAGUCHI, Masashi CHIKAMORI, Masayuki TAMURA, Hajime KAYANNE, Shinya WATANABE, Satoshi YOSHII

16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan

hyamano@nies.go.jp

Reef islands, such as motus or sand cays, are regarded as a combined product of geological, biological, and physical factors. They have been formed in the late Holocene, and the primary factors have been considered to be relative sea-level fall and resulting modification of reef-building organisms and depositional environment. However, reef islands have diversity in size, structure and component, which is expected to be a result of difference in the significant factor(s). In addition, this diversity could affect the human settlement on the islands. We use satellite data to map and characterize atoll-island types in the Republic of Marshall Islands, based on vegetated, emerged, intertidal, and submerged areas. These maps serve as a baseline for discussing the relationships between reef islands and the environmental controls and human settlement. In Marshall Islands, several types of the islands are revealed by cluster analysis of the segments of atoll rims, which could correspond to physical factors (wind and wave) and influence the date of human settlement.

Food Source Analyses Using Fatty Acid Biomarkers : A Case Study for Tilapia

Sakduh *ABDULKADIR**, Makoto TSUCHIYA
Senbaru-1, Nishihara, Okinawa 903-0213, Japan
sakdu@yahoo.com

Fatty acid biomarkers have been successfully used to discriminate the sources of organic matter and also as trophic markers to determine the transfer of organic matter within the food webs in marine ecosystem. Gut contents and muscles of tilapias *Oreochromis mossambicus* were examined by using fatty acid analyses in order to know the sources of organic matter and their transfer into the food chain in Manko estuary, Okinawa, Japan. Analyses of the gut contents of tilapias showed that organic materials were composed of zooplankton, vascular plant/mangrove detritus, dinoflagellates, microalgae as well as bacteria, as shown by composition of their respective fatty acid markers. The main contributions of organic matter sources were zooplankton and vascular plant/mangrove detritus ranged from 14.5 % to 21.1 % and 10.9 % to 14.4 % respectively. More over, all of those fatty acid markers were also detected in the muscles of tilapias indicating that those of organic matter were assimilated in the muscles of tilapias. Zooplankton and microalgae were the primary food sources for tilapias contributing 16.6 % to 25 % and 5.4% to 10.2 % respectively in the diets. These results provide evidences that tilapia truly belongs to a suspension-feeding fish. It may be useful to use fatty acid biomarker approach to study the food webs in coral reef ecosystems.

Monitoring of Red Soil Sedimentation in Shiraho Coral Reef, Ishigaki Island, Okinawa through Participation of Local Residents

Shigeki *YASUMURA**, Satoshi MAEKAWA, Tetsu SATO
118 Shiraho, Ishigaki, Okinawa 907-0242 Japan
yasumura@wwf.or.jp

WWF Japan Coral Reef Conservation and Research Centre in Shiraho, east coast of Ishigaki Island, aims to establish a co-management system of coral reef environment with local communities. We focus on participatory reef monitoring with local residents. We have been monitoring the soil runoff within Shiraho Moat every three-month from 2000 to 2003, by quantifying suspended soil particles in sea sediment. The survey was designed for beginners so that they easily participate in and enjoyed it by using sea-kayak and GPS. On the scale of 1-8, where 1 (<0.4kg/m³) was clearest and 8 was the most contaminated (>200 kg/m³), average reading was 5(14.8kg/m³). The area around the Todoroki River estuary always showed the highest level within the area (6 (87.5kg/m³) on average). More than 200 inhabitants participated as a volunteer. By participating in survey, local residents deepened recognition about the present situation of coral reef. Some volunteers who joined the survey repeatedly became to play a role of a tutor, explaining situations of sedimentation to beginners in addition to investigation methods. These residents have a potential to be a core group of people who will be actively involved in the co-management process of the coral reef environment. Majority of Group member are the immigrants recently moved in the island from main Islands of Japan attracted by its natural surroundings. On the other hand, local farmers with a long history of residence and administrators are the major stakeholders who play a key role for control of the soil runoff. The core group of participants of the survey can be the supporters of the local farmers to help taking acceptable measures of runoff prevent

Extensive Land Modification and the Decline of the Coral Reef Condition. A Case Study of the Shiraho, Ishigaki Island, Okinawa

Hitoshi *HASEGAWA**
Setagaya 4-28-1 Setagaya-ku , Tokyo Japan,154-8515 Japan
hasegawa@kokushikan.ac.jp

This study aims to clarify the relationship of extensive land modification and the decline of the coral reef condition using a series of land use maps and ortho photographs of coral reef taken from 1972 to 2003. The Shiraho Coral Reef is located along the east coast of Ishigaki Island. Shiraho reef is a relatively unspoiled environment in the Ryukyu Island, but the catchment area has been a focus of agricultural production and with intensive soil erosions. In Ishigaki Island extensive land modification started in 1972, when the administration of Okinawa was reverted to Japan. Red soil runoff, sedimentation and eutrophication of the coral reef began at the later half of 1970's. River and groundwater discharges from adjacent terrestrial areas are the largest source of nutrients to the inshore areas of the Shiraho Coral Reef. Run-off resulting from land-based agricultural activities (sugar cane cropping and cattle grazing) is the primary anthropogenic influence on water quality. Intensive cropping of sugar cane caused the strong run-off under the subtropical climate. Outflows from the farmland conditions nutrients came from chemical fertilizer. In addition, Ishigaki Island has the highest amount of production in beef cattle in Okinawa Prefecture. Nutrients, which flow into rivers directly from cattle sheds, could be a large input of nitrogen to coral reefs, resulting in the decline of the coral reefs. Intensive sedimentation and eutrophication influences water quality and coral reef ecosystem in the Shiraho. Following the increase of nutrient the sea grass communities of inner reef flat expanded and the corals reduced there area. Okinawa Prefecture and Ishigaki City tried various land management measures. But the red soil runoff and decline of the coral reef condition have continued

Global Coral Reef Targeted Research and Capacity Building: A Case for Applied, Adaptive Science to Support Management and Policy

*Anthony J HOOTEN**

4900 Auburn Avenue, Suite 201 Bethesda, Maryland 20814 United States of America

ajh@environmentservices.com

By the year 2008, the world population will exceed 6 billion people, with 75% living within 100 km of the coast. The increase in demographics near coastal and marine resources has far-reaching implications concerning impacts to marine ecosystems and their productivity (e.g. sedimentation and pollution) as well as materials being extracted from them (e.g. overfishing and destructive fishing). The importance of coral reef ecosystems to global commons, tropical developing nations, the environmental services they provide, and their relevance to poverty alleviation has been well established in the scientific and conservation literature. Yet fundamental gaps in the knowledge of coral reefs systems remain. Previous viewpoints have criticized the apparent inability of the scientific community to coordinate its efforts in filling information gaps to contribute to management and policy. For the first time in history a global, coral reef targeted research initiative has been endorsed for funding by the Global Environment Facility (GEF) to address priority gaps in knowledge that have the potential to increase management capacity and support international policy. The purpose of the targeted research is to establish an investigative framework to test specific hypotheses related to major human and natural factors threatening coral reef quality. It is comprised of a hierarchical set of standardized, scientific investigations designed by collaborative scientists internationally and implemented at regional and local levels. The program has been developed based on international scoping of investigative priorities following the 1998 ENSO, and is being designed for implementation over 15 years. The program structure involves six main working groups investigating bleaching and local ecological responses, spatial connectivity, disease, restoration and remediation, remote sensing, and modeling and decision support. The research results are coordinated by a synthesis panel and a system of peer review. The details and timeline of the first five-year phase of the program are presented.

The Establishment of Coral Reef Mesocosms in National Museum of Marine Biology and Aquarium, Taiwan

*Tung-Yung FAN**, *Lee-Shing FANG*

2 Houwan Road, Checheng, Pingtung 944 Taiwan

tyfan@nmma.gov.tw

Four coral reef mesocosms have been established for exhibit, education and research in the Coral Kingdom pavilion at the National Museum of Marine Biology and Aquarium, Taiwan since July 2001. All mesocosms use live sand and live rocks as biological reactors to control water quality and maintain biodiversity. The theme of the four tanks is the stony coral community on the reef flat, the soft coral community on the reef slope, the gorgonian coral community on the reef wall, and a gigantic isolated coral reef. Their volumes are 9, 12, 19, and 264 m³, respectively. These mesocosms simulate the tropical coral reef communities in the Kenting National Park, southern Taiwan. The communities comprised of more than 60 coral species. Most corals are healthy and grow continuously. Some brooding coral species, such as *Stylophora pistillata*, *Pocillopora damicornis*, *Seriatopora hystrix*, and *Euphyllia glabrescens* have been producing viable larvae. The pocilloporid corals have more recruits ($n = 92$) on the wall than those ($n = 22$) on the rocks. The mean annual relative growth rate of the juvenile pocilloporid colonies is 197.4 % ($n = 9$). In addition, the octocoral coral species of *Sarcophyton*, *Nephthea*, and *Junceella* had natural recruits by asexual fragments. The mean photosynthetic to respiration ratio of the stony coral mesocosm is 1.076 ($n = 9$). The knowledge and technology to establish and maintain these coral reef mesocosms are important in conservation and restoration of coral reefs. Moreover, as controllable facilities, these mesocosms are powerful tools for experimental research on the effects of global environmental change at community and organism levels.

Artificial Breeding Method of *Acropora hyacinthus* (Anthozoa, Scleractinia)

Tohru HAYASHI, *Fumihito IWASE**

560 Nishidomari, Otsuki town, Hata-gun, Kochi pref., 788-0333 Japan

tohru@kuroshio.or.jp

It becomes easier recently to culture coral because improvement of the aquarium devices. However, the technology to culture coral from the fertilized egg to matured colony has not been established yet. To establish the culture technology through the life history of coral is important to proliferate coral artificially, also to know the environments for the natural recovery of coral. The research to establish the culture technology of *Acropora hyacinthus* from egg to matured colony has carried out in the Biological Institute on Kuroshio since 1997. *Acropora* is most plentiful coral in the coral reef and is the main constitution element of coral view. *A. hyacinthus* is a common table type *Acropora* species, distributes widely from the coral reef to the temperate area in the shallow water in Japan. We have come to be able to cultivate *A. hyacinthus* from the eggs collected from the sea to branched colonies in the aquarium tank by 2003. We show the details of technology of egg collection / fertilization / culture from fertilized egg to planula larva / adhesion and fixation on the base / culture from polyp to branched colony.

Photosynthesis and Calcification in a Balanced Aquarium for Coral Reef Ecosystem

*Yutaka IKEDA**, *Hiroshi HATA*, *Ken NOZAKI*, *Masaya TSUDA*, *Hajime KAYANNE*

2-5-8 Kitaoyama Minatoku Tokyo 1078658 Japan

yikedata@hazama.co.jp

The balanced aquarium called "Monaco Aquarium" is placed at the National Museum of Emerging Science and Innovation at Tokyo in Japan. The aquarium includes hard and soft corals, sea grass, fish, prawn etc., which consist of real coral ecosystem. The volume of aquarium is 1,500 liters with artificial seawater. The water temperature is kept at 25 centigrade. The metal halide lamp and blue light (its wave length is 420nm) were provided periodically on the surface. In a day, each illuminating time of duration were ten hours for dark period, two hours for metal halide lamp only, ten hours for metal halide lamp with blue light and two hours for blue light only, respectively. In the aquarium, the measurement device of pH and pCO_2 (partial pressure of carbon dioxide in water) was set and their continuous change per one minute were monitored through display for viewers. TA (total alkalinity), DIC (dissolved inorganic carbon) were calculated from the values of pH and pCO_2 at each time. The rates of photosynthesis and calcification are estimated from the increase and decrease of TA and DIC. These rates were changed according to the illuminating period. Integrating these values, daily net photosynthesis and calcification were evaluated. As a result the net photosynthesis and calcification per unit square meter were 14.6, 0.5 mmolC m⁻² day⁻¹, respectively. These were less than the actual values of real coral reefs in Ishigaki Island, Japan and Palau Island, Republic of Palau. Some of the reasons for these low rates might be small amount of corals compared with the aquarium volume, weak irradiance and the unknown effect of blue light illumination.

Morph-related Growth Variations in Captive-Grown Colonies of *Galaxea fascicularis* (Linn.)

*Richard Thomas Jr B PAVIA**, *Laurie Jeanne H RAYMUNDO*

c/o Department of Biological Sciences, College of Science, University of Santo Tomas, Manila Philippines

rtbpavia@yahoo.com

The success of captive coral husbandry depends not only in providing appropriate abiotic conditions and selection of suitable species, but also in considering the variations that occur within single coral species and how these affect colony growth parameters such as bud production, tissue expansion, and colony morphology. To investigate the effects of intraspecific variations on colony growth, isolated polyps of three color morphs (Brown 'B', Green Septal tentacle 'Gs', and Green lateral tentacle 'Gt') of the scleractinian *Galaxea fascicularis* (Linn) were grown in captive conditions under identical environmental conditions. Over 11 weeks, growth performance differed significantly between the three morphs. Colonies of the 'B' morph exhibited greater surface area increase ('B': 177.9 ± 17.33 mm², 'Gs': 109 ± 22.8 mm², 'Gt': 146.5 ± 39.6 mm²), and bud number ('B': 32 ± 3.9 buds, 'Gs': 19 ± 1.8 buds, 'Gt': 12.3 ± 5.6 buds), while the Gs morph exhibited the highest bud density ('Gs': .053 ± .009 buds/mm², 'B': .050 ± .003 buds/mm²; 'Gt': .019 ± .005 buds/mm²). Developing colonies of each morph exhibited unique morphologies. Colonies of the 'B' and 'Gt' morphs formed spreading colonies with either high bud number and density ('B' morph) or low bud number and density ('Gt' morph). Colonies of the 'Gs' morph exhibited tall, columnar colonies with high bud number and density. This indicates that for this species, growth strategies may be morph-related. This can be utilized to achieve the desired transplantation effect: spreading and rapidly budding morphs can be used to cover large areas where rapid growth is needed while tall, slow growing morphs can be used in small areas without risk overgrowth or resultant competition.

How Can Public Aquariums Contribute to Coral Reef Conservation and Restoration? Advances in Captive Coral Breeding

*Dirk PETERSEN**, Michael LATERVEER, Helmut SCHUHMACHER

P.O. Box 532, 3000 AM Rotterdam Kingdom of the Netherlands

d.petersen@rotterdamzoo.nl

Today's public aquariums show great advances in the husbandry and asexual propagation of reefbuilding corals. Although captive sexual reproduction has been occasionally reported, there has been till now a lack of knowledge to promote ex situ coral breeding, especially on a larger scale. We present results of three years research at the marine laboratory of the new Oceanium of Rotterdam Zoo, The Netherlands. The project was aimed to develop breeding techniques using field collected gametes and larvae from brooding species, which have been maintained in a closed system aquarium. We will show maximum settlement and recruitment rates of three Caribbean and two Indo-Pacific coral species to give an idea about possibilities and limitations. We will outline how public aquariums might be involved in in and ex situ projects to support coral reef restoration and conservation.

Deepwater Corals as Fish Habitat within the Context of Seamount Landscapes

*Peter JAUSTER**, Jon MOORE, Kari HEINONEN

1080 Shennecossett Rd., Groton, Connecticut 06340 United States of America
auster@uconn.edu

Seamounts are drowned volcanoes rising from abyssal depths. The epifaunal community on seamounts is dominated by suspension-feeders and deepwater corals are dominant taxa. Fishes on seamounts exploit a range of landscape features that likely enhance probabilities of prey capture and reduce predator success. Landscape features occur at multiple spatial scales. Oceanographic landscapes occur at the scale of kilometers to 100s km where seamounts influence flow patterns of impinging currents, creating closed circulation cells over summits as well as exposed and back-eddy regions. In turn these processes influence delivery of prey from surrounding oceanic waters as well as the export or retention of local populations of organisms (e.g., fish or invertebrate larvae, juveniles, adults). Seafloor landscapes vary at the scale of meters to 1000s m with variations in substrate complexity (e.g., grain size, surface morphology, slope) and epifaunal communities. Such variations influence boundary flows and the delivery of pelagic prey, settlement and distribution of benthic prey, and the availability of shelter sites. A landscape approach for understanding the ecological role of deepwater corals as habitats for fishes will require sampling at multiple spatial and temporal scales. Preliminary observations of fish distributions from the New England Seamounts, as well as literature review, suggests a seamount landscape model for making such observations.

Deep Sea Coral Reefs in Brazil

*Debora O PIREES**

Quinta da Boa Vista, Sao Cristovao, 20940-040, Rio de Janeiro, RJ Federative Republic of Brazil
dopires@openlink.com.br

The existence of deep sea coral habitats, their great dimension and major associated biodiversity recently came to the attention of the scientific community and the general public. Over the last two decades, the state of knowledge of these fragile habitats has been improved and, currently, we know they occur in all world's oceans. Albeit their recognized scientific and socio-economic potentials, there are still large gaps of information about their distribution, states of conservation, and coral fauna composition. The same occurs with the Brazilian deepwater coral reefs, of which the available data is minimal. In 1998, A. R. Viana and colleagues recorded, in a geological and oceanographical context, the occurrence of coral banks off southeast Brazil, at the Campos Basin, which extends between 20.5° and 24°. These banks may reach hundreds of meters in length, tens of meters in width, 10-15 m in height, and develop a 40 km-long coral field. There are now records of *Lophelia pertusa* in Brazilian waters, from 62 (top of a seamount) to 1000 m in depth. These records extend approximately from 19° to 25° S, a range of some 660 km long. Available data shows that the distribution of known deep sea coral ecosystems and known records of *L. pertusa* are in coincidence. The associated azooxanthellate scleractinian fauna is very diverse and *Enallopsammia rostrata* seems to be also an important framework builder. Additional new records were recently identified, as hydrocorals, black corals and octocorals, including species of precious corals (*Corallium* spp.). The Campos Basin has been the largest offshore oil exploration area off Brazil since the 1970's. Such a long term activity, without specific evaluation and/or monitoring of deep sea coral areas, raises concerns on their current state of conservation and degree of damage already endured by these coral environment

Plesiastrea versipora: Hermatypic Coral at its Southern Latitudinal Limit

*Samantha N BURGESS**, Malcolm T MCCULLOCH, Tim WARD

Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
sam.burgess@anu.edu.au

Corals growing in high latitude waters are sensitive to changes in climate, especially seasonal fluctuations in sea surface temperature. In the cool-water, high-energy environments of South Australia scleractinian corals are positioned to record variability of temperature, salinity and ocean circulation in the Southern Ocean. Scleractinia are typically stenotypic organisms with distributions limited by relatively minor fluctuations in environmental variables. *Plesiastrea versipora* (Lamarck, 1816) is a unique species of scleractinia, because it occurs around the entire Australian coastline, which suggests it tolerates a wider range of climatic variation. In high latitudes, *P. versipora* occurs in most encrusting reef systems, with colonies of massive habit up to 3 m in diameter and growth rates of 2-4 mm per year. Therefore, individual colonies may prove to be a good sentinel organism for changes in environmental conditions in southern Australia and by extension the Southern Ocean on centennial timescales. Core samples of up to 500 mm were obtained from three regions, including the Great Australian Bight, Spencer Gulf and Gulf St Vincent, South Australia. Laser ablation-inductively coupled plasma mass spectrometry (LA-ICP MS) was used to measure climatic tracers including temperature and upwelling proxies from high-latitude corals. Skeletal extension rates of *P. versipora* were compared for intra- and inter-annual differences in environmental conditions between the cool, nutrient-enriched shelf waters and the warm, low-nutrient gulf waters.

Evaluation of Hydrological Cycle in Palau from Time-series Variation of Water Isotopic Composition

*Osamu ABE**, Naoyuki KURITA, Maki MORIMOTO, Hajime KAYANNE
464-8601, HyARC, Nagoya Univ., Nagoya, Japan
oabe@ihas.nagoya-u.ac.jp

Palau is located in the northern part of the Western Pacific Warm Pool and it is affected by latitudinal migration of the Inter-Tropical Convergence Zone (ITCZ) across the equator and seasonal variation of Asian Monsoon. Annual variations in air and sea surface temperatures are relatively smaller than northern Monsoon regions, and they are 1.5 and 1.0 deg. C, respectively. The average annual precipitation is about 3,700 mm, slightly high during northern summer and winter and low during spring and fall, except for the period of El Nino. As the ITCZ migrates easterly along the equator in response to El Nino, rainfall is significantly reduced in this area, whereas SST changes are relatively small. In general, northeasterly and southwesterly winds prevail during winter and summer, respectively over the Palau region. On annual scale, precipitation exceeds evaporation in this region, therefore this area can be regarded as atmospheric water sink to the ocean. In order to determine isotopic composition of hydrogen and oxygen, rainfall and seawater had been collected every 2 weeks at Malakal Island located in Palau Lagoon since January 1999 to December 2000. Sea surface temperature had been monitored every two hours at Malakal Island, and meteorological parameters have been recorded by the NOAA weather station at Koror Island located next to Malakal Island. Regional data of wind stress, moisture flux, evaporation, and precipitation were estimated from NCEP dataset, and regional variation of isotopic composition of rainfall was estimated from GNIP dataset. Two-year isotope records of rainfall appear to correlate with the variation of surface air temperature. Isotope records of seawater correlate strongly with sea surface salinity and also with isotopic composition of rainfall.

Widespread Bleaching at the Marine State Park of the Manuel Luiz Coral Banks, Maranhao State, Brazil (Parcel Do Manuel Luiz)

*Fernanda AMARAL**, Marco HUDSON, Andrea STEINER, Marcia COURA
Av. Dom Manoel de Medeiros, s/n. Dois Irmaos Federative Republic of Brazil
fmamaral@novaera.com.br

The Marine State Park of the Manuel Luiz Coral Banks, located 179 Km north off the coast of the state of Maranhao (00° 46' S, 44° 15' W), is a site rich in reef species in relation to Brazilian coral fauna. During surveys to find cnidarians in June 1998 great diversity was encountered: four species of calcified hydroids, thirteen species of scleractinian corals, two species of sea anemones (*Condylactis gigantea* and *Bunodosoma cangicum*), one species of zoanthid (*Palythoa* sp.), and one species of octocoral (*Phyllogorgia dilatata*), a richness that in Brazil can only be comparable to the Abrolhos region. However, the average sea surface temperature for that month was at least 1°C than for the previous year, and at least 1°C above the expected maximum monthly mean, according to data from NOAA. Therefore widespread bleaching was observed. Three of the species of calcified hydroids found *Millepora alvicornis* (25 m), *M. braziliensis* (30 m), and *Millepora* sp. (30 m) were all bleached or dead and covered by algae and/or by other animals. Only *Stylaster roseus*, of which a single specimen was observed, was unaffected. Among the scleractinian corals, bleaching was observed in specimens of *Madracis decactis*, *Agaricia agaricites*, *A. fragilis*, *Siderastrea stellata*, *Porites astreoides*, *P. branneri*, *F. leptophylla*, *Montastrea cavernosa*, *Meandrina braziliensis*, *Mussismilia hispida*, and *Scolymia wellsi*. Only *Favia gravida*, of which a single colony was observed, did not show signs of bleaching. This is the first time bleaching has been recorded on the northern coast of Brazil.

NOAA - Alliance for Coastal Technology: www.actonline.ws

*Marlin J ATKINSON**
PO Box 1346 Kaneohe, HI United States of America
mja@hawaii.edu

The Alliance for Coastal Technology is a NOAA (Coastal Service Center) - funded partnership of research institutions, state and regional managers, and private sector companies who are interested in testing, evaluating and applying sensor technologies for monitoring of coastal environments. To better understand coastal processes and manage our coastal resources, there is an emerging agenda for national and international integrated ocean-observing systems. Reliable and standardized sensors and sensor platforms to collect environmental data are essential to the success of these efforts. ACT functions as: 1) an unbiased third-party test organization for evaluating new and developing coastal sensors and sensor platforms, 2) a comprehensive information resource on coastal technology, and 3) a forum for capacity building through a series of workshops and seminars on specific technologies. ACT is a national program including eight regional partners: Maine - Gulf of Maine Ocean Observing System; Maryland - University of Maryland Chesapeake Biological Laboratory; Florida - College of Marine Science, University of South Florida; California - Monterey Bay Aquarium and Moss Landing Marine Laboratories; Hawaii - Hawaii Institute of Marine Biology, School of Ocean Earth Science Technology, University of Hawaii; and Alaska - School of Fisheries, Limnology and Oceanography, University of Alaska and Alaska Sea-Life Center. ACT is expanding to European countries including: Scotland, Britain, Norway, France, Portugal and Spain. We are also initiating expansion to Pacific Rim countries and encourage collaboration with new alliance members in the Pacific.

Why the Initial Phases of *Sparisoma* (Perciformes: Scaridae) Visit Cleaning Stations Less than the Terminal Ones?

*Roberta M BONALDO**, Joao P KRAJEWSKI
Departamento de Zoologia, Universidade Estadual de Campinas, CP 6109, Campinas-SP, Brasil Federative Republic of Brazil
robertabonaldo@yahoo.com

Parrotfishes (Scaridae) are tropical and subtropical reef fishes that feed on algae and dead coral. Scarids have complex social systems, including differentiated sexual stages, and changing color and sex from initial phase (females or males) to terminal phase males. *Sparisoma amplum*, *S. axillare* and *S. frondosum* are syntopic at Fernando de Noronha Archipelago, Equatorial Western Atlantic. We compared cleaning episodes for these three scarids to find whether the frequency of their posing at fixed cleaning stations differ for initial and terminal phases. We followed focal individuals during 5min and recorded whether or not an individual posed at a cleaning station during its foraging. Additionally, we made transects where we recorded all the adult parrotfishes and whether they were associated to any other fish. The three species occasionally stopped their foraging to pose at fixed cleaning stations of cleaner gobies, wrasses and shrimps. Additionally, all three species were cleaned "on the move" by the Noronha wrasse (*Thalassoma noronhanum*), a fish that followed these scarids during their foraging and cleaned them when they interrupted momentarily their feeding and posed to the cleaners. We found that initial phase *Sparisoma* individuals posed at fixed cleaning stations less frequently than the terminal ones and were followed more often by the Noronha wrasse. Since the initial phase individuals were cleaned by *T. noronhanum* during their foraging, they have no need to stop this activity to pose at fixed cleaning stations, as the terminal phase individuals have to do. Therefore, the mobile cleaning of *T. noronhanum* benefit the initial phase individuals of *Sparisoma*, and possibly other fish species followed by this wrasse as well.

Physiological Condition: An Important But Ignored Aspect of Larval Supply of Coral Reef Fishes

*David J BOOTH**

Westbourne Street, Gore Hill, NSW 2065 Australia

David.Booth@uts.edu.au

While variation in settlement of marine larvae is widely thought to be an important factor affecting benthic adult densities, it is variation in larval densities has been focused upon. Here, I demonstrate that variation in the physiological state, or condition, of incoming larvae can also affect recruitment to benthic populations, and in fact may decouple links between numerical variation in settlement and adult densities. Studies over multiple geographic locations over several years suggest that spatial and temporal patterns of larval condition affect early survival on benthic habitat for a damselfish, *Pomacentrus moluccensis*, and that some of these patterns persist for up to 5 years. Larval condition affects both predation risk and acquisition of planktonic prey for fish in groups. Therefore, strong and weak year classes of reef fishes may in part reflect their physiological condition at settlement.

Comparisons of the Spatial and Temporal Variation of Larval Fish Community from Coral Reef Areas in Northern and Southern Parts of Taiwan

Li-Shu CHEN, Kwang-Tsao SHAO, Yu-Tzu WANG*

P.O. Box 7-202, Keelung, TW, 202 Taiwan

LSChen@mail.ntou.edu.tw

To investigate the larval and juvenile fish community in the coral reef areas in Taiwan, fish larvae were collected at night from January 2000 to December 2003 with light trap and larval trawling net from 32 stations in Yehliu, Suao, and Kenting, which are located in northern, northeastern, and southern Taiwan, respectively. A total of 26,499 larvae representing 106 families, 306 species including 72 unidentified species were collected. The larval fish communities consisted of coastal pelagic (36%), mesopelagic (4%), sandy benthic (4%), coral reef (46%), and unknown (8%) in the surface layer of the coral reef areas. Among coral reef fish larvae, Gobiidae is the most dominant, followed by Tripterygiidae, Apogonidae, and Pomacentridae. The results of multivariate analysis showed that the factors determining the larval fish assemblages in the order of importance were: sampling tool (trap vs. net), month or season, distance offshore (port vs. sea), geographic region (north vs. south), and different stations in the same region. The reason that the distribution pattern of larval fish is inconsistent with the pattern obtained from adult coastal fish assemblages might be that most larval fishes could not be identified to species level.

Towards the Sustainable Use of the National Marine Park of Fernando de Noronha, Brazil

Cristiana DAMIANO, Sergio SALVATI, Claudio BELLINI, Lisandro ALMEIDA*

CXP 50, Alameda do Boldro, sn, Fernando de Noronha, PE, Brazil, CEP 53990-000 Federative Republic of Brazil

cdamiano@nmsc.edu.au

In many developing countries, tourism is considered a potential opportunity and a threat. Marine-based tourism involving diving is often extremely popular in tropical areas and an increased development in recent years throughout many regions has been accompanied by concerns over potentially negative impacts on coral reef communities. The potential for these sorts of impacts is of major concern to agencies responsible for managing marine parks. Sustainability of dive-based tourism can be attained if proper regulations are established and enforced. This is being attempted at the Archipelago of Fernando de Noronha, PE, which comprises an isolated group of 21 oceanic volcanic islands located 345km off the northeast coast of Brazil. The Archipelago was decreed a National Marine Park in 1988 and subsequently listed as a Natural World Heritage by the United Nations in 2001. This area has one of the most diverse marine environment in the South Atlantic Ocean, where more than 100 species of fish, 9 species of hermatypic corals (most endemic), turtles, spinner dolphins and an enormous variety of crustaceans, molluscs, sharks and aquatic plant species make up the diverse marine assemblage. Characterised by water visibilities > 40 m, Fernando de Noronha is a popular destination for SCUBA divers and is fast gaining a reputation at national and international level. More than 30000 tourists dive in the marine park each year, with this amount increasing annually and the potential disruption to coral reefs owing to high densities of divers could represent a threat. Steps were initiated to start a monitoring program to describe and quantify the impact of recreational diving on the marine environment and coral communities. The information obtained from this work will be used to develop an effective management strategy for the National Marine Park.

Comparative Studies on Feeding Habits of Four Species of Sea Urchins (Genus *Echinometra*) in Okinawa

Yuji HIRATSUKA, M Aminur RAHMAN, M Saifur RAHMAN, Tsuyoshi UEHARA*

1 Senbaru, Nishihara-cho, Okinawa, Japan

yujihiratsuka@hotmail.com

Recent studies on gametic incompatibility, physiological adaptation, adult morphology and mitochondrial DNA have revealed that Okinawan *Echinometra* must be recognized as four independent species: *Echinometra* sp. A, *E. mathaei*, *Echinometra* sp. C, and *E. oblonga*. Also, ecological studies on distribution patterns have shown that *Echinometra* sp. A are common in the intertidal and submerged areas, *E. mathaei* is distributed from intertidal to subtidal shallow waters, and other two urchins are restricted in the reef margin or upper intertidal zone. In the present study, the gut content and food availability of *Echinometra* were studied at four different habitats on Okinawan coral reefs. Gut content analysis of the four *Echinometra* species collected from the inner and the outer reef flat revealed that they mainly grazed on turf algae covering on the substratum. Similarly, turf algae were the most dominant components in the gut of the four *Echinometra* species collected from the intertidal limestone platform. On the other hand, *Echinoetra* sp. A in the seagrass bed usually consumed live seagrass leaves with some macroalgae. Moreover, the gut content of *Echinometra* sp. A in the sandy flat surrounded by the seagrass-algal bed was mostly composed of drift algae and dead seagrass leaves. These results strongly suggested that *Echinometra* spp. were herbivorous in nature, and their grazing depended on the availability of plants at particular habitat. Thus, widespread *Echinometra* sp. A was likely to utilize a greater range of foods compared with other three species which were generally restricted in the intertidal zone. Further experiments are needed to conclude whether there is any fundamental difference in feeding habits among these closely related species.

Defense Chemical of the Crustose Coralline Red Algae

Makoto KITAMURA*, Tomoyuki KOYAMA, Yoshikatsu NAKANO, Daisuke UEMURA

Furou-cho, Chikusa, Nagoya 464-8602, Japan
m.kitamura@attglobal.net

The crustose coralline red algae (CCA) extract is induced metamorphosis of scleractinian coral larvae ⁽¹⁾. However, the inhibition of settlement and metamorphosis by the CCA extract has not been well reported. It is reported that the red algae contains many organic halogenated compounds in the living body ⁽²⁾. These organic halogenated compounds are thought antibiotics or growth regulators against marine bacteria. We report that new brominated dibenzofuran (**1**) isolated from the CCA collected in offshore the Yomitan village in the Okinawa island. This structure was determined by NMR and FAB-MS. This compound **1** showed toxic activity against larvae of the scleractinian coral *Pseudosiderastrea tayamai* (>67 µg/L). Those toxic brominated dibenzofuran **1** are considered as a defense chemical of the CCA. (1) Morse DE, Hooker N, Morse ANC, Jensen RA (1988) J Exp Mar Biol Ecol 116:193-217. (2) Gribble GW, Progress in the chemistry of organic natural products (1996) 68:202-214.

Detect Report of *Acanthaster planci* on Web

Keiyuu KOSUGA*

F-StageMaxy#903, Maxy 3-14-17, Naha, Okinawa Japan
kosby@kosby.com

The coral reef in Okinawa that can be boasted to the world because *Acanthaster planci* abnormally generated eats the coral reef all over Okinawa messily is in the crisis situation now.

The coast fish and the living thing of the coral reef that is marine resources of Okinawa have decreased sharply now by the thing that the coral decreases sharply.

It is thought that the research of the mechanism of immediate measures against the capture work of a drastic red clay, the sewage measures, and *Acanthaster planci* and generation etc. are advanced in the industrial-government-academic complex, the situation of the occurrence of the crown of thorns starfish, the number of individuals, and the generation size are monitored continuously, and it is important to keep understanding the prefecture in the situation. As for **Detect report of *acanthaster planci*** that our company made, the map of the detect place is displayed. The photograph can be contributed. Not only the researcher and the person related to the fishery but also there is widely contribution from general a lot because it can in real time up-load it. To understand the location information more accurately by using carrying with the GPS function now, the system is being developed. (Schedule it the management beginning in June, 2004.)

Studies of Feeding Attractants for the Coral Predator *Drupella* sp.

Tomoyuki KOYAMA*, Makoto KITAMURA, Toshiaki TERUYA, Yoshikatsu NAKANO, Masaki KITA, Daisuke UEMURA

Furou-cho, Nagoya 464-8602 Japan
tomoyuki.koyama@ma5.seikyousei.jp

The sea star *Acanthaster planci* and the sea shell *Drupella* sp. are well known to be voracious coral predators. These predators can find a coral by detecting some chemicals from the coral body. It was reported that *A. planci* was attracted to the specific fatty acid ¹⁾ and amino acids ²⁾ from the coral extract. However the feeding attractants for *Drupella* sp. were not elucidated chemically. Recently, we successfully purified the feeding attractants for them from the water extract of the coral *Montipora* sp. using our simple bioassay system in an aquarium. In our results, *D. cornus* and *D. fragum* were attracted to the same water-soluble compounds, which are different from those of *A. planci*. The structures of them were determined by spectroscopic analysis (NMR and MS). One of these compounds was synthesized using chemical methods via simple route. Literature: 1) Teruya, T., Suenaga, K., Koyama, T., Nakano, Y. and Uemura, D. Arachidonic acid and γ -linolenic acid, feeding attractants for the crown-of-thorns sea star *Acanthaster planci*, from the sea urchin *Toxopneustes pileolus*. *J. Exp. Mar. Biol. Ecol.*, **266**, 123-134, 2001. 2) Collins, A. R. S. Biochemical investigation of two responses involved in the feeding behavior of *Acanthaster planci* (L.). II. Isolation and characterization of chemical stimuli. *J. Exp. Mar. Biol. Ecol.*, **17**, 69-86, 1975.

Foraging Differences between Two Syntopic Species of Goatfishes in Equatorial SW Atlantic

Joao P KRAJEWSKI*, Roberta M BONALDO, Cristina SAZIMA, Ivan SAZIMA
 Departamento de Zoologia CP 6109, Instituto de Biologia, Universidade Estadual de Campinas, Campinas SP, Brasil Federative Republic of Brazil
jpk@cursos.zzn.com

The goatfishes (Mullidae) include about 50 perciform species distributed in tropical and subtropical seas. All goatfishes are zoobenthivores and feed on soft sediments (sand and mud) around reefs, their barbels and mouth disturbing the substrate. We studied comparatively the foraging activity of *Mulloidichthys martinicus* and *Pseudupeneus maculatus*, syntopic in the Fernando de Noronha Archipelago, off northeast Brazil, SW Atlantic. We addressed three questions in our study: 1) Do the use of foraging substrate differ between the two goatfishes? 2) Do their feeding rates differ? 3) Do the distance traveled per given period while foraging differ between them? The foraging activity was assessed by following individual fishes for 3-5 min and recording the number of bites on five substrate types, and the distance traveled. *Mulloidichthys martinicus* fed over sandy and mixed (algae and sand) substrate but preferred sandy bottom, whereas *P. maculatus* fed over sandy, mixed and brown algae substrate but preferred mixed substrate. *Mulloidichthys martinicus* had higher feeding rate (3.43 bites/min versus 1.99 bites/min of *P. maculatus*), and roamed less per given time (2.99 m/min versus 5.39 m/min of *P. maculatus*). The differences in substrate use between the two species possibly minimize potential resource overlap between them, as already recorded for other syntopic mullids. *Pseudupeneus maculatus* had lower feeding rates probably due to its feeding on larger items, and roamed greater distance per time probably due to its foraging over a greater variety of substrate distributed over a larger area than used by *M. martinicus*. Notwithstanding the overall similarity between mullid species, they do differ on their substrate preferences and foraging activity, which indicates that mullids can not be characterized simply as generalized soft bottom foragers.

Historical Maps and Terms of Coral Reefs since the Shouho (1648) National Atlas in Japan

*Shigekazu MEZAKI**, Ken TOGUCHI

27 Seirei-cho, Seto, Aichi 489-0863 Japan

mezaki@nanzan-u.ac.jp

The first drawing and description of the coral reefs in Japan is from the National Atlas (KUNIEZU) dated 1649 in Shouho period of the Edo Era. The shape and distribution of the coral reefs were shown on the color painted maps with 1: 21,600 of the original scale in the Ryukyu Islands (Territory of the Old Ryukyu Kingdom) of the National Atlas. Though these maps had drawn mainly a geographical location and topographical situation of each island for the land governance and taxation by the Edo shogunate, the coastlines of each island had figured with ports(MINTO), capes(SAKI), beaches(HAMA), tidal flats(HIGATA), rocks(IWA), inlets(SHIMA) and coral reefs(HISI) relating to many geographical place names. For example, the biggest platform reef off the Miyako Island had been drawn as named YABISHI with the range scale of a length and a width. In some location, the width of reef channel had described for the entrance to the port in detail. According to the analysis of the maps, we could evaluate that this figure becomes valuable material where the relation to "Coral Reef and Man" can go back historically.

Crown-of-Thorns Starfish (COTS) Larval Dispersal Detection Project - A Challenge Based on Development of Immunological Identification Technique for COTS Larvae

*Kazuo NADAOKA**, Masami HAMAGUCHI, Miho SASAKI, Saki HARII, Nina YASUDA, Yoichi SUZUKI, Ken OKAJI, David IDIP JR., Yasumasa MIYAZAWA, Shinichiro KAKUMA, Kensuke YOKOI

2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552 Japan

nadaoka@mei.titech.ac.jp

Recently in the Ryukyu Islands the outbreak of the Crown-of-Thorns Starfish, *Acanthaster planci* (L.), has been a great concern due to its devastating effect on coral population. To establish proper measures to mitigate significant damages caused by the outbreak, it is of crucial importance to understand the whole stages of the life cycle of *A. planci*. Among these, clarifying the dispersion patterns of *A. planci* larvae is an essential step in understanding the mechanisms of outbreaks. However no field data on the dispersal of *A. planci* larvae has been obtained mainly due to inability in distinguishing *A. planci* among the larvae of starfish species. This inability is ascribed to the fact that a COTS larva closely resembles to some other common starfish larva in terms of body shape. A possible approach to overcome this difficulty is to develop monoclonal antibodies as immunological probes, which specifically react to *A. planci* larvae. We have already succeeded in the development and identification of *A. planci* larvae among wild-caught plankton samples obtained in Palau. We have also succeeded in a genetic analysis of *A. planci* for cross-checking of the immunologically identified results. The genetic analysis may be applied as another method to identify *A. planci* larvae in case of few samples. With these techniques for COTS larvae, we have planned to conduct plankton netting at various locations along the coasts of the Ryukyu Islands in the next spawning seasons. The information regarding the spawning of *A. planci*, which is important for analyzing COTS larvae data, will be collected in collaboration with a local network of dive shops and others. Furthermore numerical simulation and field data analysis on ocean currents will also be performed for quantitative understanding of the COTS larvae dispersal process. At the symposium, a progress report on this project will be presented.

Diversity, Abundance and Distribution of Macroalgae in Songkhla Province, Thailand

*Anchana PRATHEP**, Kanjanapaj LEWMANOMONT

Department of Biology, Faculty of Science, Prince of Songkla University, Thailand, 90112 Thailand

panchana@ratree.psu.ac.th

Diversity, abundance and distribution of macroalgae are studied at various sites from intertidal and subtidal zones in Songkhla Province. Samples are collected every 3 months from August 2002-July 2003. All four divisions of macroalgae have been found, with more than 32 species so far recorded. Two sites were chosen to be studied in depth owing to the abundance and richness of seaweed; Suan Song Thale (intertidal zone) and Koh Kham (subtidal zone). The effects of physical factors on percentage cover and distribution of *Gelidium* sp., a very abundant red alga, are investigated at Suan Song Thale. Population structure and growth of *Caulerpa* sp. are also investigated at Koh Kham, due to its interesting form and growth. Spatial and temporal variations in percentage cover of *Gelidium* sp., and in frond density of *Caulerpa* sp. have so far been studied.

Reproductive Biology and Space Use of *Entomacrodus stellifer lighti* (Pisces: Blenniidae) in Hong Kong

*Wanfei QIU**

Room 3N10, Kadoorie Biological Sciences Building, The University of Hong Kong, Pokfulam, Hong Kong

h9992070@hkusua.hku.hk

The detailed reproductive biology and space use of the blenny *Entomacrodus stellifer lighti* in Hong Kong were examined. Despite its high density in Hong Kong's rocky lower inter-tidal and subtidal zones, very little is known of the ecology and biology of this species. The gonadosomatic index (GSI) of *Entomacrodus stellifer* was examined monthly from April 2003 to April 2004. It reached the highest peak during March to April with a second peak around August. The seasonal changes of both GSI and histology of the gonads indicated that spawning in this species started in April and ended during September to October. Males have accessory glands associated with testes, and spermatids are passed into the gland before reaching the sperm ducts. Seasonal changes in the gland, as determined histochemically, and its possible function(s) are discussed. The fish produce demersal eggs that hatch within 10 days in ambient water temperature of about 22 °C. Space use of the species within the Cape D'Aguiar Marine Reserve was also examined. Most fish occupied defined home ranges with an area between 4.19 to 7.35 m², and their home ranges overlap heavily with each other. The temporal changes in space use and their relationship to the reproductive cycle of the fish are discussed.

Documenting Melanesian Traditional Aquatic Knowledge and Fishing Practices

Norman QUINN*

Discovery Bay, St Ann Jamaica

Norman_q@hotmail.com

Together with 32 Melanesian nationals we have assembled a 124 page illustrated collection of essays titled *Aquatic Knowledge and Fishing Practices in Melanesia*. The book is based on manuscripts written by Papua New Guinea (PNG) University of Technology, Lae; University of PNG, Port Moresby; and University of the South Pacific, Fiji, students. The essays were written after the students had spoken with village elders. Much of what we know about the natural resources of developed countries can be found in libraries and on the Internet. However, in Melanesia, most of this knowledge exists only in the minds of experienced and skilled men and women. Researchers have realized that traditional information is vast and more comprehensive in many respects to that documented by formal science. Young, formally educated students are among those citizens who know least about such things. Their learning years are spent far from their ancestral villages and they are seldom taught to understand and respect these knowledge systems and customs. Paradoxically, these are the citizens who will be given the duties and responsibilities to determine the future conservation and development strategies for their country. It is unlikely that their socio-economic and technological sophistication can be fully applied without the fundamental knowledge that their culture possesses of the surrounding natural resources. Melanesian educational institutes have a responsibility to help retain such knowledge and transmit it to future generations. However, without printed material for the teachers and students to use, it is excluded from the curricula. The exclusion amounts, unintentionally, to a tacit assertion that it is no longer worth learning. *Aquatic Knowledge and Fishing Practices in Melanesia* is making an important contribution to fill this void as the book will be used by the PNG Education Department in secondary schools and in universities throughout Melanesia.

Moving Snack-Bars: Reef Fishes Nibble at Marine Turtles

Cristina SAZIMA*, Alice GROSSMAN, Claudio BELLINI, Ivan SAZIMA

Departamento de Zoologia, C.P. 6109, Universidade Estadual de Campinas, 13083-970, Campinas, Sao Paulo, BRAZIL

cristinasazima@yahoo.com

Marine turtles often bear algae and invertebrates growing on their shell and soft body parts. Some herbivorous fishes join turtles to graze on the algal growth, whereas other fishes nibble at turtles moulting skin and ectoparasites (cleaning). At the Fernando de Noronha Archipelago, Southwest Atlantic, we recorded turtles seeking reef fishes to have their shells grazed and ectoparasites removed from their soft parts. Field observations were conducted in an inlet with sandy bottom and irregular rocky patches sparsely to thickly covered by brown foliose algae, red coralline algae, and stony corals. The interactions between turtles and fishes were observed directly, photographed and video-recorded during snorkelling. The green turtle *Chelonia mydas* left its ample foraging grounds to seek restricted sites with cleaning stations held by the damselfish *Abudefduf saxatilis* and the surgeonfishes *Acanthurus chirurgus* and *A. coeruleus*. On the other hand, the hawksbill turtle *Eretmochelys imbricata* foraged on sites with cleaning stations of *A. saxatilis*. This turtle either stopped foraging and sought the stations or was cleaned while foraging close to the stations. Both turtle species displayed characteristic soliciting postures at the cleaning stations, and the fish cleaners nibbled mostly at the turtles flippers, head and neck. Only *A. chirurgus* grazed exclusively at the turtles shell. In another kind of association, the wrasses *Thalassoma noronhanum* and *Halichoeres radiatus* followed foraging turtles to feed on drifting particles and invertebrates exposed during the bottom stirring by the turtles. Both parties benefit from the cleaning association, as the fishes obtain food and the turtles get rid of fouling organisms. On the other hand, following fishes are the only party benefited by the turtles activity, feeding on otherwise inaccessible food items. We suggest that feeding associations between reef fishes and marine turtles are widespread, but probably restricted to opportunistic omnivorous and/or herbivorous fish species.

A Faeces-eating Cleaner: The Wrasse *Thalassoma noronhanum*

Cristina SAZIMA*, Roberta M BONALDO, Joao P KRAJEWSKI, Ivan SAZIMA

Dept. Zoologia, C.P. 6109, Universidade Estadual de Campinas, 13083-970, Campinas, Sao Paulo, BRAZIL

cristinasazima@yahoo.com

Cleaning symbiosis among reef fishes is an interaction by which a fish obtains food from the body of another fish which, in turn, is rid of ectoparasites and dead tissues. Feeding on faeces, or coprophagy, is another kind of feeding association between reef fishes, the faeces being regarded as a diverse and rich food source. At the Fernando de Noronha Archipelago, Southwest Atlantic, the Noronha wrasse (*Thalassoma noronhanum*) is known as a benthic invertebrates-picker, plankton-eater and a cleaner holding mid-water cleaning stations. We recorded this wrasse following the parrotfishes *Sparisoma amplum*, *S. axillare* and *S. frondosum* to feed on their faeces and to clean them occasionally. These feeding associations (coprophagy and cleaning) were observed directly, photographed and videotaped during snorkelling. The parrotfishes were followed by the wrasses (1-15 individuals; 3-12 cm total length) while the former were foraging on algae and dead coral. The parrotfishes defecate in clouds on move during feeding, their faeces being promptly consumed by the wrasses. On the other hand, cleaning was recorded only while the parrotfishes interrupted momentarily their foraging and posed hovering for the wrasses. Coprophagy (N=28 events) was more common than cleaning (N=13), which would be expected since defecating (N=50) was recorded more often than posing (N=14). Feeding on parrotfishes faeces may be due to their forming clouds of sinking offal and to the wrasses ability to capitalize on this food supply, since particles in faeces are taken by the wrasse in a way similar it picks off individual plankters. On the other hand, cleaning occurs whenever a parrotfish hovers, since the wrasse is able to settle and tend temporary mid-water cleaning stations, a feature suitable for both partners in this interaction type. We suggest that other *Thalassoma* species may behave as reported herein, particularly those able to capitalize on diverse food types.

Benthic Algal Blooms of Colonial Chrysophytes (Golden Algae)- A New Phenomenon on the Great Barrier Reef, Australia

Britta SCHAFFELKE*, Kirsten HEIMANN, Anthony AYLING

PO Box 772 Townsville QLD 4810 Australia

britta.schaffelke@crcreef.com

Extensive blooms of a benthic colonial chrysophytes have been recently observed on a number of reefs in the Great Barrier Reef (GBR). The main bloom-forming species is *Chrysocystis fragilis* with lower abundances of *Chrysophaeum taylori*. The two species are chrysophytes sensu lato, currently grouped in the class Pelagophyceae. *C. fragilis* is a new record for the GBR region. It was described from Guam, and has been recorded at Palau, Pohnpei, and Hawaii. On a large number of GBR reefs chrysophytes colonise a variety of substrata in water depths from 5 m to at least 20 m. High abundances, occasionally blanketing areas of tens of square metres, were generally found in depths below 3 m, protected from wave and current disturbance. Benthic colonial chrysophytes are a taxonomically difficult group and not much is known about their biology and ecology. Photographic evidence suggests that a dense cover of chrysophytes has a negative effect on hard corals. After manual removal this cover the underlying coral tissue was noticeably bleached. Benthic algal blooms are uncommon in the GBR, except for seasonal blooms of macroalgae on inshore reefs and after disturbance events. Chrysophyte blooms may be a consequence of recent reductions in live coral cover due to coral bleaching and Crown-of-Thorns starfish outbreaks, or *C. fragilis* may be a recent introduction to the GBR region. GBR users are concerned about the occurrence of chrysophyte blooms, especially because chronic blooms of this species may have the potential to inhibit recovery of disturbed reefs.

A Calcium Carbonate Budget for Kure Atoll, Using Remote Sensing Techniques and Field Measurements

*Daria SICILIANO**, Donald C POTTS, James E MARAGOS

1156 High Street, Santa Cruz, CA 95064 United States of America

daria@biology.ucsc.edu

This paper details the theoretical and practical approach to a calcium carbonate budget for Kure Atoll (Northwest Hawaiian Islands), the northernmost atoll in the world, and presents some conclusions regarding global climate change effects on the distribution of coral reefs worldwide. Depressed carbonate production in subtropical coral reefs has been attributed to lower sea surface temperatures (SST) that cause either: a reduction in the extent of the reef building area, a reduction in coral calcification rates, or both. However, rising SST globally may also boost carbonate production, especially in marginal environments which are highly sensitive to small variations in the environmental parameters conducive to reef growth. At 28.26 °N, Kure Atoll occurs in an ecologically marginal environment, where SST seasonally falls below the physiological optimum for coral growth. Kure's unique position and isolation offer an ideal opportunity to investigate controls on reef development and distribution. We built a box model of carbonate production to test the hypothesis that net accretion is occurring at Kure Atoll. The model is based on a CaCO₃ budget for the reef framework, using a combination of remote sensing and field data. We analyzed IKONOS multispectral images of Kure atoll, obtained benthic habitat maps, improved their accuracy with extensive field data, and used them to discriminate reef-building (live coral and coralline algae dominated) from non-reef-building areas. We coupled these data with habitat-specific coral and coralline algae growth rates obtained from 3 years of field sampling at Kure atoll, as well as from field data on biological erosion from their main invertebrate and vertebrate agents to obtain a three dimensional model of carbonate production and removal at Kure Atoll. The results are interpreted in light of the Darwin Point Hypothesis and potential effects from global climate change on its location.

Diversity and Abundance of Larval Fishes in the Coast of Tanjung Merah, North Sulawesi (Indonesia)

*Augy SYAHAILATUA**

Jl. Pasir Putih I, Ancol Timur, Jakarta 14430, Indonesia

a_syahailatua@yahoo.com.au

Four weeks observations in March 2003 were conducted to sample larval fishes with a neuston net over the coral reefs and seagrass beds in the coastal area of Tanjung Merah. There were 32 taxa found in the coral reefs and 24 taxa were in seagrass beds. Gobiidae was the most dominant taxa (in term of individual number) of coral reefs, following with Nemipteridae and Teraponidae, while Syngnathoides sp. was the most abundant taxa of seagrass beds, following with Gobiidae and Apogonidae. These three larvae of reef fishes contributed 53.3% of total individual number, while from seagrass beds they made up 45.8%. The ANOVA results of individual number and Shannon-Weiner index of diversity among sites show no difference significantly at P=0.05. Therefore, larval fish in coral reefs and seagrass beds distributed similarly reflecting the strong effects on the ebb and flooding currents in the sampling area.

Regional Seas: A Global Tool for Regionally Coordinated Coral Reef Protection, Management and Sustainable Use

*Jerker TAMELANDER**, Hanneke VAN LAVIEREN

P.O. Box 30552, Nairobi Republic of Kenya

jerker.tamelander@unep.org

The Regional Seas Programme, an alliance between Regional Seas Conventions and Action Plans, has since its inception 30 years ago constituted a unique, region-specific approach to the protection of the coastal and marine environment. Seven Regional Seas contain major coral reefs, and most others contain coral communities; hermatypic, cold-water, or both. In all of these regions coral reefs and coral communities provide essential direct and indirect services for human populations and entire nations, but they are frequently degraded and/or unsustainably utilized. This, as well as changes in the development agenda, the international policy framework, scientific knowledge and socio-economic realities and trends, constitute challenges that the Regional Seas Programme must meet. Recognizing this, the UNEP Governing Council requested in its Resolution 22/2 III A, inter alia, the development and strengthening of the Regional Seas in promoting the conservation and sustainable use of the marine and coastal environment, and the incorporation of new strategic elements in their programmes of work, which were later agreed at the 5th Global Meeting of the Regional Seas in Nairobi, Kenya, 26-28.11.2003. Thus the Regional Seas Programme possesses both a mandate and the institutional capacity to provide a platform on which to implement coherent, coordinated and comprehensive action on coral reefs, as evidenced by on-the-ground activities and participation in a variety of partnerships, including ICRI and ICRAN. This paper will illustrate how the new strategic guidelines for the Regional Seas, building on the existing foundation, further the protection, conservation, management and sustainable use of coral reefs, with a view to achieving the relevant targets of Agenda 21, the WSSD Plan of Implementation as well as the Millennium Development Goals.

Biological Investigation of Drainage Water Treated with Flocculant to Plankton

*Akira TAMURA**, Masaharu KATSUMATA, Kazunori NAKAMICHI,

Akira OHNISHI, Takefumi MAENOSONO, Keiko IRIYAMA, Makoto TSUCHIYA

4-4-10, Nihonbashi-Muromachi, Chuo-ku, Tokyo, 103-0022, Japan

akira.tamura@mcaqua.co.jp

The water pollution caused by reddish soils is damaging seriously the environment of coral reef in Okinawa. In order to protect our coral environment, we have developed a new water treatment system to reduce the suspended soils (SS) of muddy water from reddish soils of land like farmland. This sludge-dewatering system combined a simplified equipment (no need any mechanical filtration process) and flocculant application can reduce SS to less than 25mg/L. Flocculant is widely used as a coagulation aid of drainage water from a muddy water, but the influence of flocculant left in the drainage water to the coast environment is not studied precisely. Here, the drainage water treated with flocculant was investigated biologically from the view-point of the decrease on the species such as plankton etc.. The drainage water treated with optimized flocculant showed harmless for plankton. But plankton were flocked together and died gradually, if a lot of residual flocculants left in the drainage water. The cationic materials like Poly-Aluminum Chloride or drainage water in a low pH will also effect the flocculation of plankton easily. Therefore, it is important to optimize the dose of flocculant by using a colloid chemical adjustment.

Anchorage of Pre-positioned Vessels in Coral Reef Habitat in the Commonwealth of the Northern Mariana Islands: A Management Challenge

*Michael S TRIANNI**, Kate A MOOTS, Michael C TENORIO

PMB 418 Box 10000 Saipan, MP 96950 Commonwealth of the Northern Mariana Islands

mstfdfw@itecnmi.com

Outside the barrier reef of Saipan Lagoon there exists an extensive shallow water shelf designated as an anchorage zone with numerous sites that pre-positioned supply vessels contracted by the U.S. Navy use on a scheduled basis. These vessels harbor supplies for use in military operations in the region, and their continued presence serves as a revenue source to the local economy. This shelf has been utilized by local fishermen, as well as by local recreational fishing charters. The anchorage zones have been used historically, seeing perhaps the greatest use during and shortly after WWII. Dive surveys on select pre-position anchorage sites by personnel from the CNMI DFW documented damage to coral reef habitat from anchoring. Surveys have shown differences in fish species composition as well as other benthic biota between anchorage and control sites. Although from a historical perspective the designated anchorage zones have received considerable use, and thus resulted in damage to coral reef habitat, the continued practice of deploying anchors on hard substrate requires reconsideration.

Lagoonal Patch Reef Assessment within Ascension Bay, Sian Kaan Biosphere Reserve, Mexico: The Use of Data to Support the Provision of a Sustainable Alternative Livelihood

*Ryan C J WALKER**, Jaqueline F TAYLOR, Hannelore WASKA, Daniel J PONCE-TAYLOR, Belinda VAUSE, Simon P HARDING, Luis G RENDON-AGUILAR, Peter S RAINES

The Tower, 13th Floor, 125 High Steet, Colliers Wood, London, Sw19 2JG United Kingdom of Great Britain and Northern Ireland

rw@coralcay.org

Pescadores de Vigia Chico is an exemplary managed community based fishing cooperative targeting spiny lobsters (*Panulirus argus*) within Ascension Bay, part of The Sian Kaan Biosphere Reserve, Yucatan, Mexico. Catch yield remains sustainable within the shallow lagoonal patch reef environment due to sound fishery management techniques and the development of two alternative livelihood strategies. The community is keen to exploit potential revenue generated through tourism by offering snorkel tours. Eleven sites within Ascension Bay were identified as being attractive to snorkelers and marked with mooring buoys. Each site was surveyed using advanced Mesoamerican Barrier Reef System Synoptic Monitoring Program methods for coral reef environments, using both belt and line point transects. Calculated biodiversity indices and reef condition indicators were assessed to assign a conservation value to each potential snorkeling site. Recommendations were subsequently presented to the community to assist in the management of Ascension Bay and support an environmentally sustainable alternative livelihood.

The Value of Volunteers: A Review of the Role of British Volunteer Based NGOs in the Establishment of Coral Reef Marine Protected Areas

*Ryan C J WALKER**, Jacqueline F TAYLOR, Simon P HARDING, Sarala VISVALINGHAM, Christine ERIKSON, Peter S RAINES

The Tower, 13th Floor, 125 High Street, Colliers Wood, London, SW19 2JG. United Kingdom of Great Britain and Northern Ireland

rw@coralcay.org

Marine Protected Areas (MPAs) are increasingly becoming established to protect endangered marine ecosystems, particularly coral reefs, their biodiversity and valuable resources. For decision makers to be able to influence government, sound and comprehensive baseline data must be available for tropical marine biological systems to justify the reasoning that areas of coastline require protection. Non-specialist volunteer researchers have been used to great effect in a number of developing nations providing manpower that would be otherwise unavailable. A review of all available literature documenting such work was undertaken. To date nine MPAs have been gazetted by three NGOs in five nations in tropical waters. These include: four Marine Reserves/Parks, in Tanzania, Belize and the Philippines; four National Marine Parks (NMPs), in Indonesia, Belize and Mozambique and one UNESCO World Heritage site in Belize. In total 5,250.4 km² of coral reefs and associated marine habitats have been gazetted as protected area since 1995. Volunteer labour mainly consisted of baseline marine plot-less belt transect surveys undertaken using a variety of methods to assess marine biodiversity. In some cases subsistence marine resource utilisation assessments and surveys were also carried out. Capacity building and training of local counterparts is also a focus in most cases playing an important role in the empowerment of local people, and installing increased environmental awareness for the inhabitants and users of such MPAs.

A Comparative Study between the Line Intercept Transect Technique and the Rapid Reef Resources Assessment Technique in Assessing the Status of Coral Reef

*Giyanto**

Pusat Penelitian Oseanografi - LIPI, Jl. Pasir Putih I, Ancol Timur, Jakarta Utara, Indonesia

giyanto@yahoo.com

Several techniques are used in assessing the status of coral reef. Two of them are Line Intercept Transect (LIT) and Rapid Reef Resources Assessment (RRA). In the LIT technique, a transect consisted of a measurement tape, placed on the reef slope parallel to the shore. The intercept for each category of biota and substrates along the transect were recorded with accuracy in centimeters. By analyzing those data, the cover of each category can be calculated. In the RRA technique, without placing the measurement tape, observer swam by snorkeling for about 5 minutes, and estimated the cover of each category that could be seen. However, both techniques have some advantages and disadvantages. To compare between those techniques, a study has been conducted in Kelagian Island, located in Lampung province, Indonesia, in October 2002. Statistical analysis indicated that there was not significantly different between LIT and RRA techniques in assessing the hard coral cover, *Acropora* cover, non-*Acropora* cover, soft coral cover, sponge cover, sand and silt cover.



Poster Session
July 2 (Fri)



Induction of Metamorphosis in Larvae of the Brooding Corals *Acropora palifera* and *Stylophora pistillata*

Andrew H BAIRD*, Aileen A MORSE

Townsville, QLD 4811 Australia

andrew.baird@jcu.edu.au

Many coral larvae require surface contact with crustose red algae (CRA) to induce metamorphosis. However, many features of the ecology of pocilloporid corals, such as their ability to colonise primary substrata, suggest that these larvae respond to different cues. We compared the metamorphosis of larvae of the brooding corals *Stylophora pistillata* (F. Pocilloporidae) and *Acropora palifera* (F. Acroporidae) in response to a variety of environmental cues. *A. palifera* metamorphosed only in the presence of 3 species of CRA. In contrast, *S. pistillata* metamorphosed in all assays, except those containing the brown alga *Lobophora sp.* Metamorphosis was highest ($80 \pm 20\%$) in unfiltered seawater, however, metamorphosis also occurred in $0.2 \mu\text{m}$ -filtered seawater. These results suggest that *S. pistillata* larvae respond to both large and small water borne molecular cues. The lack of a stringent requirement for surface contact with CRA will allow *S. pistillata* larvae to pre-empt species which require a more developed fouling community to induce metamorphosis. This feature of larval ecology may be the key to understanding the success of many opportunistic benthic species.

Dynamics and Pattern of Coral Recolonization Following the 1998 Bleaching Event in the Reefs of the Maldives

Francesca BENZONI*, Michel PICHON, Paolo COLANTONI, Giuseppe BALDELLI, Carla MORRI, Carlo Nike BIANCHI

Dip. di Biotecnologie e Bioscienze, University of Milano-Bicocca, Milano, Italy

pichon@univ-perp.fr

The 1998 bleaching event, which followed abnormally high sea surface temperatures (up to 34°C) caused widespread coral mortality in the reefs of the Maldives. As early as 1999, recolonization had started and many newly settled juvenile colonies were recorded. A dramatic decrease in numbers of juveniles was observed between 1999 and 2000, followed by a stabilization in the following years. Taxonomic composition of recruits shifted from a dominance of Agariciidae in the early stages of recolonization toward a dominance of Acroporidae and Pocilloporidae. An inventory of the scleractinian carried out in 2002 showed that the specific diversity of Maldivian corals has not decreased. No local extinction can be reported, but a number of previously abundant species are now rare. Conversely, substratum cover is still very low, and the tridimensional structure of the reef is largely lost due to the destruction of dead colonies, which were reduced to rubble. Contrary to early expectations, Maldivian reefs do not seem to be undergoing a phase shift toward a dominance of fleshy algae, soft corals, or corals different from *Acropora* and *Pocillopora*. Rather, reef recovery seems to follow a predictable ecological succession toward the pre-existing situation. Tabular *Acropora* which had almost completely disappeared in 1998 are now recorded again with an average size of up to 40 cm for some colonies. The hypothesis of emergency spawning, suggested by recruitment starting soon after the mortality event, could be a further strategy to face climatic change. The present situation in the Maldives allows for a cautious optimism about the recovery potential of the reefs. However, the expected increased frequency of thermal anomalies that may lead to bleaching, introduces a major risk. Long term monitoring of Maldivian coral communities remains the only means to understand their future evolution.

Settlement Patterns and Early Life History Strategies of the Dominant Reef Building Corals at Selected Sites on Maui, Hawaii

Eric K BROWN*

P.O. Box 1346, Kaneohe, Hawaii 96744 United States of America

Pavona@aol.com

Settlement, growth, and survivorship of recruits of the dominant reef building corals around Maui, Hawaii were investigated over a 2 year period from 1999 to 2001. Terracotta tiles were deployed at 6 sites along an exposed coastline. Every 6 months tiles were examined *in vivo* and redeployed in the same locations. Recruits ($n=4,588$) were identified down to genus, measured, assessed (e.g. live, dead, bleached, fission, fusion, partial mortality, and "phoenix") and tracked on multiple plate surfaces to distinguish between new and pre-existing recruits. Broadcast spawning *Montipora* spp. had significantly higher recruitment levels ($p=0.004$) of $329 \pm 213 \text{ m}^2 \text{ yr}^{-1}$ but grew slowly over the first 6 months ($0.01 \pm 0.08 \text{ mm}^2 \text{ week}^{-1}$) and suffered high proportional mortality (0.89 ± 0.03). *Pocillopora* spp. recruits had low overall recruitment levels ($32 \pm 11 \text{ m}^2 \text{ yr}^{-1}$) but compensated by growing faster in the first 6 months ($0.19 \pm 0.15 \text{ mm}^2 \text{ week}^{-1}$) with intermediate proportional mortality (0.86 ± 0.05). Finally, *Porites* spp. recruits that represented both broadcast and brooding spawners exhibited low to intermediate recruitment levels ($76 \pm 39 \text{ m}^2 \text{ yr}^{-1}$) with intermediate growth ($0.16 \pm 0.04 \text{ mm}^2 \text{ week}^{-1}$) and lower proportional mortality (0.79 ± 0.05) than the other two genera. Survivorship for recruits tracked over 18 months was not significantly different among genera ($p=0.09$) but varied by site ($p=0.006$) and plate surface ($p=0.001$). A possible explanation for the observed life history patterns is that *Montipora* spp. in Hawaii puts more energy into initial settlement than post settlement survival. In contrast, *Pocillopora* spp. and *Porites* spp. devoted resources to faster growth (e.g. *Pocillopora* spp.) and/or survivability (e.g. *Porites* spp.) in the early stages of settlement.

Reproductive Effort of *Mussismilia braziliensis* (Verrill, 1868) (Cnidaria, Scleractinia, Mussidae) in the Abrolhos Reef Complex, Brazil

Alice C CAPARELLI, Debora O PIRES, Barbara SEGAL*

Quinta da Boa Vista, Sao Cristovao, Rio de Janeiro Federative Republic of Brazil

lili@biologia.ufrj.br

Brazil has the only true coral reefs in the South Atlantic. Abrolhos is considered the largest and richest coral reef area in Brazil. The diversity of scleractinian reef coral species is low, with a high rate of endemism (15, with 5 endemics). The genus *Mussismilia* is endemic to Brazil, and *M. braziliensis* is endemic between latitudes 12° and 19° S. This species is very common and plays an important role as one of the major reef builders in the area. Three different sites were sampled in the Abrolhos Reef Complex, located at different distances from the coast. Fragments of ten colonies were collected in each site, during their reproductive peak, and fixed in 10% formalin. Reproductive effort was estimated through fecundity (number of eggs per polyp). Data were translated into number of eggs per cm^2 . A new staining method was used to ease identifying and counting eggs in the dissected polyps. The accuracy of the quantification of eggs obtained through dissection was compared with histological analyses, and showed no significant difference ($p=0.1619$). Our data show that fecundity increases as the polyp volume increases ($r^2=0.922$; $p=0.000$). The percentages of fertile mesenteries were similar among sites. However, the number of eggs varied among polyps, colonies and sites. The area closest to the coast ("Parcela de Leste") presents the highest mean fecundity (233.43 ± 219.4 [s.d.]) per cm^2 . This area presents the highest contribution of siliciclastics to the sediment depositing on the reefs and has also the highest cover of *Palythoa caribaeorum*, which is a strong competitor for space. "Parcela dos Abrolhos", the area farthest to the coast, presented the lowest mean fecundity (141.6 ± 126.9 [s.d.]) per cm^2 . The lowest fecundity rate was observed in the site that has the largest colonies and cover of *M. braziliensis*.

Recruitment of Scleractinian Corals at Mayotte (Indian Ocean)Dhababia CHANFI*chemin de la batterie des Lions, 130007 Marseille France, Metropolitan
chanfi@com.univ-mrs.fr

Coral recruitment at Mayotte, Indian Ocean was studied on a fringing reef, an inner reef, a pass and a barrier reef at 6m, 12m and 20m depth. The recruits were collected from terracotta tiles which were directly attached to the substrata by permanent stainless steel base plates (Mundy, 2000). Tiles were collected every 3 months between February 2001 and October 2003. Results show a high periodicity with a seasonal peak of recruitment during the warm season (in February), with 80% of the total annual recruitment occurring during this season. The highest interannual variation was observed on the barrier reef and the fringing reef. Significant differences between rates of recruitment were exhibited between sites; the maximum rate of recruitment occurred in the pass and the minimum on the fringing reef. The rate of recruitment decreases with depth at all sites. The most abundant family settling was the pocilloporids, followed by the acroporids with the under surface of the tiles being favoured at 6m, 12m depth and the upper surface at 20m depth.

Annual Variation in Reproduction of Colonies of the Hawaiian Scleractinian, *Montipora capitata*Evelyn F COX*P.O. Box 1346, Kaneohe, HI 96744 United States of America
fcocox@hawaii.edu

Montipora capitata is a broadcast spawner, releasing egg/sperm bundles on evenings following the new moons of summer in Hawaii. Colonies of *Montipora capitata* were maintained for four years in a common garden, and reproductive output was assessed non-invasively each year. Gametes were collected during spawning periods and dried. First spawning activity was delayed when the new moon occurred early in June, possibly tracking annual cycles of water temperature. On average, 85% of the reproductive output occurred on a single evening, although colonies typically spawned over several nights and sometimes over multiple months. Individual colonies generally showed the same pattern year to year. Only some of the variability in reproductive output among colonies could be assigned to the effects of individual size, however, large changes in size from one year to the next were usually followed by reduced reproductive output in the second year.

Coral Recruits to Settlement Plates in the Northwestern Hawaiian IslandsMatthew J DUNLAP*, Jean KENYON1125B Ala Moana Boulevard, Honolulu, Hawaii 96814, USA
Matthew.Dunlap@NOAA.gov

A key aspect of marine reserve design is establishing estimates of when, where, and how many recruits enter the system. At French Frigate Shoals, Maro Reef, Lisianski Island, Pearl and Hermes, Midway, and Kure Atolls, NOAA installed an array of oceanographic buoys to measure sea surface temperature and other parameters important to coral reef health. In fall 2001, settlement plates were attached to the base of these moorings to assess larval recruitment, and to enable coupling of biological data with physical data collected by the buoys. One year after deployment, a mass bleaching event affected the northerly reefs during the latter 2 months of the plate deployments. After settlement plates were collected and replaced, all organisms present on the collected plates were counted and measured. Coral recruits were present at all locations, but Maro had the highest density (270 recruits/m²/year versus the next highest at Kure of 43) and a larger mean coral diameter (2.67 mm versus the next largest at Lisianski of 2.05) than other plates. The recruitment rate at Maro is the highest rate recorded in Hawaii, but smaller than for studies in Jamaica and the Great Barrier Reef. Recruits were from the families Acroporidae, Pocilloporidae, and Poritidae. Lowest coral settlement occurred at Midway (7 recruits/m²/year), followed by Pearl and Hermes (18 recruits/m²/year). Coral recruits were more abundant on the undersides (horizontal) and insides (vertical) of plates at 5 of the 6 locations. Annual collections of these plates will address whether the 2002 recruitment numbers at these sites are typical. Since the corals counted on the 2002 plates likely settled before the bleaching event, will recruitment be different at Midway one year after the bleaching event than it was before bleaching? Specific information on recruitment dynamics is an important component of the management of remote coral reef ecosystems.

Spatial Variation in Scleractinian Coral Settlement on Artificial Substrates in the Dry Tortugas, FloridaNicole D FOGARTY*, Gregory A PINIAK, Christine M ADDISON, Don FIELD
Pivers Island Road, Beaufort, NC 28516 United States of America
fogarty@bio.fsu.edu

Settlement patterns of scleractinian corals on artificial substrates were investigated at six sites ranging from 16-18 m in the Dry Tortugas, Florida. Two sites were located in Dry Tortugas National Park, one site in Tortugas Ecological Reserve, and three sites outside the park and reserve boundaries. Two sets of five settlement arrays were deployed at each site in July 2002; each array consisted of two vertical and two horizontal terra cotta plates with varying surfaces. After eleven months, the plates were collected, photographed, bleached, and examined for settled corallites with a dissecting microscope. Corals were identified to genus; *Diploria* spp., *Agarica* spp. and *Porties* spp. were the dominant settlers at all sites. Settlement was highly variable by location on substrate (61.3% grooved surface, 34.3% smooth surface, 4.4% sides), but did not differ with tile orientation (58.1% horizontal tiles and 41.9% on vertical tiles). The density of the 160 coral settlers was highly variable among sites (ranging from 4.1 to 46.9 m⁻²). Overall density of coral recruits was 15.4 m⁻², with the highest density located at a site outside the northern boundary of Dry Tortugas National Park, while the southern sites had the least settlement. Settlement rates and spat identification are important information for coral reef conservation, monitoring and restoration efforts.

Sexual Reproduction of the Solitary Coral *Leptopsammia pruvoti* (Scleractinia, Dendrophylliidae) in the Mediterranean

*Stefano GOFFREDO**, *Josipa RADEVIC*, *Valentina AIRI*, *Francesco ZACCANTI*

Via F. Selmi 3, I-40126 Bologna, Italy
sgoff@tin.it

Leptopsammia pruvoti is a common azooxanthellate coral living in the Mediterranean Sea and along the Atlantic coast from Portugal to southwestern of England. It lives in shaded habitats from shallow water to a depth of more than 100 meters. The annual cycle of sexual reproduction in this species is studied in an area nearby Leghorn (Tuscany, Italy). *L. pruvoti* is a gonochoric and brooder. Testes require 1 yr to reach maturity with a maximum spermary diameter of 340 μ . Oogenesis lasts 2 yr with a maximum diameter of 680 μ . The rate of gonadic development increases significantly during December and January, fertilization takes place from February to May and planulation in June. Embryos have a maximum diameter of 740 μ in the first stages (periblastula), and 860 μ in mature gastrula. Released larvae have a maximum diameter of 1000 μ . The annual cycle of photoperiod and water temperature seems to coincide with the reproductive cycle. Different sex allocation has been detected between males and females of *L. pruvoti*. Volume occupied by male gonads has been found to be 4 times bigger than volume occupied by female gonads. In the self-fertilizing hermaphrodite *Balanophyllia europaea*, a close relative species studied in the same area, male and female gonads occupied the same volume. According to sex-allocation theory, a self-fertilizing species require a smaller male allocation than the cross-fertilizing species, in order to guarantee successful reproduction.

Reproduction of *Diploastrea heliophora* (Scleractinia, Faviidae) in Singapore

*James R GUEST**

14 Science Drive 4, Blk S2, NUS, 117543 Republic of Singapore
scip9051@nus.edu.sg

Diploastrea heliophora (Scleractinia, Faviidae) (Lamarck 1816) is an important reef building species throughout the Indo-Pacific. Colonies are often very resilient to stress, and individuals can be extremely long lived. Despite its relative importance as a reef builder, little is known about the reproductive biology of this species. Previous reports indicated that *D. heliophora* is a gonochoric broadcast spawner. This reproductive strategy is unusual, as most other members of the family Faviidae are simultaneous hermaphrodites. I investigated the gametogenic cycle of *D. heliophora* in Singapore. Five individual colonies were sequentially sampled over a period of 14 months from March 2001 until April 2002 around the islands south of mainland Singapore. Based on the disappearance of gonads, spawning probably occurs in April and May, although no *in situ* spawning observations were made. Interestingly, individual polyps were either male or female, however, four of the sampled colonies appeared to be hermaphroditic at the colony level (i.e. monoecious). Only one of the sampled colonies contained only male gametes throughout the study period. The apparently hermaphroditic colonies had a sequential pattern with oogenesis beginning between June and August, and spermatogenesis beginning in February or March.

Solitary Corals of the Genus *Fungia* Can Fuse with Clonemates in the Early Phase of Regeneration

*Michio HIDAKA**, *Noriko KOBAYASHI*, *Wakako OSHIRO*

Nishihara, Okinawa 903-0213, Japan
hidaka@sci.u-ryukyu.ac.jp

Most scleractinian corals are colonial, while most *Fungia* species are solitary. In colonial corals, clonemates always fuse if they are brought into contact, while in solitary corals, two individuals generally do not fuse even if they are clonemates. It is important to know when colonial or solitary character develops during the course of development for understanding the underlying mechanism of the difference between the colonial and solitary forms. In this study we tried to study when solitary corals belonging to *Fungia* develop solitary character and lose the capacity to fuse with clonemates during the regeneration process. Planula-like tissue balls were formed from dissociated cells or tissue fragments. When two tissue balls derived from the same individual were brought into contact, they fused. When individuals of *Fungia* sp. were broken into pieces, residual tissue on skeletal fragments shrank to form tissue islands. If two such tissue islands were brought into contact, they fused and formed a single polyp. Residual tissue on skeletal fragments usually developed into a new polyp, but sometimes more than one polyp developed from a tissue fragment, resulting in a colonial form. They remained to be colonial or as polyps with multiple mouths surrounded by a single tentacular ring for several months. When two newly regenerated polyps derived from the same individual were brought into contact, they fused and formed a polyp with two mouths. The present observation suggests that, in the early phase of regeneration, *Fungia* corals do not show characteristics of solitary animals but can fuse with clonemates. In some fused polyps, two mouths were very close to each other and appeared to be in the process of fusion. Polyps with multiple mouths might become solitary probably through fusion of mouths instead of separation of constituent polyps.

Spawning Patters and Larval Dispersal in Ogasawara Archipelago, Japan

*Makoto INABA**, *Masato KOBAYASHI*, *Kazuo HORIKOSHI*

Miyanojima-michi, Chichi-jima, Ogasawara, 100-2101 Tokyo Japan
inaba@ogasawara.or.jp

Ogasawara Archipelago, composed a series of oceanic islands, is located at 1000km south from Tokyo. Although about 200 species of hermatypic corals are reported in this region, the ecological aspects of corals are poorly known. In this study, we investigated the spawning patterns of corals at Chichi-jima Islands in 1998-2003, by underwater observation and the appearance of slick. We recognized the spawning of about 50 species of corals and two spawning periods; 1)late June to early July period- four staghorn *Acropora* species, such as *A. formosa*, and 2)mid August to early September period-other several species. The spawnings of former species occurred at several neap tide period as a divided spawning pattern. Late species spawning also synchronized at a neap tide period, however the spawning patterns varied. The slick in Haha-jima island and Moko-jima Islands were observed at the same timing as Chichi-jima Island. It is known that coral spawnings general occur at the spring tide period, however in Ogasawara Archipelago, all coral spawnings observed occurred at the neap tide period. To investigate the relationship between the tidal levels and larval dispersal, we conducted the drift card experiments. We release the cards in beach at night, the neap and spring tide and collected the cards from the next morning to a week. The drift cards spreaded to a wide range, from Haha-jima Island to Moko-jima Islands. The number of the drift cards peaked at the next day from release, and extremely decreased later. The difference of number of cards collected at between the neap and spring tide is no significant. The results reveals that the reproductive patterns of corals in Ogasawara Archipelago are different from other regions, and the unique traits are specific character on the Ogasawara coral ecology.

Diurnal Periodicity of Larval Release by Five Brooding Scleractinian Corals in Southern Taiwan

*Ke-Han LIN**, *Lee-Shing FANG*, *Keryea SOONG*, *Tung-Yung FAN*

2 Houwan Road, Checheng, Pingtung 944 Taiwan

tyfan@nmmba.gov.tw

Diurnal patterns of larval release by five brooding corals *Seriatopora hystrix*, *Stylophora pistillata*, *Pocillopora damicornis*, *Euphyllia glabrescens* and *Tubastraea aurea* in southern Taiwan were investigated. *S. hystrix*, *S. pistillata* and *P. damicornis* were collected at Hobihu, while *E. glabrescens* and *T. aurea* were collected at the Inlet of the Third Nuclear Power Plant. Corals were maintained in outdoor, flow-through systems to quantify hourly release of larvae. Planulation of all three pocilloporids revealed a well defined diurnal pattern. Most of planulae were released from 4:00 A.M. to 6:00 A.M. Larvae of *E. glabrescens* were released throughout the day, with two peaks occurring from 3:00 A.M. to 4:00 A.M. and from 8:00 P.M. to 9:00 P.M. Planulation of the azooxanthellate coral *T. aurea* occurred throughout the day with no diurnal periodicity. Most planulae of these species, except *T. aurea*, were released in the early morning suggests that this period of time is advantage for larval survival.

Reproductive Strategy of the Brazilian Reef Coral *Siderastrea stellata* within Six Populations through a Latitudinal Gradient

Monica M LINS DE BARROS, *Debora O PIRES**

Museu Nacional, Departamento de Invertebrados, Quinta da Boa Vista, 20940-040, Sao Cristovao, Rio de Janeiro, RJ, Brasil Federative Republic of Brazil

mlbarros@acd.ufjf.br

Reproductive characteristics and strategies of the Brazilian reef coral *Siderastrea stellata* were studied within six equidistant populations located along the geographical distribution of the species and through a latitudinal gradient of 20°. Ten colonies from each population were collected in the peak of the reproductive cycle to determine the fecundity. The collections were simultaneously, allowing the analyze of the reproductive cycle at the same time in all populations. In all populations, the species was gonochoric and brooder, with a deviated sex ratio to female colonies. The pattern of surface sea temperature variation is similar among the six sites studied. The planulation season occurred with an increase of sea temperature, occurring during the summer in all populations. The reproductive peak, stage of the reproductive cycle with a high percentage of mature oocytes, was similar in all populations, but one, a site influenced by an upwelling event during the summer. In this population, the reproductive peak was earlier, probably to avoid the effects of low temperatures on planulae development. The fecundity varied among the other five populations, forming two groups (of low and intermediate fecundity) separated from one population, with the highest fecundity. Polyp volume and colony size could be the factors causing the difference between the latter population and the others, while the differences on fecundity between the two other groups may be a consequence of demographic parameters. The lowest fecundity was observed in reef sites, where the density and number of reproductive colonies are larger than in rock shore sites, with higher fecundity. There could be an adjustment between the number of reproductive colonies and the number of gametes produced per colony in the populations and, despite of the difference on fecundity between rock shore and reef sites, the success of the reproduction, recruitment, might be almost the same.

Recovery of Coral Community in a Nature Reserve of Southern Taiwan, Two Years after a Ship Grounding

*Pi-Jen LIU**, *Lee-Shing FANG*, *Tung-Yung FAN*

2 Houwan Road, Checheng, Pingtung 944 Taiwan

tyfan@nmmba.gov.tw

The bulk carrier Amorgos grounded on coral reefs of Lungken Nature Reserve, Kenting National Park in southern Taiwan on 14 January 2001. Coral coverage of some areas had been denuded as a result of the mechanical abrasion during typhoon period. The recovery process of coral community at the damaged site was monitored by 3 permanent 1x1m quadrates on denuded natural substrata at a depth of 6 to 12 m. The number of corals was 0-2 colonies m⁻² in 2001 and 2002. A total of 94 juvenile corals were found in 2003. The mean density of corals was 31.7 m⁻² with a range of 27-35 colonies m⁻². The mean cover of recruited colonies was 3.0 cm². The family Faviidae accounted for 55.3% of all recruited colonies, followed by the family Poritidae and the blue octocoral *Heliopora coerulea* amounted to 13.8 and 3.2%, respectively. Recruited colonies of other corals such as pocilloporids and acroporids were few. The families Faviidae and Poritidae as well as *H. coerulea* were common at nearby undamaged site. The recruitment pattern of Lungken was different from other sites in southern Taiwan where recruitments usually were dominated by pocilloporids. It suggests that recruitment was influenced by nearby coral community at Lungken. The success of recolonization improves the recovery of corals at the shallow water site damaged by the ship grounding.

Ultrastructure of the Planula Cilia from Several Species of Corals

*Yoshikatsu NAKANO**, *Masako HARA*, *Toshiki WATANABE*

3422 Sesoko, Motobu-cho, Okinawa 905-0227 Japan

ynknssk@lab.u-ryukyu.ac.jp

Within the mechanisms of settlement by planula larvae of corals, especially the role of chemical inducers is well studied. However, few studies mention the role of nematocyst or mucus release, and cilia as a physical sensor for settlement. Still less is the availability of functional morphological information about settling coral planula. We have observed ultrastructure of cilia of the planula from *Acropora digitifera*, *Oulastrea crispata*, *Favites chinensis*, *Goniastrea aspera*, *Pseudosiderastrea tayamai*, *Stylophora pistillata* and *Pocillopora damicornis* by scanning electron microscopy. The planula was cultured in aquariums after spawning/releasing and prepared for microscopy each day. We identified a standard straight shape cilium (St-cilium), and a uniquely shaped cilium with a spatula like tip (Sp-cilium) of the planula. St-cilia were observed on the surface of the planula of *A. digitifera*, *O. crispata*, *F. chinensis*, and *G. aspera*. Sp-cilia were observed on surface of the planula of *S. pistillata*, *P. damicornis*, *P. tayamai* and the front face (settlement side) of the mature planula of *A. digitifera*. St-cilia were decrease on surface of the metamorphosed planula of *A. digitifera*. *S. pistillata* and *P. damicornis* are brooders, and *P. tayamai* is a surface brooder (Nakano unpublished data). On the other hand, *A. digitifera*, *O. crispata*, *F. chinensis* and *G. aspera* are spawners. We suggest that St-cilium is used for swimming and Sp-cilium is used for settlement.

Population Genetics and Larval Ecology of Scleractinian Corals in the Ryukyu Archipelago

Akira NISHIKAWA*, Kazuhiko SAKAI
3422 Sesoko, Motobu, Okinawa Japan
akira_nishioka@hotmail.com

One of the central questions in marine ecology is the degree of dispersal of propagules of marine organisms. In particular, scleractinian corals are benthic invertebrates, therefore dispersal of early life stages is a critical aspect of their population dynamics. However, planula dispersal is among the most difficult of problems to study empirically in the sea because of the impracticality of direct observation on the larval stages. There are some studies of indirect estimates for coral dispersal by studying planula behavior and population genetics. Coral planula may display many important characteristics for dispersal (i.e. longevity, settlement competency periods, position in water column, response to light intensity or chemical signal). To address questions of the influence of planula characteristics for genetic differentiation among local populations, we conducted laboratory experiment for planula ecology and allozyme electrophoresis for genetic differentiation among populations in at least four species (*Acropora tenuis*, *Acropora digitifera*, *Goniastrea aspera* and *Stylophora pistillata*) in the Ryukyu Archipelago, Okinawa. We focused only on larvae longevity (survival rates) and settlement competency periods (settlement rates) in planula characteristics. We will provide information of relationship between larval ecology and genetic differentiation among local populations in the Ryukyu Archipelago.

Sexual Reproduction of a Soft Coral *Cladiella tuberosa* Tixier-Durivault (Cnidaria : Anthozoa : Alcyonacea) on Coral Communities in the Inner and the Eastern Gulf of Thailand

Parnhathai NOBCHINWONG*, Thamasak YEEMIN

Department of Science, Faculty of General Education, Rajamangala Institute of Technology, Bangkok Technical Campus, Bangkok 10120 Kingdom of Thailand

nopchinwong@hotmail.com

The alcyonacean is a very important member of coral communities in the Gulf of Thailand. Sexual reproduction of a soft coral, *Cladiella tuberosa* Tixier-Durivault, has been studied in coral communities of Khang Khao Island, Chonburi Province, in the Inner Gulf of Thailand and Samet Island, Rayong Province, in the Eastern Gulf of Thailand since September 1998. Monthly sampling of tagged colonies and microtechnique analysis of histological samples in the laboratory were carried out. *C. tuberosa* was a gonochoric species, whose male and female colonies were separated. Several developmental stages of oocytes were found in each sampling period. Mature oocytes of *C. tuberosa* were 500-625 μ m in diameter. Fecundity greatly varied in each polyp. Spermatoocytes began to develop near the spawning period which occurred in July-September. The severe coral bleaching phenomenon in the Gulf of Thailand during April-May 1998 interrupted gametogenesis of *C. tuberosa* for several months. Moreover, partial mortality of several colonies was obviously recorded. Recovery patterns of gonadal development of the soft corals from the two study sites were outstandingly different due to certain environmental factors, such as turbidity, sedimentation rate and population structures.

Reproductive Period and Spawning Synchronicity of Scleractinian Corals in Palau

Lolita K PENLAND, David IDIP, Kloulechad JIM*
P.O. Box 7086, Koror, Palau
lkpenland@palaunet.com

The reproductive timing of broadcast spawning (scleractinian) corals has been studied in Palau since May 2002. Surveys were conducted on 7 consecutive evenings after full moon for each month. Data were documented on the lunar periodicity, the timing of spawning, and sex determination for over 70 coral species. Synchronous spawning was observed twice a year for numerous species. These mass spawning events were split over several months. The first event began in February and peaked in April/May and the second event began in September and peaked in November/December. Spawning of 10 species of *Montipora* occurred in March and September followed by mass spawning involving 21 genera in April/May, and 16 of the same genera spawned again in November/December. The spawning patterns, throughout the course of the evenings, remained consistent for the two mass spawning seasons.

Reproduction in Aquarium Corals

Eric BORNEMAN*

Department of Biology, Science and Research Bldg II, 4800 Calhoun Rd., Houston, TX 77204 United States of America

eborneman@uh.edu

Many advances have allowed the majority of scleractinian corals and octocorals to be maintained with great success and rapid growth in closed system aquaria. However, sexual reproduction remains a sporadic and unpredictable event. New methods and increasing numbers of reports have both contributed to more regular observations of reproduction events in aquaria in recent years. Unusual and unreported modes of asexual reproduction have been documented, including a recently described coral polyp extrusion that is common in, but not limited, to the family Faviidae. Other forms of unreported asexual reproduction are the formation of acanthonaut-like buds on several species in the family Mussidae and polyp bailouts in coral species outside the previously reported family Pocilloporidae. In addition, observation of sexual reproduction include variations of life history traits other than those established in prior reports and polyp tentacle egg storage in Euphylliids. The increasing numbers of aquarists observing reproduction events in aquaria coupled with the continual observation of species possible in closed system is allowing for a greater understanding of the diversity of reproductive methods in reef corals.

Intra-annual Coral Recruitment Variation on Artificial Substrata in Caribbean Shallow Patch Coral Reefs

Miguel A RUIZ-ZARATE*, Jesus E ARIAS-GONZALEZ

Carretera Antigua a Progreso Km. 6, A.P. 73 "Cordemex", Merida, Yuc. Mexico. C.P. 97310 United Mexican States
mruiuz@mda.cinvestav.mx

The coral larvae settlement activity was assessed in a shallow patch reefs environment using artificial substrata. Several objectives were addressed as to evaluate the suitability of carbonate and terracotta tiles, taking into account the type of surface exposure (superior, inferior and lateral), the variation of recruitment based on different samplings periods (within one year) and the relationship of coral recruitment variation with temperature and re-suspended sediment load. The recorded recruits' community structure was 71 % *Porites* spp., 7 % *Siderastrea* spp., 7 % Agariciidae, 5 % Astrocoeniidae and 3 % Faviidae and 8 % of the recruits were classified as unknown. According to coral recruits communities related to artificial substrata found at other localities in the Caribbean the Genus *Porites* was dominant. Recruits' density and size were similar between terracotta and carbonate tiles, indicative of their suitability for assess coral recruitment. Posterior and lateral surfaces showed higher and significantly different recruits density than anterior surface. On the other hand, anterior and lateral surfaces had largest and significantly different recruits sizes than posterior surface. These differences denote the active selection of substratum in colonization by larvae and faster growth on upper surfaces, respectively. From five exposure times (1, 2, 3, 4 and 5 months), the five months exposure time showed the highest density and the smallest recruits size significantly different than the rest of exposure times. These differences were related to a maximum recruitment from *Porites* and other coral recruits taxa. The results obtained were related to the reproductive characteristics of the coral species apparently associated to the recorded recruits. Also the maximum coral recruitment was related to the coldest months, consequently minimum and mean temperature were inversely related to recruits density and positively related to mean recruits size but these relationships were not significant.

Genetic Variation within and between Populations of the Caribbean Coral *Porites furcata* in Panama. A Preliminary Study

Carmen M SCHLOEDER, Hector M GUZMAN*

Unit 0948, APO AA 34002, USA Republic of Panama
schloederc@naos.si.edu

Reef communities in the Caribbean contain a variety of reef-building coral species. Shallow reef areas in Bocas del Toro, Panama, are dominated by *Porites furcata*, a fast growing, branching coral species and main reef builder in the Caribbean. The genetic structure of a coral population reflects the relative contributions of sexual and clonal reproductive strategies, asexual propagation usually leads to a high local abundance of only one genotype. It is hypothesized, that the single individuals in these populations in Bocas del Toro are mainly clones as a result of fragmentation, which is even more pronounced in areas with high anthropogenic activities. To give an insight in the genetic variation and the ecology of *P. furcata* populations in Bocas del Toro and strategies in terms of larval dispersal, coral samples were analyzed for genotypes with amplified fragment-length polymorphisms (AFLPs). For a preliminary study, five branches of *P. furcata* each were sampled at two different reefs in Bocas del Toro and at one reef site in Colon. Seven different primer combinations were tested for all individuals for the determination of polymorphic loci. A high variability of genotypes was found within and between reef sites. The next step in this study will be the determination of clones within two contaminated and two non contaminated reefs in Bocas del Toro.

Settlement Preferences and Post-settlement Mortality of Laboratory Cultured and Settled Larvae of the Caribbean Hermatypic Coral *Montastraea faveolata* in the Florida Keys, USA

Alina M SZMANT*, Margaret W MILLER

CMS, 5600 Marvin K. Moss Lane, Wilmington NC 28409 United States of America
szmanta@uncw.edu

The broadcast spawning massive coral, *Montastraea faveolata*, is one of the most important hermatypes in the Caribbean. It is common as large colonies up to several meters high, but infrequently found as a young recruit. This species has suffered major tissue loss and mortality in recent decades due to bleaching and disease. Thus, it is important to understand processes that will affect population recovery, especially sexual recruitment. Gametes bundles were collected during annual mass spawnings, and larvae raised in the laboratory to early competency (ca. 60 hours). Batches of larvae were given naturally aged limestone plates on which to settle, and settlement patterns mapped onto data grids within one to two weeks after settlement. The plates were attached to natural reef substrate on two reefs offshore of Key Largo FL, and resurveyed monthly for up to 3 months. Newly settled spat (ca. 0.4 to 0.5 mm in diameter) are difficult to observe without a microscope. Larvae preferred to settle on the underside-conditioned surfaces of plates regardless of plate orientation in the laboratory during settlement (i.e. they settled on "under-surfaces" even when these were oriented upwards towards light), demonstrating a strong settlement attraction to fouling organisms typical of cryptic reef surfaces. Some (ca. 25 %) settled directly on crustose coralline red algae (CCA) but most settled 1 cm or more away from CCA. Settlement was statistically aggregated, indicating either that newly settled larvae attract others to settle near them, or that there are substrate micro-patches with strong settlement induction ability. Field survivorship was low: 25 % after 1 month and 0 to 2 % after 3 months, lower than that of brooding species treated in a similar method. If such survivorship rates are typical, it will take very high densities of settlement for there to be any hope of long-term recruitment success.

Early Life History Processes in Caribbean Corals

Mark JA VERMEIJ*

Southeast Fisheries Science Center, 75 Virginia Beach Drive, FL33149 Miami United States of America
mark.vermeij@noaa.gov

In many studies coral planulae are considered as particles whose dispersal and survival is largely determined by environmental factors. In addition most information on coral population dynamics after planulae settled is based on individuals that measure between 2-4cm², a size that is often assumed as being representative of the earliest stages of coral population dynamics. By studying the earliest life stages of three Caribbean coral species we aim to determine whether the assumptions above are justified, i.e. reveal the processes that mostly affect survival and population dynamics of planulae between fertilization and successful recruitment. We found evidence for (1) the relation between colonization success and preceding history of a planula in the plankton, (2) high occurrence of chimera formation during the earliest stages of settlement, (3) limited mobility (<2cm) of single polyps early after settlement, (4) up to 80% of newly observed juveniles (<0.2cm²) can result from fragmentation rather than settlement, (5) all aspects of clonal growth are observed in individuals smaller than 2cm² and that (5) the number of settlers in a location depends on species dispersal characteristics, habitat characteristics and adult density. These findings highlight the surprisingly dynamic nature of the earliest life stages in corals and emphasize their relevance as structuring factors in Caribbean coral populations.

Reproductive Biology of Scleractinian Coral *Acropora aspera* at Panjang Island, Java Sea*Munasik**

Jl. Prof. Sudharto, SH Kampus Tembalang, Semarang 50275 Indonesia

munasik@hotmail.com

REPRODUCTIVE BIOLOGY OF SCLERACTINIAN CORAL *Acropora aspera* AT PANJANG ISLAND, JAVA SEAMunasik Department of Marine Science, Faculty of Fisheries and Marine Science, Diponegoro University, Indonesia

Abstract Reproductive biology of scleractinian coral *Acropora aspera* at Panjang Island, Java Sea (Central Java, Indonesia) was studied by histology and laboratory observations of coral spawning from 3 October 2001 - 28 April 2002. *A. aspera* is an hermaphroditic spawner. Oocytes were visible in October 2001 and from January to April 2002 on histological sections, while spermatogenesis occurred from January to April 2002. During this observation period, spermatozoa first appeared in March 2002, while both mature and immature oocytes first appeared in January and were continually produced until April 2002. However, both mature oocytes and sperm were also appeared in October 2001, indicate that multiple gametogenic cycles was occurred. Gametes were spawned simultaneously on 5 April 2002 in first quarter moon. While other colonies spawned gametes on 20 April and 24 April in third quarter moon and 4 days before full moon. Spawning occurred at 2.00-23.00, 2 hours after sunset. Only several gametes that were fertilized to developed a larva. First cleavage occurred at 2-3 hour after spawning. Synchronous division occurred in the first cleavage and produced two equal blastomeres, while asynchronous division occurred after forming embryo ca. 16 cells. Reproductive plasticity in corals has been considered to occur in corals on reef flats, where physical environment is usually harsh. The present study suggested that the shallow water *A. aspera* show asynchronously multiple spawning events, while no sign of external fertilization was occurred. Thus, *Acropora aspera* may recruit successfully not by sexual reproduction but by asexual reproduction i.e. fragmentations.

Chemical Defense Mechanisms in Hawaiian Scleractinians*Daniel J BARSHIS**, *Robert J TOONEN*

2538 McCarthy Mall, Edmondson 152, Honolulu, HI 96822, United States of America

barshis@hawaii.edu

An important method of keeping predator populations in check is the production of chemical defenses by prey. While much study has been devoted to molluscs, gorgonians, sponges, and even seaweeds, very little is known about the defense mechanisms of the stony corals. This study investigates the effectiveness of chemical defense mechanisms in Hawaiian Scleractinians. A broad survey of these defense mechanisms in the most common reef-building coral species in Hawaii will help to produce a better understanding of the predator/prey interactions that help shape Hawaiian reef community structure. Standard volumes of coral tissue will be removed from the skeleton and extracted in a 1:1 mixture of methanol and dichloromethane. Extracts will be combined into food form using freeze-dried, powdered squid mantle, and alginate acid. Extract-containing food pellets will be assayed in laboratory experiments using a combination of Hawaiian reef fish. First trials will be run in January with generalist fish predators in order to determine presence/absence of chemical deterrents. A relative palatability index will be generated to compare differences among approximately 10 common Hawaiian coral species. We are using generalists to detect the presence of chemical deterrents as it is least likely that they will have evolved mechanisms to process secondary defensive metabolites. Comparisons between extract pellets and controls will be made using Fisher's exact test. If significant results are found, further assays will be done using Hawaiian coral feeding butterflyfish in an effort to investigate possible adaptations to the production of defensive chemicals. All laboratory assays will be finished by March 2004, with data analyses to be completed shortly thereafter.

Isolation Modifies the Impact of Piscivores on Fish Assemblages of Small Reefs*Jonathan BELMAKER**, *Yaron ZIV*, *Nadav SHASHAR*

POB 653, Beer-Sheva, 84105 State of Israel

belmakej@bgumail.bgu.ac.il

A positive connection is often found between fish species diversity on coral heads and their degree of isolation. I examined whether isolation creates differences between reefs in fish assemblages through changes in predation pressure. First, small artificial reefs were placed at increasing distances from a naturally continuous reef. Species richness and density of each species increased with isolation. A similar pattern was apparent on natural coral heads. In both natural and artificial reefs the number of predatory fish per potential prey species decreased with isolation. Next, artificial reefs were relocated together with all their fish inhabitants, closer to the natural reef. As a result, resident fish exhibited a sharp decline in numbers. The decline was density-dependent, such that the per-capita rate of decline was higher on reefs with higher density. Video analysis revealed that the cause of decline was the aggregative response of predators around the artificial reefs. This study shows that the impact of piscivores on resident fish is modified by isolation. The results suggest that the high diversity of fish on small isolated reefs is enabled by low predation. This is one of the first demonstrations of density-dependent predation in adult reef fish. This study was supported by the Israeli Ministry of the Environment (Israel grant 1206-2), the PADI foundation and the American Museum of Natural History.

Natural Selection in Fluorescent Proteins from Reef Anthozoa: Pigments and More*Maria BULINA*, *Juan A UGALDE*, *Ilya V KELMANSON*, *Steven F FIELD*, *Joseph P BIELAWSKI*, *Mikhail V MATZ**9505 Ocean Shore Blvd, St Augustine, FL United States of America
matz@whitney.ufl.edu

Proteins homologous to the green fluorescent protein (GFP)-like from *Aequorea victoria* determine the majority of host-tissue colors in Scleractinian corals and other reef Anthozoa; meanwhile, the ecological or physiological significance of this coloration remains controversial. We studied the mechanics of evolutionary process that created the diversity of Anthozoan GFP-like proteins using maximum-likelihood analysis of their sequences, backed up by site-directed mutagenesis experiments. Natural selection played a key role in evolution of the three main colors - cyan, green and red - and therefore this diversity is adaptively significant. Moreover, we found that GFP-like proteins are affected by diversifying selection that is not related to color, but rather reflects continuous readjustments of an intra-molecular interface between these proteins and some unknown component. Since such type of selection is most characteristic for co-evolution scenarios, we hypothesize that GFP-like proteins are involved in evolution of host-zooxanthellae symbiosis at the molecular level.

Spatial Variation and Community Structure of the Scleractinian Corals: Genus *Acropora* in the Gulf of Thailand*Anchalee CHANKONG**, *Vipoosit MANTHACHITRA*

339-339/3 Moo 8, Paknam, Muang District, Chumphon 86120 Kingdom of Thailand

anchankong@hotmail.com

The purpose of this study is to investigate the diversity, abundance, species composition and community structure of *Acropora* in the Gulf of Thailand which are the dominant group within coral assemblages in the Gulf of Thailand situated between latitudes 6 and 14 °N and longitudes 99 and 105 °E. The 30 x 1 m. belt transect were employed through 16 sites from 8 islands along the Gulf of Thailand. A total of 440 colonies belonging to 26 species were found. Kudi Island had the highest species richness (9 species). Mannai Island, Sang Island, Sing Island and Toa Island had the second species richness (7 species). Whereas Kudi Island, Sing Island and Toa Island had the highest diversity i.e. 1.65, 1.51 and 1.35 respectively. *Acropora digitifera*, *A. hyacinthus* and *A. millepora* were commonly found on all study sites. While *A. cytherea*, *A. divaricata*, *A. latistella*, *A. tenuis*, *A. valida* and *A. valenciennesi* were uncommonly found. The pattern of the distribution of *Acropora* can be divided into 3 groups: 1) Phai Island, Mannai Island and Toa Island 2) Kudi Island and Mannok Island and 3) Sing Island and Sang Island. Which the first group dominated by *A. digitifera*, *A. hyacinthus* and *A. millepora*, the second group dominated by *A. subulata* and *A. millepora* and the third group dominated by *A. hyacinthus* and *A. florida*. The result of MANOVA indicated the different in habitat among location. Colony size were categorized into 5 classes: 1-10, 11-20, 21-50, 51-100 and >100 cm., respectively. The most abundance size were size 21-50 cm. The colony abundance were found as range between 1-10 colony/90 m². The pattern of the distribution was not correspond well with geographical location. This show the recent condition of *Acropora* in the Gulf of Thailand.

Coral Growth Rates and Zooxanthellae Density Changes of *Siderastrea siderea* (Ellis and Solander) Related to a Light Intensity Gradient due to a Pier Shadow at Guayanilla Bay, Puerto Rico

*Daisy DURANT**, *Ivette LABORDE*, *Vance VICENTE*

PO Box 907 Isla Magueyes Marine Station Lajas Puerto Rico 00667 Puerto Rico
ddurant33@hotmail.com

Light is critical in many metabolic functions of the coral/zooxanthellae symbiotic system. Rapid development of the coastal zone and growing number of pier structures raises concern of the impact it may have on benthic organisms through shading, particularly reef corals. However, scientific research documenting the effects of shading of pier structures to phototrophic benthic organisms is lacking. At Guayanilla Bay Puerto Rico, the EcoElectrica Liquefied Natural Gas and CoGeneration Plant was recently built, including a pier. A gradient of light intensity, due to the shadow of the pier, gave the perfect setting to study *S. siderea* ecology in terms of linear extension rates and zooxanthellae density under different light regimes. Forty coral colonies of *S. siderea* were transplanted in sets of 10 within each of 4 light treatments established along a transect of 50m running west and perpendicular to the pier. Transplanted and non-transplanted control colonies were stained once with Alizarin Red to measure linear skeletal extension rate and collected 16 months after. PAR measures were made at the four light treatment zones around midday on a weekly basis, from March 2000 to September 2001. Significant differences ($p < 0.001$) were found among group treatments and sex for skeletal extension rate. All treatment zones were significantly higher than under the pier zone. Significant difference in zooxanthellae density was found among light treatment groups and among colonies. These results demonstrate the significance of light on the ecology of benthic phototrophic organisms. Guidelines concerning the placement, height, width, and type of construction for docks and piers over phototrophic organisms could benefit from scientific data to address the light availability problem a priori. Consistency in the development and application of regulatory policy to address impacts of dock shading could be achieved.

Inorganic Nitrogen Cycling in Coral Reef Sediments: Implications for Ecosystem Processes

*Ron JOHNSTONE**, *Klaus KOOP*, *Anthony LARKUM*

CMS, University of Queensland, St Lucia, 4072, QLD, Australia
rnje@uq.edu.au

To describe the pathways of inorganic nitrogen in coral reef sediments, the major nitrogen transformation processes were measured in the two key sediment types in a coral reef lagoon. A mixture of stable isotope and chemical inhibition methods were used. Ammonification rates showed a seasonal difference with means of 82.7 $\mu\text{M N.l-1.h-1}$ (very fine sand;VFS) and 46.4 $\mu\text{M N.l-1.h-1}$ (coarse sand;CS) in summer, compared to 35.3 $\mu\text{M N.l-1.h-1}$ (VFS) and 26.6 $\mu\text{M N.l-1.h-1}$ (CS) in winter. In addition, there was a seasonal change in the distribution of ammonification within the different sediment types. Nitrification rates were low and also showed a seasonal difference which varied depending on sediment type. Mean rates were 83 to 256 $\mu\text{M N.m-2.d-1}$ in winter and 29 to 340 $\mu\text{M N.m-2.d-1}$ in summer. This accounted for between 14 and 59% of sediment ammonium incorporation. Similarly, denitrification rates varied with season and sediment type with rates ranging between 0.3 and 8.1 $\mu\text{M N.m-2.d-1}$. Denitrification accounted for between 13 and 92% of the nitrogen passing through nitrification. Overall, sediment nitrogen remineralisation was calculated to supply between 19 and 76% of the nitrogen required by microalgae living on the sediment surface.

Spatial Variation and Population Structure of Faviid Corals (Scleractinia: Faviidae) on Coral Assemblages along the Gulf of Thailand: 4 Years after 1998 Coral Bleaching

*Narinratana KONGJANDTRE**, *Vipoosit MANTHACHITRA*

Department of Aquatic Science, Burapha University, Chonburi 2013, Thailand.
narinratana@yahoo.com

Family Faviidae is one of the dominant coral families within coral assemblages in the Gulf of Thailand. This study investigated spatial patterns and size frequency of faviid species. The 30 x 1.5 m belt transects were employed through 11 islands along the Gulf of Thailand. A total of 13,123 faviid colonies were found belonging to 37 species from 24 genera. Mark Islands and Chang Islands had the highest species richness (33 and 30 species, respectively). Tao Islands had the lowest species richness (18 species), whereas, the other islands had 20-29 species. Colony abundance and area cover of faviid corals varied significantly among habitats and locations. Distribution pattern on reef habitats could be divided into 2 types of coral abundance. 1) Colony abundance was found on reef flat more than reef slope. 2) Colony abundance found more on reef slope. Alternatively, distribution pattern of faviid corals through coral composition on the reefs could be divided into 5 groups. 1) Reefs dominated by *Goniastrea*. 2) Reefs dominated by *Favia*, *Favites* and *Platygyra*. 3) Reefs where *Favia*, *Favites* and *Goniastrea* were common. 4) Reefs dominated by *Diploastrea heliopora* and 5) Reefs where less faviid corals were found. Size frequency of faviid species were considered from abundance and common species. Colony diameter were categorized into 5 classes there were 1-10 cm, 11-20 cm, 21-40 cm, 41-60 cm and >60 cm, respectively. The most abundance sizes classes were the first three sizes (1-40 cm). These results showed that the recent population of faviid species is the remaining colonies survived after 1998 coral bleaching phenomena in the Gulf of Thailand.

Relationships between Local Diversity, Biomass and Density According to Regional and Local Factors for Pacific Ocean Reef Fishes

*Michel KULBICKI**, *Serge ANDREFOUET*, *Pascale CHABANET*, *Eric CLUA*, *Jocelyne FERRARIS*, *Rene GALZIN*, *Alison GREEN*, *Mecki KRONEN*, *Pierre LABROSSE*, *Gerard MOUTHAM*, *Sauni SAMASONI*, *Laurent VIGLIOLA*, *Laurent WANTIEZ*

B.P. A5- 98848- Noumea New Caledonia
kulbicki@noumea.ird.nc

In the Pacific Ocean, the density or biomass of reef fish on a given reef are correlated to the diversity observed on that reef. We investigated the variations in this relationship according to both regional and local factors. Regional factors that were tested in our analysis were the distance to the biodiversity center, the size of the islands, the size of the reefs, island type and latitude. We chose two local factors: reef geomorphologic type and fishing level. Local diversity was defined as the average number of species observed during under water visual censuses along 50-meter transects. More than 2000 transects from New Caledonia (3 islands), Fiji (3 islands), Tonga (3 islands), Samoa (5 islands), Wallis (1 island) and French Polynesia (11 islands) were analyzed. Data on fishing effort was obtained indirectly using fish consumption, reef area and population density. The relationships between fish density (or biomass) and local diversity were analyzed for all species lumped together or grouped into major families (Serranidae, Acanthuridae, Scaridae, Pomacentridae, Chaetodontidae), diet categories or size class. The slope in these relationships varied little with regional factors but was strongly influenced by local factors. In particular fishing had a more significant effect on piscivores, carnivores and large species than on herbivores, plankton feeders and small fish. A first analysis on the types of fish targeted by these fisheries suggested that these statistical relationships might be used in developing indicators of fishing activity.

Interactions between Regional and Local Factors in Determining the Local Diversity of Reef Fishes in the Pacific

*Michel KULBICKI**, Serge ANDREFOUET, Pascale CHABANET, Eric CLUA, Jocelyne FERRARIS, Rene GALZIN, Alison GREEN, Mecki KRONEN, Pierre LABROSSE, Gerard MOUTHAM, Samasoni SAUNI, Laurent VIGLIOLA, Laurent WANTIEZ

IRD- B.P.A5 -98848- Noumea New Caledonia

kulbicki@noumea.ird.nc

There is a strong relationship linking local diversity to regional diversity in the Pacific Ocean. This relationship depends on both regional and local factors. Amongst regional factors we have investigated the distance to the biodiversity center, the latitude, the size of the islands and of their reefs and the island type. We have selected two local factors: reef geomorphologic type and fishing level. Regional diversity was extracted from a data base on the shore fishes of the Pacific containing 5300 taxa from 50 different localities. Local diversity was defined as the average number of species observed during under water visual censuses along 50 m transects. More than 2000 transects from New Caledonia (3 islands), Fiji (3 islands), Tonga (3 islands), Samoa (5 islands), Wallis (1 island) and French Polynesia (11 islands) were analyzed. Data on fishing effort was obtained indirectly using fish consumption, reef area and population density. The analyses show that regional factors play a major role in setting the level of local diversity. However, reef type and fishing level are also significant, their role being usually less important than regional factors. Although commercial species were the most sensitive to fishing, we found that non commercial species could also be affected by fishing beyond a certain level of effort.

New Insights on the Role of Regional Factors in the Geographical Distribution of Reef Fish Diversity across the Pacific Ocean

*Michel KULBICKI**, Serge ANDREFOUET, Eric CLUA, Rene GALZIN, Alison GREEN, Pierre LABROSSE, Gerard MOU THAM, Samasoni SAUNI, Laurent VIGLIOLA, Laurent WANTIEZ

IRD- B.P. A5 - 98848 - Noumea New Caledonia

kulbicki@noumea.ird.nc

The diversity of reef fish follows strong gradients in the Pacific. The data from 50 localities are used to investigate the relationship between reef fish diversity and regional factors such as distance to the biodiversity center, island size, island type and size of available reefs. These data were compiled from checklists and the most recent revisions of families and genera yielding a total of over 5300 taxa of shore fishes amongst which nearly 3000 can be associated to reefs to some degree. Island and reef parameters were derived from remote sensing data collection and processed in a homogeneous fashion for each reef formations of the Pacific Ocean. Preliminary investigations indicate that strong gradients of fish sizes and diets are explained by these regional factors, which however play a different role according to the family or genus. In particular we show that the relative importance (percentage of the total local diversity) of families or genera is not necessarily constant across the Pacific as suggested by previous studies. A preliminary investigation on the geographical distribution of fish sizes and diets indicate that there are strong gradients related to these regional factors.

Stable Isotopes Indicate Spatial Variations in Ultimate Food Sources of Reef Fish Communities in New Caledonia

*Michel KULBICKI**, Nicholas POLUNIN, Kovaldas BALCIAUSKAS, Nickie THOMAS
B.P. A5 -Noumea New Caledonia
kulbicki@noumea.ird.nc

The New Caledonia reef fish community varies greatly in structure between inshore and barrier reefs. The environment differs greatly in turbidity, and primary and benthic production, the level of heterotrophy of the benthos increasing near shore. The trophic structure of reef fish assemblages varies along this gradient, but within trophic categories we did not know if there were major differences in the pathways of carbon and nitrogen. To investigate the spatial variations in ultimate food source types we sampled (a) along a coast-barrier reef transect (3 reef locations over 20 km) and (b) within two bays (3 locations in each, top, middle and mouth, 3 to 5 km scale). Using $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ stable isotope data we investigated carnivores, herbivores and plankton feeders, relative to plankton and algal source materials. Plankton and plankton feeders were similar in ^{13}C across all stations, whereas in algae, herbivores and carnivores, ^{13}C increased significantly from the barrier to inshore and from the mouth to the top of the bays. ^{15}N data of algae and plankton were similar on the shore-barrier reef axis, but there were significant differences within bays. All fish trophic categories increased in ^{15}N from the barrier to the top of the bays, carnivores having the highest values and herbivores the lowest ^{15}N . Plots of ^{15}N vs ^{13}C indicated that reef fish within bays had very different ultimate food sources than fish outside; plankton appeared to be more important in bays than in the open lagoon, and within the lagoon it was more important nearshore than on the barrier reef.

An Invasive *Padina* on a Bleached Coral Site in the Andaman Sea

*Larry B LIDDLE**, Niphon PHONGSUWAN

Southampton College of Long Island University, Southampton, NY 11968 USA

lliddle@southampton.liu.edu

In 1997 Phongsuwan et al documented a massive overgrowth of *Padina* on a bleached coral site in the Surin Islands in the Andaman Sea. The bleaching at this site was observed as early as 1991. This *Padina* population has maintained itself in varying but profuse amounts until the present time. Therefore, although it is a native genus, *Padina* has behaved invasively at this site. In an attempt to understand the invasive success of *Padina* we have compared the reproductive patterns of this population with those of non-reef-associated populations from around Phuket Island, also in the Andaman Sea. There are no other reports in the literature of *Padina* as invasive alga. Patterns of sexual and asexual stages from the Surin bleached coral site differ from those of populations from Phuket Island. Also, besides the fan-shaped foliose morphology, *Padina* maintains a basal phase, more creeping in habit, from which numerous growing points emerge acting as a vegetative propagule. The invasive success of *Padina* populations can in part be attributed to this vegetative reproduction. This phase is less subject to wave action and, being in the interstices of the coral rock, is also less available to grazers. Any removal experiments designed to assess the impact of *Padina* on bleached coral recuperation, have to take this phase into consideration because, as a remnant of the massive population it can regrow readily without sexual reproduction or asexual spore germination.

Probability Modelling Using Coral-Reef Sediments, an Example from Ningaloo Reef, Western Australia

*Justin H PARKER**

35 Stirling Hwy, Crawley, Perth, Western Australia 6009 Australia
jparker@segs.uwa.edu.au

Sediment deposited in coral-reef environments is either transported from terrestrial sources near the reef or generated onsite by carbonate producing organisms living on and around the reef. The in situ biogenic component is a direct reflection of the living organisms and the variety of habitats that comprise the coral-reef environment. The objective of this study is to develop a model using the sedimentological characteristics of a small sample of coral-reef sand to predict the adjacent habitats, and probable organisms living in these habitats.

Samples were collected from selected areas of a reef system, based on geo-referenced systematic grid patterns. These samples were analysed for their sedimentological characteristics (general and foraminiferal composition and grain-size frequency distributions). Aerial photography and ground truthing were used to separately develop geo-referenced habitat maps of the selected areas. Finally probability maps were generated for each of the areas using a GIS (Geographical Information System) showing how the sediment characteristics relate to habitat predictions.

Data are presented here for the back-reef lagoon of the Ningaloo Reef Tract, a fringing-barrier reef located on the north-west Australian coastline between latitudes of 21°30' and 24° South. Significant foraminifera (those > 5% abundance) and foraminiferal associations are shown to be the most reliable habitat indicators for Holocene environments in the region. This type of study is useful for present day habitat assessment and for modelling ancient reef environments in sedimentary basins.

Epifaunal Community Associated with *Caulerpa* and *Laurencia* at Owen Island, Little Cayman, Cayman Islands

*Ashley REED, Vania R COELHO**

50 Acacia Avenue, San Rafael, CA, USA, 94901-2298 United States of America
vcoelho@dominican.edu

The morphology and secondary compounds of different types of algae may influence the structure of epifaunal communities in coral reefs. In this study we analyzed the fauna associated with three species of algae. Two of them belong to the same genus, and likely have similar secondary compounds, but are different in shape; *Caulerpa sertularioides* has a feather-like structure, while *Caulerpa cupressoides* has globular branchlets and is more compact. The third species, *Laurencia papillosa*, belongs to another genus but is structurally similar to *C. cupressoides*. The algae samples were collected adjacent to each other in an area less than 1m deep and were later rinsed in freshwater for faunal removal. The invertebrates were retained in a sieve of 250 µm mesh size. The algae samples were dried and weighed. *C. cupressoides* had about 2.5 times the number of individuals per gram over *C. sertularioides* and *L. papillosa*. *C. sertularioides* had the greatest surface area but about 10 times less individuals per area than the other two species, which had similar surface area. *C. cupressoides* had the least amount of volume per gram and about 1.5 times the number of individuals per volume found in *L. papillosa*, and almost twice that of *C. sertularioides* (the latter two plant species had similar volume per gram). Crustacean and polychaetes were the dominant groups in all samples. Some invertebrate species preferred only one type of algae, or only the *Caulerpa* species, or both *C. cupressoides* and *L. papillosa*. We concluded that although morphology and chemical compounds seem important in determining the structure of the epifaunal community, the degree of protection offered by the plant architecture apparently has a greater impact on the abundance of individuals found associated with a particular species of algae.

Maximizing Predictability by Minimizing Variance in Coral Reef Ecology: A Search across Scales

*Stuart A SANDIN**

Dept. of EEB/Princeton University, Princeton, New Jersey 08544-1003 United States of America
sasandin@eno.princeton.edu

In situ studies of coral reef organisms consistently demonstrate that seemingly random variability is the norm, not the exception, to population dynamics. For field studies, selecting the appropriate scales for analysis can minimize the observed variability, thereby maximizing the power of the study. Using simple models of population dynamics, we can predict how the inherent variability of a population will be expected to change across scales. I will present the results of a series of modeling and field studies that consider scaling of temporal variance in reef populations. Observed population variability is determined by the relative effects of mechanisms introducing stochasticity (e.g., recruitment fluctuations) and mechanisms reducing stochasticity (e.g., density dependence) at the scale of analysis. Focusing on the trophic dynamics of reef fish, I compare study results across organizational levels (i.e., functional guilds vs. single species) and across spatial scales. Variability changes noticeably across each scale range, demonstrating that appropriate selection of scale drastically alters the power, and thus the conclusions, of observational studies.

Habitats for the Damselfish *Stegastes Planifrons* in the Tayrona Natural Park (Colombian Caribbean): Selectivity and Incidences

Nadiezha SANTODOMINGO-AGUILAR, Alberto RODRIGUEZ-RAMIREZ, Jaime GARZON-FERREIRA*

A.A. 1016 Santa Marta, Colombia
nadiaks@invemar.org.co

The Natural and anthropogenic factors play an important role in the degradation of reef communities. Through the National Monitoring System for the Coral Reefs of Colombia (SIMAC) the effect of the Threespot Damselfish (TD), *Stegastes planifrons*, was assessed. *S. planifrons* is one of the most conspicuous inhabitants of the Caribbean coral reefs which causes natural disturbance by removing coral polyps for its algal turfs. Many studies had indicated a negative role of damselfishes on reef-building process, but there is a few information about the habitats, and coral species that are selected to establish their territories. This research was carried out at four reef habitat types: multispecific coral assemblages dominated by (1) *Colpophyllia natans* or (2) *Montastraea* spp; and monospecific coral stands of (3) *Acropora palmata* or (4) *Acropora cervicornis*. Both algal turfs incidence and coral species selectivity were evaluated at each of these habitats. The incidence is expressed in terms of the percentage of colonies affected by the algal turfs (Ic) and the area affected (Ia). A total of 457 territories were assessed. Most of the evaluated colonies (Ic=61%) were affected by algal turfs. Some algal mats were observed on sponges and gorgonians too. Reef building corals showed the lowest incidences of Ia: *Acropora palmata* (6%), *Montastraea faveolata* (5%), and *Colpophyllia natans* (2%), while the highest incidences were observed over *Mycetophyllia ferox* (30%), *Madracis decactis* (22%), and *Millepora complanata* (20%). TD selected particular microhabitats according to the availability of refuge and morphological characteristics (skeleton densities, corallite shape, etc.) of the coral species to be bitten. Hence, although *A. palmata* and *A. cervicornis* were selected, other hard coral species as *M. complanata* was also chosen. This research gives new information about the role of *S. planifrons* like agent of natural disturbances over the structure and composition of coral reef communities.

Using Agent-based Models to Produce Optimal Strategies for Reef Restoration by Coral Transplantation; a Comparison of the Effects of Using Species with Different Life-History Strategies

*Jai C SLEEMAN**, Ben T M RADFORD, David BLAKEWAY
35 Stirling Hwy., Crawley, Western Australia 6009 Australia
jsleeman@cyllene.uwa.edu.au

High coral cover and topographic complexity are typical spatial qualities of a healthy coral reef. When choosing coral species for reef restoration projects it is important to evaluate how differing life-history characteristics will affect the topographic features of the restoration area. This study utilizes agent-based spatial modelling to explore different scenarios of reef restoration by coral transplantation. We explore the effects of using a number of species with contrasting life-histories. The influence of life-history characteristics on coral cover and topographic complexity were measured with landscape indices. These indices were used to compare change over a range of temporal and spatial scales. For the purposes of this model, disturbance events were assumed to be of minor importance in the spatial structuring of coral reefs. This model provides a tool to select coral species with life-histories that will maximize cover and 3-dimensional habitat structure over moderate temporal (30-year periods) and spatial (10s of kilometres) scales. The use of agent-based spatial models is a relatively new technique in marine ecology and has considerable potential for use in areas such as reef restoration ecology.

Processes Structuring Caribbean Coral Communities in Marginal Environments

*Mark J A VERMEIJ**, Pedro FRADE, Rita JACINTO, Dolfi A DEBROT, Rolf P M BAK
Southeast Fisheries Science Center, 75 Virginia Beach Drive, FL33149 Miami United States of America
mark.vermeij@noaa.gov

Here we try to identify the ecological factors that structure shallow water coral communities on Curacao, Netherlands Antilles. We focus on communities that developed in innerbays that are semi-connected to the well developed fringing reefs and compare those to communities that developed on the fringing reefs themselves. Our focus is to determine if community assembly (in terms of species presence and population structure) is primarily deterministic or whether stochastic events will eventually lead to variation in community composition across space. Several hypotheses are put forward to test the relative importance of various factors considered to be important for the organization of community structure: the size of the local species pool, dispersal distances of the species involved, environmental variability and rates of disturbance. Recruitment, life-history variation (especially reproductive mode), species specific tolerance to environmental variability and environmental variation itself, all interact to produce patterns in coral community structure. These patterns are predictable to a certain degree: a small local species pool, the absence of shared ecological strategies among species, low rates of catastrophic disturbance and dispersal limitation of non-adapted species are mainly responsible for the similarity observed among innerbay coral communities.

A Novel Approach to Linking Reef Fish Assemblage Characteristics to Topographic Complexity

*Brian K WALKER**
8000 North Ocean Drive, Dania Beach, Florida United States of America
walkerb@nova.edu

Abiotic factors such as temperature, salinity, depth, current, and topographic complexity and biotic factors such as competition, food availability, and predation all play roles in determining the distribution and abundances of coral reef inhabitants. Reef fish assemblages, in particular, are affected by geomorphology and habitat distribution. The high number of variables involved in determining the spatial relationship of reef organisms complicates spatial prediction models. However, it may be possible to create general predictive models using those factors that most influence their distributions. One of the most influential factors affecting the spatial distributions of reef fish is topographic complexity. Many studies have found positive correlations between reef fish assemblage variables and habitat structure measures. This paper presents a novel method that incorporates remote sensing technology and landscape ecology GIS tools to investigate the possibilities of linking reef fish assemblages to topographic complexity on a large scale. A topographic complexity (rugosity) index is calculated from remotely sensed bathymetry data allowing the comparison of fish species distributions to areas of increased or decreased complexity. This index is calculated for the GPS-located fish assessment sites and correlated with the fish census data. The current study is based on data collected in Broward County, FL, USA, however, after calibrating the model to local reef fish assemblages, it could be used anywhere with high-resolution bathymetry data. This method may provide new perspectives for understanding the affect of rugosity on reef fish assemblage structure and distribution, as well as a new predictive model resource managers can use to economically estimate fish densities. Thus, this work is relevant to all coral reef resource managers worldwide interested in reef fish population censusing, mapping essential fish habitat, and understanding reef fish assemblage distributions for MPA designations.

Patterns of Body Size Distribution in Tropical Eastern Pacific Reef Fishes

*Fernando A ZAPATA**, D Ross ROBERTSON
A.A. 25360, Cali Republic of Colombia
fazapata@univalle.edu.co

Body size is an important attribute of organisms and its distribution among species may provide insights into ecological and evolutionary processes structuring species assemblages. We examined patterns of body size distribution of the reef fishes from the tropical eastern Pacific (TEP) to help elucidate the processes responsible for large scale variation in assemblage structure. The frequency distribution of log₂ maximum body lengths of all bony reef fishes resident in the region (N = 333) was bimodal and platykurtic and therefore not log-normal. While the size distribution of species occurring on the continent was similar to that of the entire group, that of the oceanic island fauna was log normal. The continental group had more small species but less species of intermediate size than the oceanic island group. Similar size distributions were observed for continental species present in three different biogeographic provinces (Cortez, Mexican and Panamic) that encompass a wide latitudinal gradient. TEP endemics showed a log-right-skewed and bimodal size distribution while transpacific fishes exhibited a log-normal distribution and were on average twice as large as species on oceanic islands of the TEP. The size distributions on each of the oceanic islands showed a greater mean or median or degree of left skewness than expected from a random assemblage of species sampled from an oceanic island species pool. At least two mechanisms might explain this pattern: 1) reduced dispersal ability of smaller species prevents the colonization of oceanic islands, or 2) smaller species may have greater extinction rates on islands. Some evidence indicates that extent of occurrence on oceanic islands is positively correlated with body size and that maximum density decreases with increasing body size. This provides support for the hypothesis that dispersal limitation may be important causing size distributions to be biased toward larger sizes on oceanic islands of the TEP.

The Status of the *Acropora palmata* Populations in Los Roques National Park, Venezuela

Ainhoa L ZUBILLAGA, Carolina BASTIDAS*, Aldo CROQUER

Sartenejas, Caracas, Miranda Republic of Venezuela

alzubillaga@hotmail.com

In this work we determined the status of *Acropora palmata* populations in Los Roques National Park, Venezuela. Ten 20m-long and 4m-wide belt-transects per site were evaluated in the reef front to determine the densities of recruits (<10 cm), juveniles (10-20 cm) and adults (>20 cm). The condition of each *A. palmata* colony was checked, specifically for disease signs, predation marks and the total number of the predator *Coralliophila* spp. The density of *A. palmata* adults, juveniles and recruits were significantly different ($p < 0.01$ Kruskal-Wallis test) across sites. The adult density in Cayo de Agua (1.45 SE 0.32 ind/10m²) was significantly different compared to all sites (Test of Duncan for post-hoc comparisons): Dos Mosquises (0.42 SE 0.14 ind/10m²), Carenero (0.26 SE 0.09 ind/10m²), Crasqui (0.19 SE 0.08 ind/10m²), Gran Roque (0.11 SE 0.06 ind/10m²) and Madrizqui (0.04 SE 0.03 ind/10m²). The juvenile density showed a similar trend, with Cayo de agua having the highest density (1.4 SE 0.44 ind/10m²) compared with the other sites (from 0.06 SE 0.03 to 0.80 SE 0.23 ind/10m²). The recruit density was significantly lower in Madrizqui (0.03 SE 0.02 ind/10m², $p < 0.01$) than in Cayo de agua (0.39 SE 0.1 ind/10m²), Dos Mosquises (0.39 SE 0.09 ind/10m²), Gran Roque (0.31 SE 0.1 ind/10m²), Carenero (0.34 SE 0.16 ind/10m²) and Crasqui (0.16 SE 0.08 ind/10m²). The incidence of white band (1-10%), signs of predation (5-20%) and density of *Coralliophila* spp (0-0.19 ind/col) were variable across sites. These results suggest that populations of *A. palmata* are actively recovering in Cayo de agua, Dos Mosquises, Carenero and Crasqui. However, this recovery is less noticeable in other areas of Los Roques such as Madrizqui.

Coral Disease in the Northwestern Hawaiian Islands

Greta S AEBY*

1151 Punchbowl St., Rm. 330, Honolulu, Hawaii 96813 United States of America

greta@hawaii.edu

Baseline information on the distribution and frequency of coral disease is critical in assessing changes in the health of coral reefs. In July 2003, baseline surveys were conducted at 73 sites throughout the Northwestern Hawaiian Islands (NWHI) to quantify and characterize coral disease. Evidence of coral disease was found at 63% of the sites across all regions with Maro, Laysan and Lisianski having the highest incidence of disease. The most common disease was pink spot disease caused by the digenetic trematode, *Podocotyloides stenometra*, that was found at 60% of the sites. Numerous other conditions were also observed but at much lower levels (1%-15% of the sites). Numbers of colonies affected by pink spot disease were not enumerated, but other types of conditions were counted and found to be present at low levels (avg. 0.028 diseased colonies/m² reef surveyed). A disease outbreak at one site resulted in massive tissue loss on large acroporid table corals. Disease signs similar to white plague and white band were found on some corals, but the majority of the observed disease signs/syndromes were distinct from what has been previously described for other coral reef systems. Coral genera were found to exhibit differences in types of syndromes and incidence of disease. Studies are planned to further investigate and monitor the incidence of coral diseases in the NWHI.

Coral Disease in a Large-scale Reef Mesocosm

Shelley L ANTHONY*

ReefHQ, PO Box 1379, Townsville, Queensland Australia

shelley.anthony@jcu.edu.au

ReefHQ Aquarium in Townsville, Australia contains a 2.5-million litre fully functioning living reef mesocosm used for public education, coral propagation, and scientific research. Although much progress has been made recently in the areas of hard coral growth and survival, a significant percentage of acroporids and pocilloporids are lost to a little-understood syndrome known as Rapid Tissue Necrosis (RTN) or Rapid Tissue Degeneration. RTN (thought to be synonymous with Shut-Down Reaction on natural reefs) is a rapidly progressing disorder, characterised by tissue sloughing away from the coral skeleton. Anecdotal evidence and previous studies of RTN occurrence are conflicting, further adding to the confusion surrounding this disorder. Current hypotheses include a pathogenic cause, or a reaction to stressful conditions, or a combination of both. To investigate the underlying cause of RTN, a combined approach utilising histological, microbiological, and ecological methods has been applied. New histological techniques are being used to study possible stress reactions in coral tissues, while microbiological studies search coral microbial communities for a potential underlying pathogen. Ecological comparisons between nearby natural reefs and the mesocosm are also providing information on environmental conditions and the occurrence of RTN. The large-scale reef mesocosm provides several advantages to this study, including continuous monitoring of environmental parameters, relatively controlled conditions, and easy access to diseased coral samples. Understanding the nature of RTN, its cause, and how to prevent it will be of great value to aquaria worldwide, the coral aquaculture and commercial industry, coral propagation success, and reef regeneration and restoration efforts. In addition, it may give better insight into the nature of some types of disease observed on natural reefs.

Apoptosis in Diseased Reef Corals: A First Look

Eric BORNEMAN*

Department of Biology, 4800 Calhoun Rd., Science and Research Bldg. II, Houston, TX 77204 United States of America

eborneman@uh.edu

The inability to find pathogens in many coral diseases, along with the inconsistencies of many events causing coral mortality that are not immediately amenable to a pathogen hypothesis or to necrosis, underscores the need for alternate explanations of coral disease and death. Cell death occurs by two primary pathways: necrosis and apoptosis. Apoptosis is a highly conserved, non-inflammatory, sequentially ordered cell death program that has come under wide study in mammalian and nemertean system in the past decade. While apoptosis has a role in many developmental events, immunological responses, and in normal senescence, it also occurs and results in many acute and chronic pathologic conditions. Apoptosis can be triggered by bacteria, stress, chemicals, hypoxia, anoxia, trauma, and various other events that set off the apoptotic cascade of events. To date, the occurrence and mechanisms by which apoptosis might occur in corals has not been well investigated. Induction of apoptosis was found possible using known inducers and uncharacterized chemical signals from apoptotic corals. Using modified molecular assays and histological exam, fifteen species of scleractinian corals from the families Acroporidae and Pocillopidae from both the Indo-Pacific and Caribbean regions showing signs of white band disease and shut down reaction were found to have apoptotic cells present. This is one of the first reports of apoptosis occurring in coral tissue. The implications of apoptosis in coral disease based on these findings are discussed.

Pathologies Affecting Reef Corals at the Flower Garden Banks, Northwest Gulf of Mexico

Eric BORNEMAN*

Department of Biology, 4800 Calhoun Rd. Science and Research Bldg. II, Houston, Texas, 77204 United States of America

eborneman@uh.edu

The Texas Flower Garden Banks are part of a marine sanctuary encompassing the most northerly and isolated coral reefs on the North American continental shelf. The Flower Gardens Banks have historically had a low incidence of coral disease. Diseases affecting the Caribbean basin were found including white plague type II, but at extremely low frequencies. Several other conditions that resembled known diseases (black band disease, and yellow blotch disease) were also found, although their appearance was not wholly characteristic of the pathology, and they may represent different conditions. In addition, several false diseases reported in previous works were confirmed to have fish biting behavior as their cause, rather than being pathologic in nature. Several novel pathologic conditions were discovered at relatively high incidence levels that do not fit the description or known etiology of any currently described coral disease, and included a pale ring condition, a mottled bleaching/necrosis condition, and a spreading bleaching condition. *Porites astreoides* was observed with a patchy and spreading bleaching condition. A mottled condition affecting numerous colonies of *Colpophyllia natans* was observed at both banks, and it was responsible for significant focal and spreading signs of bleaching and tissue loss. Additionally, an unidentified pale ring condition was observed in both *Diploria strigosa* and *Colpophyllia natans*. A widespread opacity existed on a vast number of colonies of many species, especially at the East Flower Gardens Bank, and its appearance on tissue resembled affected areas of the pale ring condition. Because of difficulties in standardizing nomenclature within the coral disease community, and until more of the etiology of these conditions is established, these syndromes are tentatively named pale ring syndrome, and mottling syndrome. In this report, I document levels and types of coral disease at the Flower Garden Banks, including the description of three previously unreported pathologies.

Pathologies Affecting Reef Corals in Captivity*Eric BORNEMAN**

Department of Biology, 4800 Calhoun Rd., Science and Research Bldg II,
Houston, TX 77204 United States of America
eborneman@uh.edu

Historical background levels of coral diseases are largely unknown and most research focuses on epizootics and well recognized pathologies. Many of the diseases that affect corals on reefs are not known in aquariums. However, the aquarium provides a unique opportunity to observe and study the disease process. Several pathologies appear to be largely confined to captive conditions, or the disease process is somehow favored in closed systems. Other pathologies display the same signs as in their wild counterparts, although the etiology of both wild and captive conditions is incompletely understood. Aquarium corals are susceptible to conditions that resemble white band disease, red band disease, and they produce abnormal growth lesions (neoplasia). Additionally, novel pathologies occur that have not been reported in the wild. Brown jelly infections are common, and may involve a ciliate pathogen. Other organisms have been found associated with corals that produce consistent signs of bleaching and disease, including a tanaid amphipod associated solely with corals of the genus *Acropora* and a pit crab associated with numerous species, but especially *Catalaphyllia jardinei* and *Trachyphyllia geoffroyi*. Rapid tissue necrosis, or shut-down reaction is very common in many species, but especially Acroporids, and preliminary work suggests that it is an apoptotic event. Bacteria of the genus *Beggiatoa* have been found associated with disease events in numerous taxa of scleractinian corals and zoanths. A rotting condition is also common among species in the soft coral family Alyconidae. Further investigations will determine if the conditions reported here are unique to aquarium corals or if they are present in wild communities but at currently low levels of incidence.

Molecular Microbial Ecology of Coral Diseases*John C BYTHELL**, *Olga PANTOS*

Ridley Building, Newcastle upon Tyne NE1 7RU United Kingdom of Great
Britain and Northern Ireland
j.c.bythell@ncl.ac.uk

A significant constraint to the understanding of coral diseases is the identification of different diseases. Unlike higher organisms with complex tissues and organs that may be targets for different disease agents, corals have tissue-level organisation and different disease signs are often difficult to distinguish. While some patterns of tissue loss are distinctive, others like white plague, patchy necrosis, white band disease and white pox are not. Different stages of one disease may be difficult to distinguish from another and different rates of lesion progression or appearance may be due to different disease agents, the physiological and morphological features of different hosts or differences in health status. Using culture-independent molecular (16S rRNA) techniques, we have examined the bacterial diversity associated with several patterns of tissue loss across a range of host coral species. To fully characterise the bacterial community, the formation of clone libraries and analysis by RFLP-screening and sequencing has proven successful in a number of studies. However, these methods are time-consuming and expensive. In order to screen large numbers of samples we have used Denaturing Gradient Gel Electrophoresis (DGGE). While detecting only a small subset of the total bacterial community, we show that DGGE patterns are consistent across replicate samples from the same disease lesion and that relative diversity of DGGE banding patterns are highly correlated with sequence diversity obtained from clone libraries. Patterns of similarity between DGGE profiles of different forms of tissue loss on a variety of host species are presented. Results are also compared with an experimental temperature stress treatment. The natural bacterial flora associated with different (healthy) coral species are clearly distinct and the perturbation of this natural flora is dependent on disease state and stress treatment.

Distribution of Red-Blotch Disease and Effect of Boring Sponges on Solitary Corals in Tuticorin Coastal Waters of Gulf of Mannar, Southeast Coast of India*Chellaram C, Jamila PATTERSON*, Edward J K PATTERSON*

44-Beach Road, Tuticorin - 628 001, Tamil Nadu Republic of India
coralchella@rediffmail.com

The Gulf of Mannar (GOM), covering an area of approximately 10,500 sq. km includes a chain of 21 islands surrounded by fringing reefs and patchy reefs. The southern part of GOM currently consists of four islands that are heavily affected by pollution due to the discharge of un/partially treated effluents from industries and domestic sewage. The present work was concentrated on the monitoring of coral diseases and the effect of boring sponges on corals in situ habitat. A survey was undertaken adopting Belt Transect (1m x 15m) method and 60 transects were made to quantify the number of Red-band or Red-blotch affected colonies. Accordingly, Red-band or Red-blotch disease was recorded near the port area of Tuticorin coastal waters, which was absent around the islands. The study site of the Tuticorin port area was dominantly covered with *Turbinaria* sp. and Red-band or Red-blotch disease mainly affects selective species of corals such as *Turbinaria mescenterina* and *Turbinaria peltata*. Among this, *Turbinaria peltata* was most susceptible to this disease. Overall about 15-20% of *Turbinaria* sp. in Tuticorin waters is affected by Red-band or Red-blotch disease. Secondly, sponges destroy corals (known as boring sponges), which have the ability to dissolve the calcium carbonate (coral skeletons and bivalve shells) and cause problems to the coral growth. In Tuticorin waters, about 0.25-0.5 % of corals are affected by coral boring sponges. Research is continuing to identify the causative microorganism for the Red-blotch disease.

Host Specificity between Coral-inhabiting Snail *Coralliophila violacea* and Massive Coral *Porites* : An Analysis of Host-searching, Host-recognition and Larval Preference*Ming-Hui CHEN**, *Keryea SOONG*

Checheng, Pingtung, Taiwan 944, Republic of China Taiwan
minghui@nmmba.gov.tw

Host specificity, i.e., the number of host species which a symbiont can associate with, is an important trait to both the hosts and the symbionts. Its mechanisms are often less clear. Understanding this mechanism is important to elucidate the interaction between these symbionts and their hosts, e.g. speciation and host-switch process of symbionts. Although many species of *Coralliophila* living on the surface of corals are identified, only a few species are known about their biology. For example, two Caribbean species, *C. abbreviata* and *C. caribaea* are active predators and are found on a broad variety of scleractinians. The Indo-Pacific *C. violacea*, on the other hand, is only found on poritid corals. In this study, the host-searching, host-recognition behaviours of adults, the survival of adults on different corals and the larval preference were studied to elucidate the mechanism of host specificity in the snail *C. violacea*. The following results are found in these studies: (1) the larvae of *C. violacea* prefer *Porites* to other scleractinians, and (2) the adults of snails can recognize and find the host corals, and (3) the adult of snails only can live on the coral *Porites*. These results suggest that the preference of larvae is the key factor of causing the range of their host, the ability of recognizable and finding their original host in adult stage also enhance this limited host range.

A Model of the Spatial and Temporal Dynamics of the Yellow Blotch Syndrome

*Roberto CIPRIANI**, *Aldo CROQUER*

A. P. 89000, Caracas 1080 Republic of Venezuela

rcipri@usb.ve

The yellow blotch syndrome is one of the most widespread coral disease in the Caribbean, mostly affecting species of the *Monastrea* complex. It takes its name from the yellow-cream color of the infected polyps standing between the dead and healthy tissue of the colony. In this paper, we develop a grid model to simulate the dynamics of the disease. The model is parametrically stochastic, sequentially updated, and discrete in time and space. The possible states of each cell are: (a) a dead colony or empty space; (b) a colony susceptible to infection; (c) an infected colony; and (d) an immune colony. Non-densodependent recruitment of all species occurs in empty spaces ($Pr = P_{rec}$). All coral species are subject to natural mortality, independent to disease-induced mortality ($Pr = P_{nat}$). Coral colonies are hemispheres that grow at a rate P_{gro} . When a healthy colony is infected, the disease spreads from the top of the hemisphere to its base, with a rate equal to P_{sub} . When the entire surface of the colony has been infected, the colony dies. However, a colony may recover from the infection. The disease spreads from sick to healthy colonies by means of unspecified vectors moving between colonies, simulated by infecting at random, healthy susceptible colonies from a grid area around the donor, with $Pr = P_{inf}$. We validated the model by comparing the simulated prevalence of the disease with that obtained in the field, using parameter values reported in the literature and from real colonies. Prevalence data from the model was obtained by simulating on it the sampling technique used in the field. With this model we tested the effects of sampling bias of the size distribution of colonies in estimating the dynamics of the disease.

Some Aspects on the Dynamics of the Yellow Blotch Syndrome: A Grid Model Perspective

*Aldo CROQUER**, *Roberto CIPRIANI*, *Ernesto WEIL*, *David BONE*

A. P. 89000, Caracas 1080 Republic of Venezuela

croquer@telcel.net.ve

We develop a stochastic, time and space discrete, grid model to simulate the dynamics of the yellow blotch syndrome, one of the most widespread diseases in the Caribbean. Each cell in the model represents one possible state of a simulated coral colony: (a) dead colony or empty space; (b) colonies susceptible to infection; (c) infected colonies; and (d) colonies belonging to immune species. Structurally, colonies are simulated as hemispheres of different age/size. When a healthy colony is infected, the disease spreads on the surface of the colony, from the top to its base, with a rate equal to those recorded in the field. Colonies die when their entire surface is infected. Spatially, the disease spreads by the effects of unspecified vectors moving between nearby colonies. Comparing sequential values of disease prevalence with those obtained in the field, validated a number of different dynamics, used to test our questions. Other parameters such as recruitment, death, recovery, and growth rates were obtained from real samples and from the literature. Our results suggest that the yellow blotch syndrome is capable of remaining in the community for long periods of time, over 3000 years in our simulations. Once the epidemic starts in a healthy community, the main effects are the reduction of susceptible colonies and the increment of non-susceptibles. This process occurs independently of the rate of recovery. In communities with old colonies, low recruitment, and equal distribution of susceptible and non-susceptible colonies, the yellow blotch syndrome does not prevail. To introduce the disease into the community requires multiple successive infections of several colonies. Our results show how temporal and spatial interactions between coral colonies may produce complex dynamics of coral diseases. They also sustain that grid models are useful tools to study these dynamics.

Temporal and Spatial Variability of Stony Coral Diseases in Los Roques and Morrocoy National Parks, Venezuela

*Aldo CROQUER**, *Ernesto WEIL*, *David BONE*

Sartenejas, Caracas, Miranda Republic of Venezuela

croquer@telcel.net.ve

This study goals were to compare the prevalence of common Caribbean coral diseases between an oceanic, near pristine reef system (Los Roques) and a continental-human-affected reef system (Morrocoy) in Venezuela. Three reef sites were surveyed, two in Los Roques and one in Morrocoy. Surveys were conducted once a year (dry season), starting in 1999 and ending in 2001. For each site, a total of eight, 20 x 2 m belt-transects (CARICOMP) were permanently marked to ensure repetitive surveys upon the same areas. Every single coral colony was identified and their status (healthy, damaged or diseased) assessed and counted to determine the prevalence of the different coral diseases and other damage resulting from predation or sedimentation. The number of colonies affected by each disease was compared within (depths) and across sites by a two-way Analysis of Variance. The variability of the prevalence of coral diseases through time (1999 - 2001) within each site was compared by a two-way-repeated measure Analysis of Variance. During the surveys performed at both localities, two main epizootic trends were observed: (1) diseases that were always present regardless of the site, depth or time (e.g. yellow blotch, dark spots) with variable prevalence, and (2) temporal diseases that suddenly appear and show high prevalence resulting in high tissue and colony mortality for a short time period (e.g. white plague and black band). Results indicate that in all three sites, Herradura ($4.31 \pm 0.65\%$ to $6.13 \pm 1\%$) and Costanero (5.38 ± 1.34 to $6.48 \pm 1.11\%$) reefs in Los Roques, and Sombrero in Morrocoy (4.1 ± 1.02 to $5.2 \pm 1.89\%$), disease incidence increased significantly ($p < 0.01$) between 1999 and 2001. Similar trends in both geographic localities suggest that disease outbreaks might more related to changing environmental conditions like global warming than to direct human impact.

Decline of *Madracis mirabilis* Population at Morrocoy National Park, Venezuela: The Role of Coral Diseases

*Aldo CROQUER**, *Ernesto WEIL*, *Sofia VALERO*, *Nora MALAVER*

Sartenejas, Caracas, Miranda Republic of Venezuela

croquer@telcel.net.ve

During the last 4 years a significant decline in live cover (from 7.58% in 1999 to 3.33% in 2001) of the thin, branching coral *Madracis mirabilis* was observed at Sombrero Key, Morrocoy National Park (10°52'N-69°16'W), Venezuela. Increasing number of colonies showing the typical signs described for white plague type II indicates that this disease might be responsible for the observed decline. Three healthy and three disease colonies were collected to study the bacterial communities associated with them and to be compared with water mass bacterial communities. Fourteen biochemical tests (different carbon, nitrogen and energy sources) were performed for all strains isolated from each sample. These strains were also plated in TCBS and *Pseudomonas* agar in order to determine if community composition varied between healthy and disease tissues. The biochemical profile was compared by Chi-square tests, cluster and a principal coordinates analyses. The biochemical profile of each bacterial community was dependent (Chi square = 9374.66 df = 41 $p < 0.01$) on the compartments (healthy, disease and water). The isolates collected from mucus of affected tissues showed a high percentage of bacteria able to degrade urea (60-80%) and complex compounds such as lipids (65-85%), when compared with both no-disease and water mass isolates (< 5%). The total abundance of *Vibrio* spp significantly increased from the healthy (< 5%) to disease tissues (40%), while *Pseudomonas* spp. significantly decreased from healthy (39%) to disease tissues (< 5%). These results suggest that the current decline of *Madracis mirabilis* live cover at Sombrero Key might be produced by this coral disease. Samples have been taken for verification of the presence the white plague pathogen *Aurantimonas corallicida*.

Factors Affecting the Incidence and Infectivity of Coral Disease on the Great Barrier Reef

*Joanne E DAVY**, *Ross J JONES*, *Linda L BLACKALL*, *Maoz FINE*, *Ove HOEGH-GULDBERG*

Seddon Building, The University of Queensland, Brisbane, QLD 4072, Australia

j.davy@marine.uq.edu.au

Coral reefs are under ever-increasing threat from coral diseases, most of which are inadequately described and poorly understood. The gaps in our knowledge include a poor understanding of the potential links between coral bleaching, increased seawater temperature and coral disease. In the Indo-Pacific region, this is compounded by the fact that few surveys of coral disease incidence have been conducted. Previous research carried out in the region has highlighted differences in disease occurrence between the Indo-Pacific and Caribbean regions, indicating avenues for further research. Preliminary data concerning the incidence of coral disease at two sites within the Great Barrier Reef Marine Park (GBRMP) are presented along with the results of experiments designed to test methods of artificial induction of disease in GBR corals. Details of experiments planned to test the effects of sub-bleaching and bleaching temperatures on the occurrence of disease in GBR corals, and methods to assess the microbial associations of healthy and diseased GBR corals, are also outlined.

Changes in the Spatial and Temporal Distribution of Reef Fish Infected with Copepod Ectoparasites

*Rachel J FINLEY**, *Graham E FORRESTER*

105 Coastal Institute in Kingston, 1 Greenhouse Road, Kingston, Rhode Island 02881 United States of America

goby@uri.edu

Spatial patterns in the abundance of marine organisms with pelagic larvae are initially determined by settlement patterns and then modified by post-settlement processes. The result is often spatial patchiness in density. Post-settlement interactions such as competition and predation are often related to density and a higher mortality rate is generally observed within dense patches of individuals. Similarly, disease clusters may be expected at high host densities if pathogens are directly transmitted. The distribution of two benthic reef gobies *Coryphopterus glaucofraenum* and *C. dicrus* infected with gill copepod parasites, *Pharodes tortugensis*, were examined to determine: 1) spatial patterns in the density of the population as a whole, and 2) whether parasitized individuals were randomly positioned throughout the population. The population of two benthic gobies were censused in a 780 m² area of continuous reef near Guana Island, British Virgin Islands, six times in September and October 2003. At each census a spatial coordinate was determined for each fish, the size in millimeters was estimated, and infection status determined. Spatial and temporal patterns of the goby populations and distribution of parasitized hosts are analyzed using: Kullback's Space-Time Statistic, Spatial Analysis by Distance Indices, and Nearest Neighbor Distance Analysis. Our previous work on this host-parasite relationship showed that parasitized gobies have slower growth, suffer higher mortality, and female fish have lower reproductive output. Additionally, lab studies show that the parasite can be directly transmitted between individuals. These results indicate that the parasite may be a process influencing the post-settlement patterns of the goby, especially if parasite transmission is related to host density.

Coral Disease and Health Consortium

*Sylvia B GALLOWAY**, *Andrew W BRUCKNER*, *Cheryl M WOODLEY*

Hollings Marine Laboratory, 331 Ft Johnson Rd., Charleston, SC 29412 United States of America

sylvia.galloway@noaa.gov

In response to the U.S. Coral Reef Task Force and their National Action Plan to Conserve Coral Reefs, the Coral Disease and Health Consortium (CDHC) was created in 2002 to provide coastal and ocean managers with scientific understanding and tools to protect healthy coral reef ecosystems and restore degraded ones. Coral diseases have dramatically increased in frequency and distribution over the last decade, leading to unprecedented decreases in live coral and altering the function and productivity of coral reef ecosystems. With more than 50 national and international partners from industry, academia and government contributing their time and expertise, the CDHC is unifying the coral research community, educating and training a new generation of scientists, and creating a new paradigm for studying coral health and disease. Modern molecular technologies and biomedical concepts are being used with traditional ecological assessment tools to provide early warning of coral diseases, identify causative factors and possible solutions for prevention or mitigation, and offer managers viable risk management options to deal with disease outbreaks. Several examples of CDHC activities will be highlighted, including a recent coral disease investigation, the establishment of a coral pathology review panel, the institution of new diagnostic molecular probes, and the initiation of effort to sequence a stony coral genome, as well as the establishment of facilities to provide coral organisms for laboratory research, and holding an international workshop focused on developing effective means of assessing coral health by applying standard ecotoxicology tools along with human-type diagnostic tools.

Changes in the Microbial Communities Associated with *Gorgonia ventalina* during Aspergillosis Infections

*Diego L GIL-AGUDELO**, *Carey MYERS*, *Kiho KIM*, *Garriet W SMITH*

603 Earth and Water Science Building, University of South Carolina, Columbia, SC, 29208 United States of America

gilagude@mcsi.sc.edu

Relationships between corals and microbes have been known for decades. The surface mucopolysaccharide layer (SML) secreted by corals is a rich environment where bacteria can live and proliferate with population levels often being several orders of magnitude higher than in the surrounding waters (at least for culturable microbes). Some studies have suggested that these communities play an important role in energy and nutrient flux in marine environments. We hypothesize that the microbial community structure of the SML also plays a role in disease process. This hypothesis is based on studies that have shown differences in bacterial communities associated in healthy and diseased corals. We tested this hypothesis by characterizing the microbial community structure of the SML using BIOLOG Eco-plates and then comparing metabolic profiles of surface microbiota sampled from diseased and healthy areas of the Caribbean sea fan, *Gorgonia ventalina*. Overall, metabolic profiles of the surface microbiota were significantly different than those in the water column after analyzing the data using Step-Wise and Discriminant analyses. Furthermore, differences between communities living in healthy and diseased corals were also found. Although changes in the microbial communities were also observed between samples obtained over affected and unaffected areas in the same colony, these changes were not as obvious as the ones between healthy and diseased colonies. Our results suggest that the microbial communities living in the SML are affected by the presence of Aspergillosis, even if they are not in direct contact with the affected area. This could suggest changes in the composition of the SML due to reactions of the coral to the infection as defense mechanisms or changes due to the action of the pathogenic agent.

Targeted Research on Coral Disease and a Global Assessment

*C Drew HARVELL**, F AZAM, E JORDAN, L RAYMUNDO, E ROSENBERG, G SMITH, E WEIL, B WILLIS

Corson Hall, Cornell University, Ithaca, New York United States of America
cdh5@cornell.edu

The emergence and prevalence of diseases/syndromes in the Caribbean in the past few decades appears unparalleled in the geological record. But disease prevalence is not understood regionally or globally. One hypothesis is that rising disease occurrence is related to increasing anthropogenic impacts. Warming temperatures are linked with increased disease outbreaks not only in corals, but in other marine organisms, human, agricultural and wildlife diseases. The targeted research project seeks to understand the impacts of localized stress and compounding effects of climate change on coral disease. We have prioritized the research avenues that will provide the most direct outcomes to managing reefs under disease threat and also lead to the most productive opportunities for global capacity building in coral epidemiology, disease ecology and management. These priorities are: 1) a global assessment of coral diseases, 2) advancing understanding of epidemiology (origins, vectors and spread rates) of coral diseases, 3) evaluating major mechanisms of coral disease resistance, 4) pinpointing the ongoing impacts of coral disease on coral biodiversity, coral community diversity and population growth. We will present our preliminary Global Coral Disease Assessment from Mexico, Caribbean, Australia, Philippines and Palau.

Present Status of *Diadema antillarum* Populations in the Southwest Coast of Puerto Rico

*Miguel A LUGO**, Ernesto WEIL

Department of Marine Sciences, UPR, PO BOX 908, Lajas PR. USA. Puerto Rico

miguel.lugo@noaa.gov

Twenty years ago an epizootic event significantly reduced populations of the black sea urchin *Diadema antillarum* across the Caribbean and the western Atlantic. In this study, densities and size structures were measured in reef localities off the southwest coast of Puerto Rico to assess the current status (after 20 years) of populations of *D. antillarum*. Densities were estimated by counting all urchins in each of five band transects (20 x 2 m) placed at three depth intervals (0-3m, 4-10m, >10m) in each reef (n = 15). All urchins found in the band transects were then collected and their test diameter measured with calipers to estimate the size structure of the populations. To assess relationships of these parameters with the structural complexity (rugosity), the habitat rugosity was determined using the chain method of CARICOMP along the band transects. Densities per reef varied between 0.07 and 0.82 ind/m², with mean density of 0.23 ± 0.07 ind/m² for the entire area sampled. Densities of *D. antillarum* decreased across depth zones. The size frequency distribution varied between depth zones (P<0.05, Kolmogorov-Smirnov) with increasing numbers of small individuals were observed in deeper waters and medium-to-large sized urchins were dominant in shallow waters. A Poisson logistic regression showed that the densities of *D. antillarum* were influenced by factors like depth and site (P<0.0001). The test revealed that rugosity did not have a statistically significant effect on densities but a trend to higher densities in more complex areas was observed. Overall, it appears that populations of *D. antillarum* are coming back with some areas showing high densities and high proportion of juveniles. Densities in the reefs studied seem to be influenced by depth with most of the urchins inhabiting the shallow areas possibly because of lack of intra-specific competition due to the still low density levels

International Registry of Coral Pathology

*Shawn MCLAUGHLIN**, Kathy L PRICE, Cheryl M WOODLEY

904 South Morris St., Oxford, Maryland United States of America
shawn.mclaughlin@noaa.gov

An International Registry of Coral Pathology (IRCP) has been established at the Center for Coastal Environmental Health and Biomolecular Research in Oxford, Maryland, USA in affiliation with the Coral and Disease and Health Consortium (CDHC). The coral registry provides a centralized repository for information on coral disease, histological techniques, and related research efforts. IRCP is currently soliciting and cataloguing specimens representative of healthy and diseased corals to provide the coral research community with dynamic and valuable resources including a published atlas of coral histology and a web-accessible database. A relational database is being developed as a web based application. Diagnosis of contributed specimens is made by panels of pathologists, coral biologists, and medical and veterinary experts in the CDHC with the goal of establishing a consensus on diagnostic criteria for specific coral diseases. A repository of slides, tissue blocks, fixed tissues, and related photographs and reprints will be available to interested researchers for study and teaching purposes. The success of such a registry relies upon the participation of the research community it serves. IRCP also collaborates with other researchers in coral disease investigations and participates in coordinated responses to coral mortality events. Current research investigations include evaluations of various fixatives for tissue preservation; comparisons of decalcification solutions; application of immunohistochemistry techniques; and, adaptation of petrography methods to permit examination of the skeletons of corals eliminated during routine histology procedures.

The 2003 Acroporid Mortality in the Florida Keys (USA): A Systematic Approach to a Disease Investigation

*Shawn W POLSON, Mats L LUNDQVIST, Sara C POLSON, Samantha L RYAN, Dana E WILLIAMS, Margaret W MILLER, Shawn M MCLAUGHLIN, Billy D CAUSEY, Richard W CURRY, Douglas MORRISON, Cheryl M WOODLEY**

Hollings Marine Laboratory, 331 Fort Johnson Rd, Charleston, South Carolina 29412 United States of America

polsons@musc.edu

A rapid mortality of Acroporid corals inhabiting reefs in the Florida Keys was reported in the spring of 2003. The mortality was characterized by a line of sloughing tissue, which moves across the coral, rapidly denuding the skeleton. Signs were first noted on the staghorn coral, *Acropora cervicornis*, on reefs in the Florida Keys National Marine Sanctuary (FKNMS) near Key Largo. A similar pattern of mortality was subsequently noted on *A. cervicornis* colonies in Biscayne National Park (BNP), *A. palmata* colonies within the FKNMS, and on *A. prolifera* and *A. palmata* in Dry Tortugas National Park (DTNP). In response to these unusual mortalities, the Coral Disease and Health Consortium (CDHC) coordinated one of the first comprehensive investigations of an infectious coral disease outbreak. The efforts of CDHC partners instituted standard operating procedures for responding to an infectious disease outbreak. These included (1) quarantine, (2) following strict protocols that minimized cross contamination and disease transmission while allowing timely sampling of both affected and unaffected corals (i.e. moving from clean to sick areas), and (3) decontamination of divers and their gear. Samples were collected for histopathology, microbiology and molecular diagnostics and processed on site, with each sample's role in future laboratory analyses predetermined. This allowed samples to be collected and handled in a manner that minimized degradation of the component(s) of interest and optimized samples for laboratory tests. Preliminary results of bacterial community analysis by 16S rRNA gene sequencing indicate a shift in the microbial community structure between healthy and diseased samples from multiple locations with additional data suggesting the possibility of multiple etiologies across the affected range.

Ecological Physiology of the Black Band Disease Cyanobacterium *Phormidium corallyticum*: An Investigation into the Dark Metabolic Capabilities

*Davecia RAGOONATH**, *Monique SALAZAR*, *Laurie RICHARDSON*
University Park, Miami, Florida, 33199 United States of America
drago001@fiu.edu

Phormidium corallyticum is a gliding, filamentous cyanobacteria found in the microbial consortium of black band disease of coral reefs. Growth at optimal temperature (30 °C) in aerobic and anaerobic conditions was compared in light and complete darkness using 17 different sterilized carbon sources in duplicate. Culture material was dispersed using an inoculation device to dispense equal volumes of *P. corallyticum*. After 7 days, the anaerobic dark control experiment (containing no carbon source) did not survive. *P. corallyticum* survived for the entire 30 day period using sucrose, lactose, valine, ribose and sorbitol as carbon sources in both aerobic and anaerobic conditions. After 10 to 12 days, *P. corallyticum* was unable to survive using tryptophan, lysine, arabinose, arginine and inositol in anaerobic, dark conditions. Death occurred after days 17 and 18 using glucose, fructose, mannitol, histidine, xylose, asparagine and maltose in anaerobic dark conditions. These preliminary metabolic usage results may yield insights into the dark physiological capabilities of *P. corallyticum*.

Physiology of the White Plague Type II Pathogen *Aurantimonas corallicida*

Elizabeth REMILY, *Laurie L RICHARDSON**
Biology Department, Florida International University, 11200 SW 8th St.,
Miami, Florida 33199 USA
tinydaisy@hotmail.com

Since the first observation of coral disease thirty years ago, the relative impact of coral diseases has escalated to the extent that they are now considered to be a major factor in reef decline. Coral diseases have been shown to cause dramatic short term declines in many different coral species, especially the reef building corals. If this trend is continued, coral diseases may play roles in permanently restructuring reef communities and in the overall degradation of the already threatened reef ecosystem. White plague type II (WP2), first documented in 1995 on Florida's reefs and now widespread throughout the Caribbean, has become one of the most devastating of coral diseases. The WP2 pathogen was isolated, was found to be a new bacterial genus, and was named *Aurantimonas corallicida*. A suite of laboratory growth experiments was performed using a pure culture of *A. corallicida* to investigate the physiology of *A. corallicida* under a variety of ecologically relevant conditions. These included a range of temperature, pH, and light, along with an investigation into synergistic effects. Elevated nitrogen and phosphorous concentrations were also investigated. Results revealed an optimal temperature range from 30°C to 35°C and an optimal pH between 6 and 8, which varied with change in temperature. Additionally, with increasing temperature the pH tolerance range for growth by *A. corallicida* widened. Manipulation of light intensity and the addition of nitrogen and/or phosphorous had no effect on pathogen growth rate. Results will be discussed in terms of the potential roles of both natural environmental variation and anthropogenic influence on WP2 incidence.

Culture and Identification of *Desulfovibrio* spp. Sulfate-reducing Bacteria from Black Band Disease on Reefs of the Florida Keys and Dominica

Shay VIEHMAN, *Deetta K MILLS*, *Laurie L RICHARDSON**
9700 SW 328th St., Homestead, Florida United States of America
shay_viehman@nps.gov

Black band disease of corals is a pathogenic microbial consortium composed of a wide variety of microorganisms. Together, many of these microbes contribute to an active sulfur cycle that produces anoxia and high levels of sulfide adjacent to the coral surface, conditions that are lethal to coral tissue. Sulfate-reducing bacteria, as sulfide producers, are an important component of the sulfur cycle and the black band community. Previous molecular survey studies have shown multiple *Desulfovibrio* species present in black band disease infections, but with limited consistency between bacterial species and infections. This study compared 16S rRNA gene sequences of sulfate-reducing bacteria selectively cultured from six black band disease infections on four coral species in the Florida Keys and Dominica. The 16S rRNA gene sequences were obtained through both direct sequencing of PCR products or by cloning. A BLAST search revealed that eight out of eleven cultures sequenced showed greater than 98% homology to *Desulfovibrio* sp. strain TBP-1, a strain originally isolated from marine sediment. Although the remaining three sequences were less homologous to *Desulfovibrio* sp. strain TBP-1, they did not match any other sulfate-reducing (or other) species in GenBank. Results of our study will be compared to published results from other studies that included the identification of *Desulfovibrio* sp. found in different black band disease infections, including black band on different coral species and in different geographic areas.

Pathological Studies on Coral Tumors of *Porites* spp., Okinawa, Japan

*Naoko YASUDA**, *Yoshikatsu NAKANO*, *Hideyuki YAMASHIRO*
Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus,
Okinawa, Japan
ynknssk@lab.u-ryukyuu.ac.jp

We investigated several types of tumors appearing on the surface of *Porites lutea* and *P. solida* to elucidate pathological traits of them. Morphological, reproductive and physiological differences were compared between ordinary and tumorous tissues. Tumors are distinguished from ordinary tissue as swelled structure and more or less bleached color. The tumors of *P. lutea* are divided into four types; completely bleached (Bl), pale bleached (Pbl), brown (Br), and transformed (Tr, polyps are separated by thick coenosteum). In *P. solida* only Br-tumor was observed. Density of zooxanthellae was significantly reduced in all types of tumor of *P. lutea* in comparison to ordinary tissue. Although Bl-tumor does not have symbiotic algae, it has been hardy for more than one year in the field without photosynthetic supply from the symbiont. P/R ratio was measured for Pbl-, Br- and Bl-tumor in *P. lutea*, the results showed 70% for Pbl compared to the ordinary tissue, almost same for Br, and almost zero for Bl. In *P. solida* both P/R ratio and zooxanthella density showed no difference. *Porites* corals are gonochoric. We determined the reproductive ability of polyps in tumors. In *P. lutea*, spermatogenesis was normal but egg production was largely reduced. On the other hand, even spermatogenesis was not observed in the tumor of *P. solida*. In the larger tumors of *P. lutea*, the density of calices was reduced without changing their calice size. Although the *Porites* corals are characterized by cerioid colony form (without coenosteum between corallites), in the tumor of *P. lutea* coenosteum developed, resulting in plocoid structure. Such transformation was not observed in the tumor of *P. solida*. Pathological differences varied among species in *Porites*, however, negative effect has developed for those corals carrying tumors.

**The Microbial Diversity in Normal and Bleached Scleractinian Coral,
*Porites lutea***

*Hiroko YOKOUCHI**, Haruko TAKEYAMA, Tetsuro FURUKAWA,
Hiroki TANIGUCHI, Makoto OMORI, Tadashi MATSUNAGA

2-24-16, Nakacho, Koganei, Tokyo Japan

hiroko99@cc.tuat.ac.jp

Massive scleractinian coral, *Porites lutea* is one of the predominant reef building corals and harbored various microorganisms such as dinophyta, chlorophyta, protozoa, and fungi. It was known that some coral bleaching triggered by bacterial infection, and bacteria associated with coral affected on the coral health. Bacterial diversity in *P. lutea* was still unclear. In this study, molecular analysis of bacterial community in *P. lutea* collected in Akajima, Okinawa was examined using denaturing gradient gel electrophoresis (DGGE). Partially bleached corals were found in Akajima on August of 2003. Normal specimens were collected in Akajima from January to October in 2003. 16S rDNA was amplified using bacterial universal primers from DNA extracted freeze-dried sample, and nested PCR was carried out using GC-clumped primer. Diversity and succession of bacteria associated among normal and bleached corals was compared in DGGE profiles of amplified 16S rDNA. In normal *P. lutea*, Green sulfur bacteria and γ -Proteobacteria predominantly was identified by DGGE analysis. However, they were not observed in bleached coral, member of Cytophaga-Flavobacterium-Bacteroides (CFB) and Gram positive bacteria were particularly appeared from bleached coral. These results suggested that these bacteria are possibly used as the microbial indicators for coral diagnosis.

Critical Limits of Sediment Accumulation Rates for Reef Corals in Abrolhos, Bahia, Brazil

Leo X C DUTRA, *Ruy K P KIKUCHI**, Zelinda M A N LEO

Centre for Ecological Economics and Water Policy Research (CEEWRP)
University of New England Armidale NSW 2351 Australia
lximenes@pobox.une.edu.au

This work evaluates the effects of sediment accumulation on reef corals from the Abrolhos area, Brazil. Sediment accumulation rate was measured in five reef stations during October/2001 and March/2002. Live coral cover, diameter of coral colonies and species diversity were measured in the same stations according to the AGGRA (Atlantic and Gulf Rapid Reef Assessment) protocol, along six belt transects (10m x 1m), and the number of recruits were counted in five quadrats (25 cm) located at every 2 m along the transects. Pearson's correlation was used in order to confirm the relationship between biotic and abiotic parameters. Sediment accumulation rate of 10 mg.cm⁻².day⁻¹ seems to constitute a critical limit for coral survival. Above it, there is a significant inverse relationship between the sedimentation rate and the measured biotic parameters, such as live coral cover, average diameter of *Millepora alcicornis* colonies, total number of recruits and number of *Siderastrea stellata* recruits. In places where sediment accumulation rates are higher than this value, there is a considerable decline in the coral community health indicators. Morphological and distribution variations of the reefs structures are, most probably, the major factors that expose the corals to the effects of sediment influx. The stations located at the top of the bank reefs closest to mainland show the highest values for the rate of sediment accumulation and the highest percentage of siliciclastic sediments, which also seems to influence reef vitality. Negative impact of terrigenous sediment content is shown by the inverse relationship among its content, which decreases relative to carbonate sediments from nearshore to offshore, and the reef vitality indicators, which increases from the inner to the outer reefs.

Transport of Flood Sediment on the Molokai Fringing Coral Reef, Hawaii

Michael FIELD*, Curt STORLAZZI, Kathy PRESTO, Andrea OGSTON,
Michael BOTHNER

400 Natural Bridges Drive, Sant Cruz, California 95076 United States of America
mfield@usgs.gov

During the winter of 2001-2002 we obtained synoptic data on currents, wave stresses, and suspended sediment concentration from a series of bottom mounted instrument packages on the fringing reef flat and fore reef of Molokai, Hawaii. Intense rainfall during the 2001-02 winter produced coastal flooding and delivered large quantities of terrigenous sediment to the reef. Our prior studies on the reef flat showed that high levels of suspended sediment concentration (SSC) occur when trade winds blow at moderate to high speeds during high tides.

During the weeks following the flood deposition, we observed a double pulse of elevated SSC on the reef flat. The first pulse was associated with high tides and strong trade winds, typical of the long-term record; the second pulse may have been related to advection of mud eroded from an adjacent recently formed flood deposit up current of the instrument location. Turbidity hit a maximum several days after the flood as turbid water flowed along shore and dispersed seaward.

Waves were a major factor in re-suspending and re-distributing sediment onto the fore reef. Sediment collected in tube and time-series sediment traps following the flood was significant, due to direct plume deposition and re-suspension by large wave -induced near-bed shear stresses (~2 N/m²) during the flood event. Heavy rainfall in January caused more flooding, and associated high wave stresses (about 1.2 N/m²) also resulted in significant sediment trap collection rates on the fore reef. In early January, even modest stresses (0.5 N/m²) created substantial trap collection rates. Our results indicate that transport of flood deposits on reefs is complicated, and includes a history of initial deposition and temporary storage on the reef flat. This is followed by re-suspension during periods of large wave-induced bottom stress and subsequent advection along and across the reef.

The Impact of Anthropogenic Activities to the Water Quality of Coral Reefs, South Taiwan

Pei-Jie MENG*, Hung-Jen LEE, Min-Li TSAI, Ching-Ya YEN, Chia-Ming CHANG

2 Houwan Rd. Checheng, Pingtung, 944, Taiwan.
pjmeng@nmmmba.gov.tw

Since July 2001, the National Museum of Marine Biology & Aquarium (NMMBA), under the supports of Kenting National Park Headquarters and National Science Council, has been conducting a Long-term ecological monitoring program of biological, chemical and ecological impacts from anthropogenic activities. Nevertheless, the ecological protection areas in the Kenting National Park was poorly described before the program. We collected seawater samples around Nanwan bay from 20 different collection sites over a 3 years period of time since 2001. Water samples collected were immediately analyzed for temperature, salinity, pH, dissolved oxygen, BOD₅, nutrients (as nitrite, nitrate and phosphate), ammonium, chlorophyll a, suspended solids and turbidity. The results of temperature (ranged from 20.1 to 33.4°C), salinity (ranged from 0.19 to 34.80 psu), pH (ranged from 7.56 to 9.41), dissolved oxygen (ranged from 3.53 to 15.59 mg/L), dissolved oxygen saturation (ranged from 48.5 to 200.0%), BOD₅ (ranged from 0.1 to 7.4 mg/L), nitrite (ranged from nd to 450 ug/L), nitrate (ranged from 1 to 1800 ng/L), phosphate (ranged from nd to 1288 ug/L), ammonium (ranged from nd to 4.44mg/L), chlorophyll a (ranged from 0.02 to 15.25 ug/L) and turbidity (ranged from 0.31 to 509 ntu) were varied with seasons and locations. Obviously, the higher values of turbidity and suspended solids were affected by run-off around the Nanwan Bay. The fluxes of nutrients and suspended solids were dependent of the rainfall, and a relatively consistent correlation was found between nutrients and suspended solids abundance in the water mass and the rainfall. Therefore, the coral reef around Nanwan Bay have been affected by the higher values of nutrients, BOD₅, suspended solids etc. In summary, the water quality of Nanwan Bay has been damaged.

Salinity Variation on an Off Shore Coral Reef after a Period of Intense Rainfall

Norman QUINN*, Barbara L KOJIS

Discovery Bay, St Ann Jamaica
Norman_q@hotmail.com

A Star Oddi underwater data logger was deployed on a reef at 9 m about 5 km off the island of St. Thomas, U.S. Virgin Islands. During a period of 10 days over 0.5 m of rain fell over the island causing wide spread flooding and damage on land. This paper will discuss the salinity variation associated with the rainfall and discuss implications for coral reef monitoring and management.

Impact of Carbon Dioxide on the Gorgonian *Pseudoplexaura porosa*: Coupling between Photosynthesis and Calcification

*Alexandra AMAT**, *Samantha DE PUTRON*, *Nellie BRYLEWSKA*

Ferry Reach, St George GE01 BERMUDA

alexandra.amat@laposte.net

During the last decade, the study of the responses of coral reef organisms to increased atmospheric CO₂ levels has extensively focused on scleractinian corals and coralline algae. The understanding of the metabolic response of these calcifiers to CO₂ is complicated by their high rates of photosynthesis and calcification, resulting in interconnected sources of carbon. Zooxanthellate gorgonian corals are important and conspicuous components of many reef systems. They are also active carbon producers, although photosynthesis and calcification progress at a lower rate than the main reef builders. Therefore, they can be used as a model to better understand the chemical and biological control of calcification. Here we investigate the impact of an elevated concentration of CO₂ on the physiology and metabolism of the gorgonian *Pseudoplexaura porosa*. A total of 40 branches, 40-50cm in length, of *P. porosa* were collected at two reef sites in Bermuda (32°N, 65°W). Half were acclimated in water equilibrated with atmospheric pCO₂ levels of 400 ppm (control), the other 20 branches at 700-1000ppm (elevated). After 10 days of acclimation, gamete release was observed from the branches in the control tank, in accordance with the documented timing of spawning for this species in Bermuda. Spawning was greatly reduced from the branches held under elevated pCO₂ levels. At the end of a three month period, respirometric chambers were used to measure photosynthesis and respiration (oxygen and carbon measurements), along with calcification (alkalinity technique), from several branches acclimated to the control and elevated pCO₂ levels. The apex of the branches were then sampled to determine spicule weight, shape and size, as well as chlorophyll, protein, zooxanthellae, carbon, nitrogen and phosphorus concentrations analysis. The differences observed for all these parameters in response to elevated pCO₂ levels will be presented and discussed.

Coral Calcification and Water Temperature

*Janice M LOUGH**

PMB 3, Townsville MC, Queensland 4810 Australia

j.lough@aims.gov.au

Average calcification and extension rates in the massive coral *Porites* are closely linked with average water temperatures. The calcification rate changes by 0.33 g.cm⁻².yr⁻¹ and extension rate by 3.1 mm.yr⁻¹ for each 1°C change in average sea surface temperatures (Lough and Barnes, 2000). The robustness of this relationship between *Porites* growth rates and average water temperatures has been confirmed with the addition of data from new sites. The relationship now extends for corals growing in average water temperatures between 23-29.5°C. This relationship also allows identification of reefs where *Porites* are not growing at expected rates. Earlier evidence of an increase in average calcification rates on the Great Barrier Reef, which matched rising water temperatures, is revisited with the addition of new data from long coral cores.

Effect of Early Marine Diagenesis on Coral Reconstructions of Surface-Ocean ¹³C / ¹²C and Carbonate Saturation State

Anne MULLER, *Michael K GAGAN*, *Janice M LOUGH**

Steele Building, St. Lucia, Qld 4072, Australia

a.muller@earth.uq.edu.au

Recent research suggests that future decreases in the carbonate saturation state of surface seawater associated with the projected build-up of atmospheric CO₂ could cause a global decline in coral reef-building capacity. Whether significant red uctions in coral calcification are underway is a matter of considerable debate. Multi-century records of skeletal calcification extracted from massive corals have the potential to reconstruct the progressive effect of anthropogenic changes in carbonate saturation on coral reefs. However, early marine aragonite cements are commonly precipitated from porewaters in the basal portions of massive coral skeletons and, if undetected, could result in apparent non-linear reductions in coral calcification toward the present. To address this issue, we present records of coral skeletal density, extension rate, calcification rate, ¹³C, and ¹⁸O for well preserved and diagenetically altered coral cores spanning ~1830-1994 AD at Ningaloo Reef Marine Park, Western Australia. The record for the pristine coral shows no significant decrease in skeletal density or ¹³C indicative of anthropogenic changes in carbonate saturation state or ¹³C of surface seawater (oceanic Suess effect). In contrast, progressive addition of early marine inorganic aragonite toward the base of the altered coral produces an apparent ~25% decrease in skeletal density toward the present, which misleadingly matches the non-linear 20th century decrease in coral calcification predicted by recent modeling and experimental studies. In addition, the diagenetic aragonite is enriched in ¹³C, relative to coral aragonite, resulting in a non-linear decrease in ¹³C toward the present that mimics the decrease in ¹³C expected from the oceanic Suess effect. Taken together, these diagenetic changes in skeletal density and ¹³C could be misinterpreted to reflect changes in surface-ocean carbonate saturation state driven by the 20th century build-up of atmospheric CO₂.

Interacting Effects of Pco₂ and Temperature on Metabolism of a Scleractinian Coral

Stephanie REYNAUD, *Nicolas LECLERCQ*, *Samantha ROMAINE-LIoud*, *Christine FERRIER-PAGES*, *Jean JAUBERT*, *Jean-Pierre GATTUSO*, *Denis ALLEMAND**

Av. Saint MARTIN, 98000 MONACO France, Metropolitan

sreynaud@centrescientifique.mc

The effects of increased pCO₂ and temperature on photosynthesis, respiration and calcification rates were investigated in the scleractinian coral *Stylophora pistillata*. Cuttings were exposed to temperatures of 25°C or 28°C and to pCO₂ of 460 or 760 μ atm for several weeks. The contents of chlorophyll c₂ and protein remained constant throughout the experiment while the chlorophyll a content was significantly affected by temperature, and was higher under "high temperature-high pCO₂" condition. The cell specific density was higher at "high pCO₂" than at "normal pCO₂" (1.7 vs. 1.4). Net photosynthesis normalized per unit protein was affected by both temperature and pCO₂, whereas respiration was not affected by the treatments. Calcification decreased by 50% when temperature and pCO₂ were both elevated. Calcification under normal temperature did not change in response to an increased pCO₂. This is not in agreement with numerous published papers that describe a negative relationship between marine calcification and CO₂. The confounding effect of temperature has the potential to explain the large variability of the relationship between calcification and pCO₂ reported in the literature and warrants a re-evaluation of the projected decrease of marine calcification by the year 2100.

Carbon Production in Coral Reef Ecosystem at Sesoko Island, in Okinawa

*Ryoko TOKESHI**, *Hiroyuki FUJIMURA*, *Yukio KITADA*, *Kouhei TANIGUCHI*,
Tamotsu OOMORI, *Yoshikatsu NAKANO*

6-1 Kasugakouen, Kasugashi, Fukuoka, Japan

tekeryo@riam.kyushu-u.ac.jp

In coral reef, there are many kinds of living organisms that have high potential of carbon production. The ecosystem in fringing coral reef at Sesoko Island is complicated since the biological activity in such coral reef is affected by both meteoric water from land and sea water from open ocean, respectively, as well as variations of photon flux, tide and other environmental parameters. Under the condition, studying the system of carbon production is tedious, however it is important to elucidate the factors of carbon cycle in the sea. The purpose of this study is to establish the organic and inorganic carbon production in coral reef by constructing BOX-MODEL and to demonstrate the dynamic system of community metabolism. In this study, for a year between December 2002 and November 2003, many parameters (temperature, salinity, dissolved oxygen, pH, depth and current speed) were directly monitored in every 15 minutes in coral reef at southeast area of Sesoko Island, Okinawa. Time series alkalinity and pCO₂ values in sea water were calculated from DO-pH and from pH-alkalinity values, respectively. Then for estimating carbon production in coral reef ecosystem, BOX-MODEL was constructed. This BOX-MODEL has been composed of the material balance of input and output using the concentration difference among three regions of open ocean, coral reef and coastal area. Organic carbon production was calculated from the concentration difference in time series dissolved oxygen between open ocean and coral reef, and then inorganic carbon production from the difference in alkalinity. As the results, seasonal variation on these carbon productions was well calculated with BOX-MODEL. Their carbon production was consistent with the photon-photosynthesis relationship. In this study, average gross production is 300-400mmol/m²/day, respiration is 120-250mmol/m²/day and net production is 150-250mmol/m²/day.

Warming of the Great Barrier Reef Leading up to Coral Bleaching*Severine CHOUKROUN, Craig R. STEINBERG**

PMB#3 Townsville MC, Queensland Australia

c.steinberg@aims.gov.au

Elevated Sea Surface Temperature (SST) is the primary stress for corals that lead to bleaching. This occurred over significant areas of the Great Barrier Reef (GBR) during 1998 and 2002. Each successive event being the most widespread and intense on record. The 1998 event was characterised by warming in the central coastal and inner lagoon of the GBR, whereas in 2002 the whole Coral Sea experienced elevated temperatures. The significance of these events both locally and globally have driven a significant research effort at AIMS. NOAA AVHRR SST imagery has provided an excellent method to assess the spatial and daily development of heating over the GBR. However little work has focussed on characterising the distribution of temperature down and into the water column. The Generalised Ocean Turbulence Model (GOTM) was applied to investigate this process. It is a one-dimensional water column model that allows the thermodynamics, hydrodynamics and the resultant turbulence to be modelled. We show the development of these extreme events in the central GBR where AIMS has a network of weather stations across the continental shelf. The air-sea heat balance and the effects of mixing by winds, tides and currents have been modelled and verified against temperature loggers. By understanding the mixing processes, surface hot waters can be dissipated or redistributed throughout the water column alleviating the thermal stress through wind or tidal mixing. Results show the effects of only short bursts of heating during doldrum like conditions (no wind, clear skies) can lead to rapid heating beyond coral bleaching thresholds.

Predicting Coral Bleaching Events Using a Blended Satellite Sea Surface Temperature Data*Halmar HALIDE**

Makassar 90245, South Sulawesi, Indonesia

halmarh@yahoo.com

A simple neural-network support model is developed to predict sea temperature that leads to coral bleaching events around Magnetic Island, North Queensland, Australia. The model's input is a monthly blended satellite IGOSS-NMC Sea Surface Temperature data while the output is a monthly predicted sea surface temperature up to 12 months in advance. The predicted temperature determines whether or not a bleaching will occur in few months time. An earlier study, conducted at the same location using an in-situ sea temperature data, finds that bleaching events occur when the maximum sea temperature in a particular year is 0.38 °C higher than that of the previous year (Halide, 2001; Halide and Ridd, 2002). The present model is validated against observed temperatures and events from year 1990 to 1999. The temperature prediction has a Pearson correlation ranges from 0.78 to 0.82. The best Peirce score for predicting a bleaching or non-bleaching event is 0.86 ± 0.21 . This is significantly higher than that of the no-skill random forecast of 0.0 ± 0.34 . This study is able to demonstrate that, in the absence of any in-situ temperature measurement, a satellite data could be used for predicting bleaching events. The model's skill, however, is limited only on predicting an event that will occur one month in advance.

Detection and Characterization of Cyanobacterial *nifH* Genes (Nitrogen Fixation) in Mayotte Island Lagoon (Indian Ocean; 12° S, 45° E)

Areen BOULOS, Loïc CHARPY*, Cheng-Cai ZHANG, Jean BLANCHOT, Marie-Jose LANGLADE

COM rue de la batterie des lions 13007 Marseille France, Metropolitan lcharpy@com.univ-mrs.fr

Mayotte Island has a large and deep lagoon where N_2 -fixing *Trichodesmium* blooms are frequently observed in austral summer. During not bloom conditions, the phytoplankton biomass is dominated by the small coccoid cyanobacteria *Synechococcus*. Here, we investigate the presence of N_2 -fixing organisms in the $<10\mu\text{m}$ size class. By using degenerate oligonucleotide primers it has been possible to amplify, clone, and sequence a segment of the *nifH* gene from $<10\mu\text{m}$ natural assemblage. We found several strains of organisms which have the *nifH* gene inside and outside of the lagoon. Examination of the DNA and amino acid sequence shows that, for one of the strain, the gene is most closely related to that of *Synechococcus*. The other strains are in the way of identification. These preliminary results indicate that a variety of N_2 -fixing organisms exist in coral reef waters and that N_2 fixation should have a major role in the lagoon N budget, even during non *Trichodesmium* bloom conditions.

Nitrate Uptake by a Scleractinian Coral

Renaud GROVER, Jean-Francois MAGUER, Denis ALLEMAND*, Christine FERRIER-PAGES

Avenue Saint Martin 98000 Monaco
rgrover@centrescientifique.mc

We assessed the uptake rates of nitrate by the scleractinian coral *Stylophora pistillata*, by following ^{15}N from seawater into the coral tissue. $^{15}\text{N}\text{-NO}_3^-$ enriched seawater was used as a ^{15}N source. In a first experiment, the uptake rate of "nitrate-enriched" corals grown in $5 \mu\text{mol L}^{-1} \text{NO}_3^-$ was compared to those of control corals grown in $\leq 1 \mu\text{mol L}^{-1} \text{NO}_3^-$ incubated at two different $^{15}\text{N}\text{-NO}_3^-$ concentrations (0.3 and $3 \mu\text{mol L}^{-1}$). Most of the $\%^{15}\text{N}$ enrichment occurred in the zooxanthellae fraction. Uptake rates were not significantly different between nitrate-enriched and control corals, suggesting that they were not dependent on a nitrate acclimation. These rates increased with the in situ nitrate concentration and varied from $1.2 \pm 0.2 \text{ ng N h}^{-1} \text{ cm}^{-2}$ to $6.1 \pm 1.1 \text{ ng N h}^{-1} \text{ cm}^{-2}$ in the algal fraction at 0.3 and $3 \mu\text{mol L}^{-1} \text{NO}_3^-$, respectively. In a second experiment, uptake rates of "ammonium-enriched" corals grown in $5 \mu\text{mol L}^{-1} \text{NH}_4^+$ were compared to those of control corals grown in $< 1 \mu\text{mol L}^{-1} \text{NH}_4^+$ incubated at $3 \mu\text{mol L}^{-1} \text{NO}_3^-$. These rates were significantly lower with high NH_4^+ concentrations in seawater. In the algal fraction, they ranged from 0.1 to $0.6 \text{ ng N h}^{-1} \text{ cm}^{-2}$ in NH_4^+ -enriched corals and from 2.2 to $4.5 \text{ ng N h}^{-1} \text{ cm}^{-2}$ in control corals. Nitrate can therefore be considered as an important source of nitrogen for corals, at least when ammonium concentrations are low in seawater.

Organic Production and Calcification in Coral Reef Communities in Bora Bay, Miyako Island, Okinawa, Japan

Yoshio ISHIKAWA*, Yoshimi SUZUKI, Beatriz CASARETO, Tamotsu OMORI
836 oya, Shizuoka, Japan
ishisim@ies.or.jp

The relationship between calcification and organic production based dissolved oxygen, total alkalinity and calcium was studied at Bora Bay in Miyako Island, Okinawa, Japan during the period of 1994 to 1995. Ca was determined with an automatic photometric titration using zincon and Zinc-EGTA. The diel changes of calcium, total alkalinity and dissolved oxygen concentrations were measured in coral reef waters throughout four field enclosure experiments: dome type chambers of 1m in diameter were settled onto benthos in four different areas with including different coral species and excluding living corals in one of the enclosures. TA to Ca ratio ranged from 1.3 to 2.0 with an average value of 1.8 for living coral and benthos, and was 2.9 for benthos. The slope of 1.8 for living coral and benthos is close to the theoretical slope of 2.0 based chemical reaction. The slope of 2.9 for benthos is influence of decomposition for carbonate. Calcification rate ranged from 12 to $216 \mu\text{molC/l-day}$, while net organic production ranged from 119 to $261 \mu\text{molC/l-day}$, and respiration of organic carbon ranged from 167 to $279 \mu\text{molC/l-day}$ for all experiments. Pg/R ratios were greater than 1 with an average value of 1.8 at Bora Bay. The ratio Pg/C was 6.3 for experiments with living coral and benthos and 35 for only benthos, suggesting that gross organic production at Bora Bay is greater than calcification. High Pg/C ratios may be derived from the high productivity of benthic organisms such as epiphytic and endolithic microalgae, turf algae, and symbiotic zooxanthellae in benthic invertebrates. Bora Bay is characterized as organic production is greater than calcification in carbon metabolism.

Spatial Heterogeneity of Biogeochemical Components at the Sediment Interface: Relations with Ecological Units in an Insular Coral Reef Ecosystem (Moorea, French Polynesia)

Muriel SCHRIMM*, Mehdi ADJEROUD, Roselyne BUSCAIL

Universite de Perpignan, 52 av. Paul Alduy, Perpignan France, Metropolitan
schrimm@univ-perp.fr

The present study was designed to identify the major sediment types around Moorea and to examine the spatial variability of the biogeochemical composition of surface sediments, in relation to geomorphological units and benthic communities distribution. A total of 35 stations were sampled at 4 sites around the island, on the various geomorphological units identified. Several descriptors were used to precisely determine and characterise the different sediment types: inorganic carbon (IC), organic carbon (OC), nitrogen (N), C/N ratio, hydrolysable organic carbon (HOC), total amino acids (AA), and total carbohydrates (CH). A strong spatial heterogeneity was found in the biogeochemical composition of surface sediments at the scale of Moorea Island. Four major sediment types, that did not exactly match the geomorphological units of the reef system, could be distinguished around Moorea by the multivariate analyses (PCA and clustering). The first type corresponds to the inner half bay bottoms, and clearly represents the "terrigeneous" influence, mainly characterised by a clear deficit in carbonates and, conversely, by an enrichment in organic compounds (OC, N, AA, CH) that were highly degraded. Two other sediment types were influenced by the carbonated reef system and were highly carbonated (IC around 11 %; i.e. carbonates around 90 %), showing low organic compound concentrations. They were also characterised by high HOC concentrations. These two "reef-characteristic" sediment types can be distinguished by their N concentrations and C/N ratio. The fourth type represents a transition between "reef-characteristic" and "terrigeneous" sediment types. A gradient along the bays was also found, as for other reef communities. Finally, our study also demonstrates the effectiveness of HOC, total AA and CH to differentiate sediment types in reef systems, together with the more "classical" descriptors: IC, OC and N. They are reliable descriptors for spatial variability surveys and may be used as indicators of reef "health".

Effect of Nitrate Enrichment on Release of Organic Carbon and Nitrogen from Zooxanthellate Coral *Acropora pulchra* and Subsequent Microbial Decomposition under Laboratory Conditions

Yasuaki TANAKA*, Toshihiro MIYAJIMA, Yu UMEZAWA, Hideki FUKUDA,

Isao KOIKE, Hiroshi OGAWA, Takeshi HAYASHIBARA
1-15-1 Minamidai, Nakano-ward, Tokyo Japan
ya-tanaka@ori.u-tokyo.ac.jp

Human induced eutrophication is increasingly becoming common on fringing coral reefs. Physiological responses of coral and zooxanthellae to eutrophication have been relatively well studied, but studies of the effects on the dynamics of coral exudates have been a few, although its importance for coral reef ecosystem has been well recognized. In this study, organic carbon and nitrogen released from the reef-building coral *Acropora pulchra* collected at Shiraho Reef in Ishigaki Island, Japan and their subsequent microbial decomposition was investigated under nitrate enriched conditions using ^{15}N -nitrate and ^{13}C -bicarbonate as tracers. Under low nitrate condition ($+2 \mu\text{M}$ ^{15}N -nitrate), nitrate was rapidly consumed possibly by zooxanthellae in the coral within 2 days, while only 38% of NO_3^- was used for 4 days incubation under high nitrate condition ($+50 \mu\text{M}$ ^{15}N -nitrate). Both DOM and POM accumulation in $+50 \mu\text{M}$ bottle averages 30% less than in $+2 \mu\text{M}$, showing that nitrate enrichment significantly reduced the amount of DOM and POM production. C:N of accumulated DOM and POM in $+50 \mu\text{M}$ (22.9 and 14.2) was higher than in $+2 \mu\text{M}$ (19.9 and 9.0) on average. These observations suggest that nitrate enrichment caused significant physiological responses not only in zooxanthellae but in host corals that are primarily responsible to DOM and POM release. After 4 days of incubation and removal of coral from the cultures, the culture media were incubated for > 3 months under dark condition to follow the microbial decomposition of accumulated DOM and POM. During the first 45 days, significant decomposition of DOC occurred, while PON degradation was slow and both DON and POC remained almost same concentrations. These results suggest that bacterial population utilized DOM as a carbon source and POM as a nitrogen source. The difference of initial nitrate concentrations, however, did not affect the decomposition of accumulated bulk DOM and POM.

Seasonal and Spatial Variations of Nitrogen Sources for Macroalgae and its Controlling Factors Assessed by $\delta^{15}\text{N}$ and Other Chemical Components in Algal Thalli at Fringing Coral Reefs

*Yu UMEZAWA**, Toshihiro MIYAJIMA, Yasuaki TANAKA, Isao KOIKE,

Hideo OHBA, Takeshi HAYASHIBARA

1-15-1, Minamidai, Nakano, Tokyo Japan

omezawa@ori.u-tokyo.ac.jp

Although ^{15}N in macroalgae has been used as a bio-indicator to monitor the time-integrated uptake of land-derived nitrogen, the limited information about physiological characteristics of nutrients uptake by target macroalgae have hampered proper interpretation of spatial and temporal differences of algal ^{15}N obtained in the coral reefs. Thus, we conducted laboratory experiments focusing on nutrients uptake under different environmental conditions using brown algae, *Padina australis*, which is distributed in seasonally and spatially broad extents at coral reefs in Okinawa south west of Japan. The effects of isotopic fractionation associated with macroalgal N uptakes seemed to be minor compared with the case of phytoplankton, due to combination of inherent factors in macroalgae (e.g., translocations of N components from the mature parts to apical parts and adjustments of the amount of chlorophyll pigments), and considered to be ignored at nitrogen limited conditions where the algal N contents were kept under 1.5 - 1.6%. Also, the seasonal and spatial distributions of chemical compositions (e.g., ^{15}N , ^{13}C and N contents) in whole thalli of *Padina* spp. together with nutrients (e.g., nitrate and phosphate) in water column were measured intensively in the reef. Taking into account of the effects of isotopic fractionations from the algal N contents of samples, it was concluded that periodic terrestrial nitrate inputs as high concentrations were actively incorporated in benthic macroalgae mostly within 300m from the shoreline, depending on the water circulation, effluent nitrate concentrations and other primary productivity. In spite of the absence of the terrestrial input of high nitrate contribution, higher N contents in algal thalli were observed rather at the offshore areas where corals were flourished and physical disturbances were large. It was suggested that *in situ* mineralized or offshore-derived DIN supplied with high fluxes was also significant N sources for benthic autotrophs in coral ecosystems.

Reefs at Risk: Mining, Aquaculture, Shoreline Development and Public Finance in Kanaky/New Caledonis

*Rick ANEX**, *Stephanie FRIED*

BP. 623 Bourail 98870 New Caledonia

dakuwaqa@lagoon.nc

New Caledonia, or Kanaky, a French Overseas Territory situated in the Southwest Pacific, is an island archipelago identified by leading scientists as one of the world's top ten "biodiversity hotspots." Kanaky contains the largest concentration of nickel laterites in the world. Surrounded by an extraordinary barrier reef. Kanaky contains one of the world's largest lagoon systems. This little-researched reef and lagoon system is home to a vast number of marine species including many found nowhere else. Recently, marine researchers discovered over 2,700 species of marine mollusks at one site, alone, several times the number of species recorded from any other comparable area in the world. In January 2002, the French government proposed these reef ecosystems for listing as a UNESCO World Heritage Site. In March, 2002, sixty-two coastal and marine scientific experts designated the reefs of New Caledonia to be of "Outstanding Universal Value" in terms of their biodiversity attributes and placed these reefs at the top of priority list for World Heritage designation in the Pacific. Many of Kanaky's reef ecosystems are in good to excellent condition owing to their physical isolation and minimal human pressure from fishing. Unfortunately, however, these reefs are under increasing threat from the following sectors: Industrial open-pit nickel mining and associated air and water pollution; Intensive development of industrial shrimp aquaculture planned for much of the coastal zone; Commercial shoreline development. This paper presents a brief overview of current threats to Kanaky reef ecosystems and an analysis of the manner by which public finance, including bilateral financial institutions have supported or are likely to support activities which threaten the health of these extraordinary marine ecosystems.

A Review of Scleractinian Species Diversity in India, its Importance in the Reef Ecosystem Remediation and System Remediation- An Appraisal

*Satyanarayana CHOWDULA**

Coral Taxonomist, Fire Proof Spirit Building, Zoological Survey of India, Indian Museum Complex, 27 J.L. Nehru Road, Kolkata - 700 016. Republic of India

chsnarayana@hotmail.com; chowdula_narayana@rediffmail.com

India the organiser of the first international coral reef symposium was struggling hard since 1969 to save and conserve its diverse reefs, which are present on all the corners and was partially successful due to various reasons. As a result almost all its reefs are under severe threat due to site-specific anthropogenic interferences and natural threats like cyclones and the dreaded global threat "bleaching". In the very recent past this tenth coral area possessor stood up to the occasion with the support extended by friendly countries. At present it is in a position to enhance its capacity and almost all its reefs are reasonably quantified. This is evident from the many fold increase in the number of publications, reef researchers and most prominently new records of reef dwelling species. Biodiversity of an environment acts as a litmus paper to the health of that environment. A recent study of some Andamans reefs revealed their pristinely condition and highlighted their importance as seeding grounds for other reefs in the Indian Ocean which are severely affected by bleaching. The state of Andamans, with high scleractinian diversity and new records for, are a litmus test for the reefs of India and neighboring countries. But the real acid test is to build genuine commitment to the conservation of Indian reefs, to formulate effective strategies, and to implement actions that will lay a strong base for protecting the reefs, without delay. Scleractinian diversity is taken as a reckoner to assess the status of each reef region in the light of the site-specific disturbances and an assessment of the expected zooxanthellate scleractinian diversity with a comparison to the diversity in the countries around is attempted. Fresh site-specific strategies are suggested to sustainably conserve the reefs.

Co-management of Coral Reef Protected Areas: A Chimera or a Winner??

*Nancy DASCHBACH**

PO Box 4318, Pago Pago, American Samoa 96799 American Samoa

nancy.daschbach@noaa.gov

Co-management regimes have been touted in many success stories as the way to involve different decision-making stakeholders in the development and management of coral reef protected areas. Although on the face of it this strategy would seem to satisfy the most agents and agencies, it can become a delicate and protracted process fraught with misunderstanding and distrust. Clear and careful articulation of each others goals and expectations is essential and needs to be reiterated regularly. Operating models in American Samoa such as those with the National Marine Sanctuary, the National Park, the American Samoa Government and local villages will be examined for successes and outcomes of challenges met.

Community-based Coastal Resource Management Applied in the Municipality of Cagayancillo

*Arturo O FABURADA**, *Marlowe G SABATER*, *Maria Zoe C LATUMBO*,

Marivel P DYGICO

#3 WESCOM Road, Puerto Princesa City, Palawan, Philippines

artzky@hotmail.com

The Island-Municipality of Cagayancillo is a cluster of small islands located in the middle of the Sulu Sea. It is a sixth class municipality of the province of Palawan with a land area of 2,526 hectares and inhabited by about 6,000 people mostly belonging to the ethnic group of Cagayanen. The main sources of income are fishing and seaweeds farming. Beginning in the late 1980s, fishermen from Cagayancillo were influenced by transient fishermen from other provinces to use destructive methods such as dynamite and cyanide fishing. This caused rapid deterioration of the coral reefs of Cagayancillo including the Tubbataha Reef (which was declared as a National Marine Park in 1988), which belongs to its political boundary. This also led to the collapse of their seaweed industry. The Park Management, therefore, included in its management plan objectives the enhancement of the capacity of Cagayancillo residents to manage their resources in a sustainable manner. This was done through information and education campaign simultaneous with research and monitoring. Having increased local awareness on the importance of their marine and coastal resources, communities in Cagayancillo became actively involved in developing their 10-year Coastal Resource Management Plan. Capacity building interventions were then focused on participatory planning and decision-making processes. Local resource management structures were formalized based on partnership between government and communities. Resource management strategies were designed to balance environment and human concerns. Likewise, science and traditions were given due consideration. At this point, local resource managers are taking the initiatives in developing financial mechanism to sustain their coastal resource management actions.

Privatising Fish? Barriers to the Use of Marine Protected Areas for Conservation and Fishery Management in Melanesia

Simon J FOALE, Bruno K MANELE*

Resource Management in Asia-Pacific Program, Dept of Anthropology, RSPAS, Australian National University, Australia ACT 0200 Australia
simonjf@bigpond.com

In this paper we examine the strengths and weaknesses of state-supported Customary Marine Tenure (CMT) systems in two independent Melanesian states in the context of burgeoning commercial and subsistence fisheries. Both Papua New Guinea and Solomon Islands are categorised by most observers as “weak states” where access by foreign-owned fishing companies to state-owned resources (e.g. tuna) is typically easy to obtain by allegedly bribing the relevant politicians and bureaucrats at national and/or provincial level. By contrast, access to near-shore fishery resources necessitates negotiation with the landowners of adjacent coastal zones. However the expansion of markets and rapid increases in populations in the region are exerting pressures on subsistence and commercial fisheries that are already creating significant problems. In Solomon Islands the recent civil unrest has also meant that any escalation in marine resource piracy is likely to proceed unchecked. The management tool of choice for multi-species fisheries across the world, and particularly in cash-poor developing countries is the Marine Protected Area (MPA), and this system has proved quite successful in many instances, particularly in rich, industrialised countries. However, with some exceptions, typical Melanesian CMT regimes make MPAs difficult to establish because many coastal zones are finely divided along clan boundaries, such that few clans would be willing to “lock up” their own reefs for the benefit of neighbouring clans. How then can local communities in these countries most effectively manage their marine resources in an environment of escalating fishing pressure and weak governance? In this essay we analyse the social and institutional contexts of near-shore community-based fishery resource management, and explore options for the future. We look at the utility of educating reef owners about the life cycle of marine organisms and how this information could empower villagers to better formulate their own management regimes.

Predator Dominated Ecosystems: The Political Ecology of Marine Protection in the Northwestern Hawaiian Islands

Stephanie FRIED*

P.O. Box 520, Waimanalo, Hawai'i United States of America
stephanie_fried@yahoo.com

This paper explores the political ecology of marine protection efforts in the Northwestern Hawaiian Islands which comprise the most remote archipelago on earth. This largely uninhabited region of spectacular biodiversity is located where little fishing occurs, where clear scientific evidence exists for strong protection measures, and where there is tremendous public support for such measures. In theory, this should be a simple region in which to establish a marine protected area. In 1909, U.S. President Theodore Roosevelt issued an executive order designed to protect the NWHI. By the mid-1970s, however, significant NWHI lobster populations had been discovered. Over the following decades, more than 10 million lobster and close to 200 species of bycatch were removed from the ecosystem by a small number of vessels, operating far in excess of “maximum sustainable yield” estimates. At the same time, the population of the highly endangered Hawaiian monk seal (*Monachus schauinslandi*) plummeted and juveniles were found starving and emaciated in their NWHI breeding grounds. In response to public concerns, almost a century after Roosevelt’s protection efforts, U.S. President William Clinton issued executive orders in 2000 and 2001 designed to further protect the NWHI through the establishment of the 340,000 km² Coral Reef Ecosystem Reserve, the largest protected area under U.S. jurisdiction. This paper explores the factors (including leadership by Hawaiian cultural-rights activists, local fishers, and community-based non-governmental organizations, backed by experienced scientists and key political figures) that have, to date, supported protection efforts for this vast and fragile ecosystem. It also explores those factors (including national political actors, the politics of science, and the corrosive impact of entrenched conflicts of interest) that weigh against the establishment of meaningful protection measures for the NWHI.

The Landing Tour and Conservation Issue at Yabiji Reef (Miyako Islands, Okinawa, Japan). II. Construction of Community Based Framework towards Reef Conservation

Kenji KAJIWARA*, Hisashi MATSUMOTO

3485 Karimata, Hirara, Okinawa 906-0002 Japan
pulchra@lime.ocn.ne.jp

Miyako Islands, located in 300 km southwest of Okinawa Island, has some reef conservation issues in common with other reef areas. One of the weighty subjects is the tourism use of coral reef. Two local shipment services have been operating landing tours at Yabiji Reef, an isolated patch reef group. It is thought to be the largest tourism activity in the number of the tourists, at coral reefs of Japan. The shipment services carry about 2,000 or 3,000 tourists by large ferries, and land them onto the reefs during the ebb of spring tide for about 3 days in April. Although prefectural fishery regulation ordinances state the banning coral taking, and limit shellfish taking, the Japanese legal system for reef conservation including enforcement is inadequate generally. The Hirara City local government of Miyako Island, has been promoting a conservation project against the landing tour issue since 1998. The project includes investigations of reef status and actual tour situations, raising awareness on coral reef, recommendation of alternative or improved tour style, and the formation of reef use guidelines based on community consensus. The results of investigations suggested that introducing interpreters, who give information or warning for reef conservation to the tourists, may be able to reduce the negative impacts on the reef community. Thereat Hirara City has been training citizens as coral reef interpreters, and test-introducing them to the landing tour since 2001. Some citizens, who participated in the program, founded a NGO, “Reef Interpretation Society, Miyako Islands” in 2002, and they hold reef observation events for the residents to raise awareness on reef nature and culture. These movements tempering the conflictive atmosphere of the stakeholders, and it set a discussion table for reef use guidelines which is based on community consensus.

The Landing Tour and Conservation Issue at Yabiji Reef (Miyako Islands, Okinawa, Japan). I. Investigation of Coral Status for the Base of Stakeholders Discussion

Hisashi MATSUMOTO*, Kenji KAJIWARA

4377 Karimata, Hirara, Okinawa 906-0002 Japan
matu0088@cosmos.ne.jp

Yabiji Reef, an isolated patch reef group consisting of about 100 table and platform reefs in a 10 × 6.5 km area, is located at the northern offing of Miyako Island. Two shipment services have been operating landing tours at Yabiji Reef since 1983. They carry about 2,000 or 3,000 tourists by large ferries, and land them onto reefs during the ebb of spring tide, for about 3 days in April. Although significant disturbance is expected from this activity, the Japanese legal system has almost no legislation on reef conservation. The Hirara City local government in Miyako, has been promoting a conservation project against the landing tour issue since 1998. Hirara City established a conservation policy to investigate the reef status and promote stakeholders discussion towards sustainable reef use. There were almost no objective information about Yabiji Reef, regarding biological aspects, tourism situations and even the topographical chart. As the first step, Hirara City investigated reef coral fauna at Yabiji Reef in 1998-2000, and has been monitoring the growth of the coral community since 1998. The investigated area of coral fauna was limited within the range from reef edge to reef flat, however 13 families, 37 genera and 174 species of reef building corals were observed. Yabiji Reef could be divided into 5 faunas based on the composition of coral species. It suggests the various environments exist within of Yabiji Reef, which might assist decision making about reef use with a zoning system. But coral growth data also shows non-anthropogenic disturbance exists over the corals on reef flats, thus the anthropogenic disturbance must be reduced to the utmost.

Improving Management of Small Marine Protected Areas (MPAs) through Networking and Integration of Participatory and Co-management Frameworks

*Severino G SALMO III**, *Porfirio M ALINO*, *Ma Antonette R JUINIO-MENEZ*,
Liana TALAUE-MCMANUS

The Marine Science Institute, College of Science, University of the Philippines,
Diliman, Quezon City, 1101 Philippines

jon@upmsi.ph, jonsalmo@edsa.com.ph

The networking of fourteen small marine protected areas (MPA; average size of fifteen hectares) in the four adjoining municipalities of Bolinao, Anda, Bani and Alaminos City (Lingayen Gulf, northwestern Philippines) as a strategy to improve MPA management is presented. The management frameworks of these MPAs are generally categorized into two: community-based (in the case of Bolinao and Anda), and is managed primarily by community-based or peoples organizations; and co-management (in the case of Bani and Alaminos), and is a joint undertaking between the local government units (LGU) and the peoples organizations. These frameworks underwent different establishment process and have different implementation mechanisms. The former capitalizes on community empowerment and strengthening of community-based institutions while the latter relies on the duly delegated mandate of LGUs in performing administrative and resource-use regulatory functions. Both management frameworks have varying levels of accomplishments and success. However, all MPAs encountered trans-municipal/city boundary problems. Most prominent of which are poaching and encroachment of fishers from other municipalities/city, unclear delineation of management units of each municipal/city governments, and incoherent management plans. To address this problem, the MPA managers from the four municipalities/city initiated the networking of MPAs at two levels: within their municipal/city waters; and among municipal/city governments. MPA networking facilitates the integration of management frameworks and fosters critical collaboration among MPA managers. More importantly, networking helps in systematizing and improving MPA management through sharing and drawing of lessons among sites, cross-site visits, facilitating inter-LGU patrolling, and facilitating the formation of an inter-LGU MPA management council. This case study therefore aims to present and evaluate the accomplishments, and draw lessons and recommendations in facilitating the networking of small MPAs over a five-year period (1998-2003).

Clan versus Community-based Marine Management Practices in Melanesia

*Mark SOLON**, *Chris TUMI*

P.O.Box 697, Kimbe. West New Britain Province. Papua New Guinea

directormnd@global.net.pg

This paper critically highlights issues relating to clan or community-based traditional marine management practices in Melanesia, with particular reference to Papua New Guinea (PNG). A clan is defined as a group of families with the same ancestral origin, and a community is defined as a group of clans using a common dialect and living in a particular area. The clan-based management approach to conserving coastal marine resources may prove to be more effective than the community-based approach, because in the former, sustainable use and protection over the resources involves group effort and commitment from the clan members as they realize the scarcity of the clan owned resources and the need their is for the protection of these resources for the generations to come. In the latter, sustainable resource utilization and conservation in most cases, is a concern for only a few number of people, most probably due to larger resource base, increased population and economic pressures being experienced by the community members. Several case studies from PNG will be presented that discuss the strengths, weaknesses, challenges, and conflicts for the two management approaches, and will highlight future implications for effective conservation and management of coastal resources by local peoples as well as conservation groups.

Reefs at Risk in the Caribbean - Information to Support Priority Setting and Management

*Jon MAIDENS**, *Lauretta BURKE*

10 G Street NE, Washington DC 20002 USA

jmaidens@wri.org

Coral reefs are highly valuable resources in the Caribbean, providing a wide range of goods and services and supporting many economic activities and livelihoods. There is considerable activity in the region focused on assessment and monitoring of coral reefs, but, surprisingly, information is still fairly limited, and not well consolidated. Currently lacking are comprehensive data sets on status of, threats to, and protection of coral reefs for the Wider Caribbean region. The Reefs at Risk in the Caribbean project is a collaborative effort which integrates available information coral reef locations, observed impacts to coral reefs, and changes in condition. The project then attempts to fill in some data gaps through inferential modeling of threats to coral reefs from human activities, including coastal development, pollution and sediment from land-based sources, and overfishing. Data from remote sensing are used by project partners to develop coral reef maps; to map changes in land cover which feed into a watershed-based analysis of sediment threat; and to estimate extent of sediment plumes in coastal waters. Spatial and hydrologic modeling are implemented using a geographic information system (GIS) to evaluate degree of threat to coral reefs from human activities. Results show significant differences in level of threat, nature of threat, and coral reef condition across the region. The threat indicators are used as input to an economic valuation of coral reefs where the sustainable value of healthy reefs is compared to the value of degraded reefs (using the threat scenarios

Biodiversity and Trophic Functioning of a Mexican Caribbean Fringing Reef System: Stability and Degradation

Fabian A RODRIGUEZ-ZARAGOZA, *Enrique NUNEZ-LARA*,
Roberto C HERNANDEZ-LANDA, *Hector RODRIGUEZ-SANCHEZ*,
*Jesus E ARIAS-GONZALEZ**

Km 6 Antigua Carretera a Progreso, A.P. 73, Cordemex, C.P. 97310, Merida, Yucatan, Mexico

fabian@mda.cinvestav.mx

The Mexican Caribbean fringing Reef system is located along the eastern coast of the Yucatan Peninsula. Coral reefs are distributed in a semi-continuous barrier stretch along 400 km of coast. The systems exhibit a gradient of reef complexity, which increases from North to South, due to the continental shelf geomorphology. In terms of human uses, it can be divided into three regions: 1. Tourist region located in the North; 2. Reserve region located in the Center (Sian Ka'an Biosphere Reserve -SKBR area); Fishing region located in the South from the southern limit of SKBR to Belizean Border. The human uses have impacted and degraded coral reefs in different ways. The main objective is to identify how human uses affect the biodiversity and reef stability in functioning (i.e. biomass, net production, resiliency, etc.) We have performed a spatial multi-scale survey desing on 13 coral reefs distributed along Mexican Caribbean coast. Each reef was divided into 4 habitats: lagoon, front, slope and terrace. From *a priori* nested analysis of variance (nesAnova) we obtained similar reef habitats within the three mentioned regions. We constructed a mass balance models for three nested slope habitats to describe its trophic functioning. Models were developed from fish abundance obtained directly from reefs and considering a top-down control. Afterward, we modeled the stability in function of persystense, resilience and resistance of the systems from mass balance models. Biodiversity results were correlated with stability and other trophic macro-descriptors to determine how human uses influence coral reef ecosystems stability and degradation.

Reefmodel: an Agent-based Model for Exploring the Effects of Coral Reef Biodiversity Changes on Fisheries Yield

Andre Jon UYCHIAOCO, *Rollan C GERONIMO**, *May T LIM*, *Johnrob Y BANTANG*, *Edgardo D GOMEZ*

Velasquez St., Diliman, Quezon City 1101 Republic of the Philippines

rollan13@upmsi.ph

The quantitative contribution of biological diversity to ecological function is poorly known beyond experimental grassland and microbial communities. Biodiversity is not easy to quantify beyond a limited few taxa and is even more difficult to experimentally manipulate. Because of the lack of studies and extensive data required to assess and quantify the effects of biological diversity on reef ecological functions particularly on fisheries yield, and the tempo-spatial limitations in conducting experiments to directly measure such relationship, an agent-based model of a hypothetical coral reef ecosystem, ReefModel, was designed and built based on some simple relationships and assumptions. Developed using RePast, ReefModel is composed of 2 interacting layers: a cellular-automata reef bottom and an agent-based simulation of fishes and invertebrates. The reef bottom provides the environment on which the agents live; while the agents mediate the competition between the components of the reef bottom. Corals and algae compete for empty spaces using straightforward spatial rules. Above this lattice, agents sense, move, feed, grow, and reproduce. During reproduction, the genome traits of a parent agent are mutated by a certain factor for each of its offspring. This provides the variability among individuals and also simulates evolution which is needed to generate sufficient diversity of agents. The model is first run through an evolutionary phase wherein initial parameters and values are fed into the model and then run for a long period to generate the necessary "agents" pool. In the ecological phase fisher agents selectively fish high biomass cells. Several simulations for the ecological phase are run at different initial levels of diversity (i.e. at 100%, 10%, and 1% of the diversity generated at the evolutionary phase). The resulting target fish biomasses are then translated to economic values.

Effective Search and Mapping of Coral Reef Information

Steven H WONG, *Peter THOMPSON*, *Sandra L AGUILAR**, *Hongli LUO*,
Doug HARPER, *Mei-Ling SHYU*

75 VIRGINIA BEACH DRIVE, MIAMI, FLORIDA United States of America

steven.wong@noaa.gov

Documents and datasets related to coral reef research, management and outreach are voluminous. The efficient and effective mechanism for search, visualize, and query the information is critical to the success of activities intended for the conservation of coral reef ecosystems. We have developed a web-based coral reef database and mapping system to facilitate scientific research, project coordination, and the outreach to the general public for the coral reef ecosystem research and management. The system functions as an information repository, search engine, and mapping tool. Users of the system are able to actively upload/download contents; schedule and share events; search documents, data and metadata; and visualize/query datasets with a GIS (Geographic Information System) interface. The contents in the system include news, announcements, presentations, reports, data, metadata, images, and web links. One of the main features of our system is its capability to search information based on attributes from both the metadata and data. This capability overcomes the limitation imposed by conventional metadata search engines and database management systems. With the conventional search mechanism, finding information based on attributes from both the metadata and data contents may take multiple steps. However, it can be done in a single search in our application that is based on an Internet file system. An Internet map server is integrated with the Internet file system so that data files from the search results or from the file folders (accessible on web browsers) can be selected for visualization and query within a GIS interface. Researchers have been using the system to effectively conduct investigations, coordinate projects, and outreach to the general public on a wide range of coral reef subjects.

Coral Reef Ed-Ventures: An Environmental Education Program for School Children in Belize

*H Allen CURRAN**, Susan ETHEREDGE, Elizabeth CALLAGHAN, Paulette PECKOL

98 Green Street, Northampton, Massachusetts 01063 United States of America
acurran@email.smith.edu

Coral reefs, with their beauty and diversity of life, are fascinating to people of all ages. Healthy, well-managed reef systems are of great importance to coastal communities in many tropical countries, but local knowledge of reef ecosystems may be limited, and the study of coral reef ecology commonly is not a part of school curricula. Nonetheless, coral reefs are an ideal topic for teaching even young school children about fundamental ecological and environmental principles. As an outgrowth of the AGRRA Program to monitor the health of coral reefs in Belize and in cooperation with the Hol Chan Marine Reserve in San Pedro on Ambergris Caye, students and faculty from Smith College in Northampton, Massachusetts, USA, initiated the Coral Reef Ed-Ventures Program in summer 2000. Now in its 5th year, Smith College student teachers and up to 70 Belizean school children, ages 7 to 11, participate in an intensive two-week, inquiry-based program to learn about coral reefs. The focus is on understanding the needs of a healthy reef ecosystem, how various organisms interact within the reef, threats to the reef, and how to conserve the reef's resources. Our instruction teaches marine science with a multi-disciplinary approach that includes literature, visual arts, and performing arts. The curriculum has built-in flexibility, and the children are engaged in active, hands-on classroom and field trip-based learning experiences. Daily program activities include demonstrations, experiments, crafts, games, local field trips, stories, and journal writing. Pre-and post-program questionnaires, completed by the children, are used as assessment tools. Upon completion of the program, students are awarded Coral Reef Expert cards and Junior Ranger certificates by the manager of the Hol Chan Marine Reserve at the Coral Reef Ed-Ventures graduation ceremony.

Basic Educational Tools: Tabulation of Resources at the 10th ICRS

*Miguel A LUGO**, Carol FRETWELL

1305 East-West Hwy. SSMC4 Rm. 10126, Silver Springs, Maryland 20910
 United States of America
miguel.lugo@noaa.gov

Having long recognized the need expressed in the description of Mini-symposium "4-24, Fostering Positive Change for Coral Reefs — Educational Resources," the Outreach and Education Working Group of the U.S. Coral Reef Task Force proposes to offer its collective services from among those who will already be in attendance, to physically collect information and descriptions, in a log (database) form, of the educational resources promulgated and/or used by attendees of the ICERS, in particular, participants in the education mini-symposium and exhibitors present. We are hopeful that an exhibitor (perhaps NOAA, or the Waikiki Aquarium, or some other exhibitor) would contribute space for a chair at one of their exhibits. Contributions have already been pledged for clipboards, pens, and time to create the "volunteer schedule." Volunteers are still being sought to provide the keying-in of data into an electronic database (after the ICERS), to be posted and freely available on the Working Group's website, available for linking from other sites. The data collected would include short descriptions of the resource available, the extent to which it can be altered to fit local needs, any proprietary restrictions on use of the resource, availability (numbers and method of acquisition), and type of media being used. Additional information such as funding sources or avenues of revenue generation may also be collected.

Coral Reef Survey and Monitoring for Management in Central Sulawesi, Indonesia: Educational Aspects

*Samliok NDOBE**, Abigail M MOORE, Sofyan A YOTOLEMBAH, Harto DARWINTO

Jl Tendean No 7, Palu 94111, Central Sulawesi Republic of Indonesia
Kamilia@plasa.com

Yayasan Adi Citra Lestari (YACL) is a local NGO based in Palu, Central Sulawesi, a Province with over 2000 km of coastline and many small islands, most fringed by coral reefs, with numerous barrier reefs and atolls. In 2000, when YACL was a local partner in Reefs at Risk SE Asia, there was little or no data for most reefs, and no locally based survey/monitoring capacity. YACL initiated a capacity building programme for coral reef survey and monitoring, including training in SCUBA and GCRMN methods. Supported by The David & Lucille Packard Foundation, UNEP EAS/RCU, NOAA, PADI Project AWARE and the Reef Check Foundation, the result is a committed survey team recruited from the local community. Substantial data has been collected and submitted to local, national and international stakeholders. Examples of data usage include planning for Pulau Pasoso and community development (YACL); input to a data base for local Government (MCRMP); decision support for creation/upgrading of three MPAs; materials for ICZM training, etc. One major challenge at the outset was a lack of training and other materials in Indonesian language. YACL was forced to develop the ability to produce the materials needed. Initially, many training materials were produced. As the programme developed, outreach materials have become increasingly necessary. Existing materials, most originally in English, have been adapted but many have been created in-house. A variety of media has been used - printed items such books, posters, forms, etc and audio-visual media such as video and other computer-based presentations. A selection of materials produced and how they have been used is shown in this poster. Selected items will be available in limited numbers. Some have been or will shortly be made available via the YACL website, <http://www.yacl-sulawesi.org>.

Junior Park Ranger Program - Foster the Heart to Feel the Importance of the Familiar Sea of Coral Reef -

*Takahiro OKANO**, Yoshiyuki SUZUKI

2-27 Yashima-Cho, Ishigaki-city, Okinawa-prefecture 907-0001 Japan
TAKAHIRO_OKANO@env.go.jp

The Ministry of the Environment has carried out the "Junior Park Ranger Program (JPR)" as a joint program with the Ministry of Education, Culture, Sports, Science and Technology for the purpose of developing the children's understanding and interest to the nature by making children experience the work of National Park Ranger. International Coral Reef Research and Monitoring Center (COREMOC) in Ishigaki Island has implemented the program of learning the relations between coral sea and the people in the elementary school lessons. As for the children and their parents' generation in Ishigaki Island as well, the sea spreading out in front of them is "far" due to the recent change of the lifestyle. JPR aims to remind children to be aware of the importance of coral reefs and have pride to their familiar area by learning the abundance of coral reef, the relation with their life and the beauty. 53 kids of two elementary school took part in the program in 2002 and 2003. They surveyed the life in coral reef and tidal flat by snorkeling and exploratory research. At the end of the Program, they reported the result to the local residents. In the program, the guidebook "Teachers Guide for Hands-on education on Coral Reef" compiled by COREMOC has used. JPR enabled the children to be deeply impressed by the beauty of coral seas by introducing the snorkeling program, which was hardly adopted by the regular curriculum on the safe side. JPR could be active together with our staff members who familiar with the environmental education and coral reef conferring with the school teachers who know their children's understanding and growth. It is also very important for growing awareness in the region by children announcing their learning result to the adults of the area with their words.

MOP: Extending Coral Reef Education Beyond Science Majors in Hawaii*Frank G STANTON**

96-045 Ala Ika, Pearl City, HI United States of America

fstanton@hawaii.edu

The Marine Option Program (MOP) is a successful marine education program designed to integrate an awareness of the ocean environment into a wide range of college studies. Its strength is in fostering a positive attitude towards the coral reef environment of Hawaii in non-science degree programs. The program began in 1971 with the intent to allow any college student within the University system to learn more about the ocean by taking marine related courses, doing an independent project of their own choice, and participating in a wide network with other similarly interested students. Courses can be selected from a wide variety of programs including all the natural sciences, as well as art, engineering, journalism, law, economics, travel industry management, and Hawaiian studies. The MOP project is a customized experience for students to develop the links between their career and the marine environment. Projects take the form of internships with marine or career-related organizations, research projects, marine education projects, or even works of art and multimedia. Students become part of a network providing academic support, scholarships, job opportunities and social events that serve to foster an continuing interest in the ocean. Completion of the program results in a certificate that is included on the student's academic record. MOP graduates have moved on with careers in government, business, and education taking with them a greater awareness of the coral reef environment.

The Status of Coral Reefs of Solomon Islands

*Daniel C AFZAL**, *Alec T HUGHES*, *Gregory P BENNETT*, *Peter RAMOHIA*
PO BOX 97, Gizo, Western Province, Solomon Islands
[wwwf@solomon.com.sb](http://www.wwf.com.sb)

The Coral reefs of Solomon Islands are mainly narrow, fringing and intermittently distributed. Some of the largest areas of coral reefs occur where there are large lagoon complexes variously protected by volcanic Islands, raised islands, sand cays or by barrier reefs. They are recognized as having global biodiversity significance and relatively undisturbed marine ecosystems; and for their economical value in supporting the traditional subsistence economy and commercial harvesting. In the Solomon Islands, coral reefs are coming under ever increasing pressure from a suite of natural and anthropogenic impacts, driven by increasing population growth, uncontrolled use of marine resources for subsistence and cash, large scale resource extraction, and recent coral bleaching. Despite anecdotal evidence of the gradual decline of reef health and despite calls for improve of management, there is little coordinated scientific data on the coral reefs of Solomon islands and the effects of the impacts. Research and monitoring to date has been on an ad hoc basis with little coordination or standardization at the national level. The ethnic conflicts in 2000-2002 have hindered coral reef monitoring and research. In 2003 a partnership involving Government, Non-Government Organizations, research Institutions and the commercial sector established the Solomon Islands Coral Reef Monitoring Network. The network has surveyed representative reef sites and conducted GCMRN and Reef Check Training programs for partners and community members. In this paper we present the first standardized data from the coral reefs of Solomon Islands. We look at scenarios for the future statuses of coral reefs and marine resources in the country and make recommendations for their conservation and management

Status and Management of Coral Reefs in the United Arab Emirates

Ashraf AL CIBAHY, *Nasser AL SHAIBA**
P.O. Box 45553, Abu Dhabi, UAE United Arab Emirates
aalcibahy@erwda.gov.ae

Rapid economic development of the UAE over the last 30 years has been coupled with a dramatic increase in urbanization and associated infrastructure development. Anthropogenic influences represent another factor which adds to the stress of coral reefs. The coastal waters in particular that of Abu Dhabi are one of the most inhospitable environment for the coral growth where high seawater temperatures and salinities are close to or exceed the tolerance limits of hermatypic corals. The offshore bank and patch reefs are estimated to have approximately 10% live coral cover on average. The poor development of these reefs has been attributed to high sedimentation and temperature anomalies which cause mass mortalities of Acropora and other branching species. The cycle of mortality, breakdown and re-growth inhibits framework accumulations. The absence of a reef framework results in fragments being exported and deposited elsewhere. Recruitment is delayed due to low number of survivors and recruits must settle on the original substratum. Consequently, no upward growth of reef structure is achieved. Diversity in UAE in general is low (less than 60 species) and many coral communities are dominated by monospecific stands. Reef based tourism is limited, but reefs off the coast have proportionally high economic value in terms of fisheries. UAE has endorsed regional and international agreements and has adopted federal laws, and local orders to protect and develop living marine resources including coral reefs. This report represents the status of coral reefs, the existing conservation and monitoring initiatives and key issues pertinent to their management. *Head of Marine Protected Areas, MERC E-mail: aalcibahy@erwda.gov.ae Environmental Research and Wildlife Development Authority (ERWDA) P.O. Box 45553, Abu Dhabi, UAE

Status and Trend of Coral Reef Resources in the Marine Protected Areas in Central Visayas, Philippines

*Joselito Francis A ALCARIA**, *Solon D BAGALIHOG*
DENR, Region 7, Banilad, Mandaue City, Cebu, Philippines Papua New Guinea
jfaalcaria@yahoo.com

Central Visayas comprised the four island provinces of Cebu, Bohol, Negros Oriental and Siquijor in Central Philippines. Within these areas twelve marine sanctuaries are established. These marine sanctuaries are among the sites of DENR 7, CEP maintained and managed by the communities. The monitoring program of the coral reef resources within the CEP sites aimed to assess the status of the corals of the CEP sites through time; to determine the trend of the coral reef resources within the period of monitoring; and to assess the status of the fish resources within the reef areas under the program. The live hard coral cover in the marine sanctuaries had decreased ranging from 1.11% to 90.66% from 1997 to 1998. The highest decline among the ten marine sanctuaries was observed in Sulangan marine sanctuary registering 90.66% in 1998. Other sanctuaries like Apo Island and Lomboy have continuously declined in % live coral cover from 1997 to 1999. Fish population density in Apo marine sanctuary dropped significantly during the 1998 monitoring while other sites have high fish population density. Although the fish densities in some sanctuaries have decreased but not as much as the data gathered from Apo. Marine sanctuaries in Tulapos and Apo including Zaragosa were found to have more number of fish species recorded compared to other sites in the region in terms of the number of species. In the later part of the project implementation, two marine sanctuaries in Negros Oriental were monitored since 1999 and were found to have more species documented. Annual estimates of fish biomass in most coral reef sites in the region are fluctuating and at declining trend.

Status of Coral Reefs of Andaman and Nicobar Islands, India

*Jayakumar Balagurunathan ALFRED**, *Krishnamoorthy VENKATARAMAN*
M BLOCK, NEW ALIPORE, KOLKATA 700 053 INDIA
jayakumar3113@yahoo.com

The Andaman and Nicobar group of Islands is located in the south east of the Bay of Bengal, between 6°-14° N latitude and 91°94° E longitude with 530 islands, of which only 38 are inhabited along with a number of exposed islets and rocks. Andaman and Nicobar has two Marine National Parks viz., Mahatma Gandhi and Rani Jhansi Marine National Parks and Great Nicobar Biosphere Reserve. The coral fauna is diverse when compared to other parts of India. Today, among all the reefs in India, many areas in Andaman and Nicobar remain to be in near pristine condition (56 to 65% live coral). However, during a recent survey of the Mahatma Gandhi Marine National Park area in South Andaman, it was observed that siltation has caused mass mortality of corals at Tarmuguli and Hobday Island. The corals near old Wandoor area and Chidiatapu of South Andaman and Dugong creek and Hut Bay area of Little Andaman have died mainly due to siltation. 112 species of sponges, 1200 species of fish, 8 species of shark and spiny lobsters, dugongs, dolphins and sea turtles are some of major fauna reported from these islands. The Andaman and Nicobar group of islands supports 177 species of scleractinian corals, 120 species of algae, 70 species of sponges, 27 species of prawns, 30 species of crab along with lobster and barnacles. In recent days, a lot of construction and developmental activities are going on in many areas of Andaman and Nicobar Islands. Sand mining is the major activity that leads to destruction of coral reefs in many islands in Andaman and Nicobar Islands. Invasion of crown of thorn starfish (*Acanthaster planchi*) and White Band Disease are reported in many reefs in Andaman and Nicobar Islands.

Status of Coral Reefs in the Kingdom of Saudi Arabia*Khalid AL-SHAIKH**, Abdul Mohsen AL-SUFYANI, Friedhelm KRUPP

P.O. Box 11071, Jubail 31961 Kingdom of Saudi Arabia

kalshaikh@hotmail.com

The Saudi Arabian Red Sea and Arabian Gulf coasts are characterised by complex tropical marine ecosystems including a wide range of reef types, such as coral cays, fringing, platform, patch and barrier reefs, with a life hard coral cover averaging 20-50 %. Threats from human activities, such as industrial and urban development, oil exploration, maritime transport, fishing and recreation, are presently localised, but increasing rapidly. Most reef areas along the Red Sea coast are still in a healthy condition. Red Sea and Gulf reefs were severely affected by the 1996 and 1998 bleaching events. Only reef areas along the Gulf of Aqaba coast escaped bleaching. In the northern and central Red Sea bleaching was patchily distributed and most reefs have recovered. In the southern Red Sea effects of bleaching were more widespread and severe, but there are also signs of recovery. In contrast, all nearshore and many offshore reefs along the Saudi Arabian Gulf coast have died, with hardly any signs of new recruitment by 2003. In response to these events Saudi Arabia has developed a National Action Plan for Coral Reef Conservation, which focuses on improving the knowledge base about coral reef ecosystems in its territorial waters and reducing human-induced pressure. Coral reef surveys and limited monitoring activities are being carried out by King Abdulaziz University, Jeddah, King Fahd University, Dhahran, and the National Commission for Wildlife Conservation and Development, Riyadh. Given the outstanding ecological and economic value of Saudi Arabian coral reefs, strengthening the human and institutional capacity for reef research, monitoring and management and the establishment of additional marine protected areas are of highest priority.

Status of Research on Coral Communities in Hong Kong SAR, China*Put ANG JR.**

Shatin, NT, Hong Kong SAR, China Hong Kong

put-ang@cuhk.edu.hk

Hong Kong is located in subtropical region near the mouth of the Pearl River in South China. No major reefs are formed but coral communities are found mainly in the eastern and northeastern coastal areas. Eighty four species of Scleractinian corals have recently been identified from Hong Kong waters and a reference collection has now been set up. Various tertiary institutions have research topics involving corals or coral communities. Recent on-going researches include studies on coral predation by corallivorous gastropods, bleaching, photosynthetic performance of corals as a response to coral algal interactions, dynamic changes in coral community structures, coral reproduction and recruitment, and changes in reef fish assemblages after designation of Tung Ping Chau as a marine park and Cape D'Aguilar as a marine reserve. Several monitoring programmes are in place. These include monitoring on corals, fish, and marine flora in Tung Ping Chau and Hoi Ha Wan Marine Parks and corals in Yan Chau Tung Marine Park. Reefcheck is also an annual event sponsored by the Agriculture, Fisheries and Conservation Department of the Hong Kong SAR Government and participated by more than 20 groups of volunteers. In 2003, Reefcheck covered 30 sites around Hong Kong. It is providing very useful information on the general health conditions of coral communities in Hong Kong waters.

Assessing Bioerosion Activities of Echinometra Sea Urchin on Nukubuco Reef, Fiji*Subhashni D APPANA**, Veikila C VUKI

P.O.Box 8413, Nakasi, Fiji or P.O.Box 1168, Biology Department, The University of the South Pacific, Suva, Fiji

appana_sd@usp.ac.fj

Bioerosion is a major factor influencing reef construction and morphology. Sea urchins are major bioeroders of coral reefs and the calcium carbonate condition of coral reefs may reflect the abundance of sea urchins. The Echinometra spp. are well known agents of large-scale bioerosion and have been the cause of reef damage in the Caribbean, Eastern Pacific and Western Indian Ocean. By burrowing into coral rocks they protect themselves from predators, wave and current action, and to some extent from desiccation at low tide. The bioerosion rates of sea urchins, Echinometra sp. A (green-white-tipped) on Nukubuco reef was estimated by calculating the net carbonate accumulation. Cage experiments bioerosion rates ($\text{kg CaCO}_3/\text{m}^2/\text{urchin}/\text{d}$) were $35-37 \times 10^{-3}$ at the reef crest and $30-43 \times 10^{-3}$ at the reef flat. It is clear that the Nukubuco reef balance between reef growth and reef destruction is shifting, with bioerosion becoming the dominant process. Keywords: Bioerosion, Bioaccretion, Echinometra sp. A, Net carbonate accumulation

Living Coral Reef Resources of Sarawak, with Special Reference Kuching Area*Daud AWANG**, Mohd Zakaria MOSHIDI, Abd Aziz MUDA

Institut Penyelidikan Perikanan Malaysia Sarawak, Jalan Perbadanan, Bintawa, 93744 Kuching, Sarawak Malaysia

daudaw@yahoo.com

Belt transects surveys conducted on the reefs of Pulau Talang Talang Kecil and Talang Talang Besar. The Line Intercept Transect Method was used to assess the distribution of coral reefs. This was a first scientific survey conducted within this area. Study was carried out from April to September 2002. Around 18 benthic were identified during the survey. Objective of this study is to identify the distribution of coral reef composition as a first database in Sarawak with special reference Kuching area. Statistical Analysis, One-factor ANOVAs showed that no significant difference in percentage of benthic between Pulau Talang Talang Kecil and Besar ($P > 0.05$), which the P-value was 0.59.

Present Status of Unique Turbid Reefs in Gulf of Kutch, the First Marine National Park in India and Poshetra, its Sanctum Sanctorum and Strategies for their Sustainable Development

*Anandkumar AYYASWAMY**, Satyanarayana CH, Alfred J R B

Zoological Survey of India, M-Block, New Alipore, Kolkata-700 053, INDIA. Republic of India

anandayya@yahoo.com

Gulf of Kutch, the first Marine National Park in India is unique and fragile, because of its location in the dry tropical monsoon climate, large semi-diurnal amplitudes, high velocity water currents, high sediment input, negative water balance. Out of the 42 islands present 34 are with coral reefs in the southern Kutch. It is also tectonically unstable and raising at a rate of 1.3cm per year. A recent earthquake took a toll of more than 50000 human lives. The biota is subjected to constant stress. Biodiversity is less documented, attributable to the unfavorable conditions prevailing. Only 37 species of hard corals belonging to 24 genera are documented a decade back. Branching corals like *Acropora*, *Pocillopora* have become extinct. It is studied with and threatened by industries dealing with Salt, Cement, Chemical, Ship building and mostly Industries dealing with importing of Petroleum products due to its proximity to Gulf countries. Tourism is also at its peak because of its historical significance. Poshetra the Sanctum sanctorum of Kutch is significant because of the presence of more number of submerged reefs with high biological diversity; good growth of mangroves, breeding and nursery ground for many shell and finfish and is a treasure chest of fossils. This valuable section of Kutch is under threat due to a proposal to construct a port. Surveys carried out by Zoological Survey of India to assess the quantitative and qualitative status of scleractinian fauna of Kutch not only exposed significant observations related to Ecosystem diversity and Faunal (Hard coral, Associated & Vertebrate) diversity but also its importance in relation to the fisheries and fossil deposits. The study exposes the very sensitive ecological, social and economic status of the reefs and answers many unanswered questions. It aims at formulation of effective strategies for sustainable development.

Changes in the Coral Reef Community Seven Years after a Mass Mortality Event in Morrocoy, Venezuela

*Carolina BASTIDAS**, Aldo CROQUER, David BONE

CCS 90050, PO Box 025323, Miami FL 33102-5323 USA Republic of Venezuela

cbastidas@usb.ve

Playa Caiman (CAI, Parque Nacional Morrocoy PNM) was monitored from 1993 to 1996 as part of the CARICOMP program. In 1996, abnormal oceanographic conditions affected all marine communities in the park. At CAI, hard coral cover declined from 40 to 3%, and this site was dropped from the CARICOMP program. We assessed the changes in the coral community seven years after this event using the same protocol on the ten fixed transects previously monitored. Comparisons among data from March 1993, January 1996 and August 2003, showed that living cover of sessile taxa recovered to existing levels prior to the mortality ($68\% \pm 5$ SE vs. $60\% \pm 6$ SE; $p > 0.05$). When excluding encrusting octocorals (*Erythropodium* spp. and *Briareum* sp.), however, the living cover declined from 62% in 1996 (± 4 , SE) to 34% (± 5 , SE) in 2003. The hard coral cover was significantly lower in 2003 than in 1996 ($2.5\% \pm 0.67$ vs. $43\% \pm 5$). Thus, although there was a recovery in living cover, there are proportionally more encrusting octocorals, and less hard corals in 2003 than in 1996. In 2003, we observed 272 recruits (colonies < 5 cm in diameter) for an overall density of 1.4 recruits/m². Although hard coral cover has not recovered, there is evidence of successful recruitment at CAI. Therefore, there must be either a strong post-recruitment mortality or a variable recruitment rate with less recruitment before 2003. The relative abundance of the new recruits differs from that of the adult community in 1996. This suggests that if the community eventually recovers with the current recruitment abundance and composition, it will have a different structure. Given the lack of increase in hard coral cover in the past seven years, the time scales for a recovery are difficult to foresee.

Recent Mortality and Other Health Conditions of the Sea Fan *Gorgonia ventalina* in Santa Marta, Colombian Caribbean, 15 Years after a Mass Mortality Event

*Sonia BEJARANO**, Nelson A MANRIQUE, Jaime GARZON-FERREIRA

Cerro Punta Betin, Santa Marta, Magdalena Republic of Colombia

sbejarano@invemar.org.co

Coral reef degradation has taken place worldwide increasingly during last decades, apparently along with growing human populations and their inevitable unbalancing impacts on coastal regions. A sign of such degradation at many Caribbean localities including Colombian reef areas is complete population decimation of gorgonian sea fan *Gorgonia ventalina*. Today, 15 years after mass mortality of this formerly conspicuous coral reefs dweller, exact causes remain merely hypothesized and no population health assessments have been performed. This study was developed to contribute to this critical lack of information and also on the way to compare current situation with a series of assessments carried before mass mortality (1987) and eight years later (1995) at Santa Marta area (Colombian Caribbean). Sea fan habitats were extensively explored during 2003 and 120 60m² belt transects were surveyed at 20 shallow sites to determine incidence of mortality, diseases and other health conditions on remaining populations. Sea fan skeletons accounted for more than 90% of colonies at various sites, revealing the presence of former luxuriant populations unknown until today. Conditions threatening actual recovering populations were classified as recent mortality, predation, diseases and fouling by algae or invertebrates. While mean incidence of the fungal disease aspergillosis was remarkably low (1.3 ± 4.6 %colonies) and other diseases were absent from the study area, striking abundance of gastropod predators occurred (32.8 ± 4.4 to 7.5 ± 4.4 %colonies). Grazing activity of some species provided considerable amount of available substrate for algae and invertebrate colonization, while other colonizers overgrew sea fan living tissue either causing direct partial mortality or not. Valuable quantitative data and detailed descriptions are provided for various mortality sources previously reported sporadically. A comprehensive analysis of the way they interact and endanger persistence of this vulnerable species is presented as base for future research initiatives and for generation of species and habitat conservation strategies.

Coral Reefs Monitoring in the French Caribbean Islands (Martinique, Guadeloupe, Saint-Barthelemy)

*Claude BOUCHON**, Yolande BOUCHON-NAVARO, Max LOUIS, Pedro PORTILLO

B.P. 592, Pointe-a-Pitre, Guadeloupe (France)

claud.bouchon@univ-ag.fr

The coral reefs of the French Caribbean Islands (Martinique, Guadeloupe, Saint-Barthelemy) have been monitored since 1999. Benthic communities as well as reef fish assemblages were surveyed on a biannual pattern. Coral coverage remained stable on the studied period, whereas the algal assemblages (macro-algal, turf and cyanobacteria) exhibited important seasonal variation which render the monitoring necessarily pluriannual. Reef fish communities had very variable patterns according to the location in the different islands and showed strong seasonal variations. In all the studied areas, the number of species, the number of fishes and their total biomass were higher during the dry season (February to July). Fish communities become richer during that period, due to the recruitment of the fish juveniles, which mainly occurs during that period.

Status of Coral Reefs of Peninsular and Eastern Malaysia

*Annadel S CABANBAN**, *Affendi YANG AMRI*, *Ridzwan ABDUL RAHMAN*,
Yusri YUSUF, *Badrul HUZAIMI TAJUDDIN*

Sepangar Bay, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia
annadelc@ums.edu.my

More information on the coral reefs in Peninsular Malaysia and East Malaysia has been gathered from 2000 to 2003 by the Marine Parks Centre, Department of Fisheries, Malaysia and Sabah Parks in collaboration with national and international volunteers. Reef Check method was the main survey method and sometimes complemented with manta tow surveys, exploratory dives, and sampling species richness. In Peninsular Malaysia, coral reefs in Pulau Redang, Pulau Tioman, and Pulau Tinggi Marine Parks were surveyed in 2000 while the coral reefs in Pulau Perhentian were in 2003 by Coral Cay Conservation, Incorporated and researchers under the auspices of the Marine Parks Center. These Marine Parks are impacted by coral bleaching in 1998 and by sedimentation, eutrophication, overfishing, and disturbance from anchors, diving, and snorkelling. In general, the coral reefs in the east coast of Peninsular Malaysia are in better condition compared to the coral reefs in the west coast, possibly due to higher sedimentation rates from coastal land development. In East Malaysia, more coral reef areas were surveyed by Greenforce, Singapore International Foundation, Sabah Parks, and Universiti Malaysia Sabah (UMS). Most reefs surveyed were assessed as disturbed by fish-bombing and overfished but have high diversity of corals, fishes, and algae. Malaysia has some coral reefs with excellent coral cover although many areas have reduced coral cover. Individual surveys were done quite extensively but temporal and spatial comparison of coral cover is challenging as various methodologies were used and only few permanent transects were monitored consistently. In conclusion, coordinated surveys and planned monitoring are needed to provide accurate assessment of the status of the coral reefs. An attempt to address this need was initiated by the Borneo Marine Research Institute, UMS in May, 2002 with funding from the Department of Environment, Japan.

Coral Conservation in Hong Kong

*Alan LK CHAN**, *K CHAN*

7/F, Cheung Sha Wan Government Offices, 303 Cheung Sha Wan Road,
Kowloon, Hong Kong
alan_lk_chan@afcd.gov.hk

Hong Kong is located at the northern edge of the tropical Indo-Pacific region and experiences a sub-tropical climate. Corals in Hong Kong do not form extensive reef system. Instead, they form scattered fringing coral communities along the coasts. Despite the geographical constraint, the coral fauna and the associated marine life in Hong Kong are rich and diverse. There are 84 species of scleractinian corals and over 300 reef-associated fish species recorded in Hong Kong waters. Coral communities in Hong Kong face various forms of threats/ disturbance including coastal development, fishing and recreational activities, etc. The Agriculture, Fisheries and Conservation Department of the Hong Kong Special Administrative Region has put in place a series of measures and programmes which encompasses public education, monitoring, research, management and law enforcement to protect and conserve the coral communities in Hong Kong. We have organized a range of educational and publicity activities to enhance public understanding of the importance of protecting the marine environment and coral communities. Active monitoring is conducted at major coral sites through annual coral surveys Reef Check. We also undertake comprehensive coral studies to extend our knowledge and baseline information on coral communities in Hong Kong for sound and adaptive management. To protect coral communities from anchor damage, coral marker buoys have been installed at sensitive coral areas where recreation pressure is high. Underwater monitoring results indicate that damages to corals caused by boating activities have been significantly reduced following the installation of marker buoys. We have designated four marine parks and one marine reserve for protection and conservation of important marine ecological systems, including coral communities. Feasibility studies are underway to identify more suitable areas for marine parks designation. A comprehensive and direct regulatory framework is established in Hong Kong for the protection of coral communities.

The Status of Coral Reefs in Taiwan from 1997 to 2003

*Chien-Hsun CHEN**, *Chang-Feng DAI*, *Keryea SOONG*, *Chaolun A CHEN*,
Tung-Yung FAN, *Hernyi HSIEH*

Room 424, Institute of Oceanography, National Taiwan University, Taipei 106,
Taiwan, R.O.C. Taiwan
d91241002@ntu.edu.tw

Taiwan is near the northern boundary where coral reefs can no longer form. The southern tip of the island and many offshore islands have well-developed fringing reefs. However, corals form patchy communities rather than reefs along northern and northeastern coasts. Coral reefs in Taiwan are threatened by typhoons, sedimentation, wastewater pollution, and destructive fishing. To monitor the changes of coral reefs, we applied the ReefCheck protocol to survey the reefs at 8 localities from 1997 to 2003. The percentage of hard coral cover (HCC) among sites showed a wide range of variation and the average ranged from 22.9 to 36.3% and 25.9 to 32.1% for reef flat and reef slope respectively. There was no significant difference in HCC among years because both increasing and decreasing trends were observed. However, more sites at reef slope showed a trend of HCC increasing and more sites at reef flat showed the trends of decreasing. This suggests that the reef flat habitat is possibly suffering more frequent or stronger disturbances. Moreover, 71% of the cases showing the trend of HCC decreasing were coupled with increasing of other substrates such as bare rock, dead coral, or algae. The abundances of fish and invertebrate indicators were at low levels suggesting that most reefs were under the stress of overfishing. The results of trend analysis indicate that seven-years' survey is not sufficient to reveal the trend of coral reef change and a long-term monitoring program of more than 10 years is required. A combination of coral cover data and growth forms may also provide better resolutions to reveal the status of coral reefs.

Status of Singapore Coral Reefs

*Loke-Ming CHOU**

14 Science Drive 4, Singapore 117543. Republic of Singapore
dbscim@nus.edu.sg

The coral reefs of Singapore are located in one of the busiest harbours of the world, and are exposed to a variety of anthropogenic impacts. The most widespread impact is sedimentation, particularly over the past four decades. It resulted in a steady decline in live coral cover since monitoring commenced in 1987, and a reduction in the depth limit of scleractinians, from 10 to 6 metres. Despite these ecological responses, reef biodiversity remains high. Only two of the almost 200 scleractinian species recorded are believed to be locally extinct. The 1998 bleaching affected Singapore reefs on a scale not previously known. Recruitment and growth continue to remain vigorous with major mass spawning events taking place in March or April. Such resilience helps to support restoration activities, which are being investigated.

Software to Aid Reporting Monitoring Data

Greg COLEMAN, Ian MILLER, Kate OSBORNE, *Hugh SWEATMAN**

PMB 3, Townsville MC, Queensland 4810 Australia

g.coleman@aims.gov.au

Many monitoring programs commit by far the greatest part of their efforts and resources to collecting data, though the effectiveness of a program ultimately depends heavily on analysis and reporting. Two pieces of software used by the AIMS Long-Term Monitoring Program streamline reporting. (1) The Reportwriter program calls up text from previous reports from an Oracle database and provides a window in which to enter updated text into a database table. It also gives access to standard summary graphs and to other graphs showing results for the individual taxa that underlie the summaries. The text and the standard summary graphs can then be exported as Acrobat files for printing or to HTML for web presentation. (2) As part of the broad scale surveys of reef perimeters, observers fill in a multiple choice questionnaire concerning the general characteristics of each quadrant of the survey reefs. Drawing these questionnaire entries from a database, a second program constructs text to describe each quadrant of each survey reef. These automatically generated descriptions are linked to aerial photographs of the reefs on the AIMS Monitoring web page (see www.aims.gov.au/reef-monitoring).

Status of Coral Communities in Hong Kong, 2004

*Andrew S CORNISH**, Denise MCCORRY

Pokfulam Road Hong Kong

acornish@hkucc.hku.hk

Much can be learnt from Hong Kong, where coral communities lie alongside one of the most densely populated cities on the planet. As a result of a sub-tropical climate and a complex hydrology predominately influenced by estuarine conditions to the west, corals primarily occur as shallow non-reefal coral communities in eastern waters. Research into these communities has been fairly extensive since the first quantitative studies in the late 1970s but only a few programmes consist of on-going monitoring of multiple sites. One of these, ReefCheck has been carried out since 1997 as this global initiative was piloted in Hong Kong. Coordination of ReefCheck was taken over by the government in 2000 and it is now their primary coral monitoring programme with 32 sites surveyed in 2003. Additional recent and more focused studies have found higher coral diversity than previously known, with 85 scleractinian species now recorded. The available data suggest that although corals are under considerable natural stress and have been eliminated from some areas due to additional impacts from reclamation and pollution, most coral communities today are holding their own, as indicated by a high number of species and coral cover. Persistence and survival is due to natural resilience and partly to chance, as eastern waters which support most corals are away from centers of development, buffered by country parks and protected in Marine Parks. In addition, government has placed an increasing emphasis on minimizing disturbance to corals, including the creation of no-anchoring zones. However, reef fish populations show severe signs of overfishing, something the creation of Marine Parks has done little to address.

The Venezuelan Coral Reef Monitoring Network (VCRMN): Summary of Activities during the 2003

*Aldo CROQUER**, Carolina BASTIDAS, Eduardo KLEIN, Martina KURTEN

Sartenejas, Caracas, Miranda Republic of Venezuela

croquer@telcel.net.ve

In 2003, the INTECMAR (Universidad Simon Bolivar) and the Global Coral Reef Monitoring Network for South America (STA-GCRMN) conducted a series of monitoring activities in Venezuela. Four new coral reef sites were established to improve the monitoring capabilities of the country. Madrizqui (MDQ) and Dos Mosquises (DMS) are located in the Archipelago of Los Roques, whereas Cayo Norte (CNOR) and Caiman (CAI) are in the Morrocoy National Park area. In this work we present a comparison among these sites and with other Venezuelan and Caribbean coral reefs in terms of the sessile benthic community, the incidence of coral disease (both following the CARICOMP methodology), and the fish community structure (using AGRRA and REEF methodologies). The scleractinian coral cover differed significantly ($p < 0.01$) among sites (CNOR = 50.3%, DMS = 47.3%, MDQ = 18.2%, CAI = 1.4%). Interestingly, a site from the heavily affected nearshore reefs of the Morrocoy area had the highest coral cover among these sites. The coral cover in Cayo Norte and Dos Mosquises are among the highest values recently reported in Venezuelan coral reefs (e.g. Morrocoy = 30-45%, Mochima bay = 2-40%, Cienaga de Ocumare = 6.3-34.5%, etc) and also above for certain Caribbean coral reefs (e.g. Colombia = 35%, Curacao = 35.9%, Bonaire = 30%, etc). A total of 96 species of fishes were identified during the surveys performed in all sites. The total densities varied from 2.5 ind/m² (Cayo Norte) followed by Dos Mosquises (2.3 ind/m²) Caiman (2.1 ind/m²) and Madrizqui (1.53 ind/m²). The total incidence of coral diseases ranged from 2.66% (Madrizqui) to 15.11% (Cayo Norte), being the most common across sites, the yellow blotch syndrome (1.38-12.95%), white plague disease (1.32-3.97%) and dark spots syndrome (0.33-1.32%). The addition on new sites located at the eastern Venezuelan mainland and the regular monitoring of these new sites will allow the consolidation of VCRMN in the short-term.

Climate Change?, Mass Fish Deaths, Livelihoods and the Status of Coral Reefs in Nauru in 2004

*Margo DEIYE**, Reuben SULU

Nauru Kiribati

cfdo@naurufisheries.com

Mass fish deaths were recorded in Nauru between October to December 2003. The majority of the fish that were dying seemed to be the coral reef fish species. Coincident with the fish deaths was a certain level of coral bleaching. This paper reports on the mass fish deaths, possible causes of such an uncommon phenomenon and the state of the coral reefs after the mass fish deaths.

Induction of Heat Shock Protein 70 in the Coral Reefs of the Persian Gulf Exposed to Natural Environmental Stressors

*Peyman EGHTESSADI-ARAGHI, A. MAGHSOUDLOO**

#9, Etemadzadeh St., Fatemi Ave, P.O.Box 14155-4781, Tehran, Iran
eghtesadi@inco.ac.ir, eghtesadi@ibb.ut.ac.ir

During the past two decades, coral reefs have experienced extensive degradation worldwide. Coral reef communities of the Persian Gulf has also suffered from a severe decline of populations in the last decade in this region which is subjected to natural and human-made environmental pressures. This area is a semi-enclosed marginal sea with harsh conditions for the marine organisms, especially coral reef communities with regard to salinity, temperature and extreme low tides. Coral bleaching and mortality have been associated with elevated seawater temperature and elevated air temperature during periods of aerial exposure. Also, widespread coral mortality and limits of distribution coral species in areas such as Florida, Panama and Hawaii have also been related to temperature stress. We have studied the application of the heat shock protein (HSP) expression in the coral reefs as a biomarker for environmental stress and forerunner of coral community destruction. In this way the activity of repairing enzymes has been determined and also the antibodies to cnidarian Hsp70, cnidarian Hsp60, and cnidarian Cu/Zn superoxide dismutase has been applied for HSP determination. Our results indicate that corals that experienced this environmental stress had higher HSP (chaperonin) levels and protein

Coral Reefs in the State of Kuwait

Muna N FARAJ, Eiman K MOHAMMED, Hani A AL-TAMIMI*

P.o. Box 24395 Safat, Kuwait 13104 State of Kuwait
muna@epa.org.kw

The coral reefs of Kuwait are the most northerly in the world. They are located in the southern region of the marine environment of Kuwait in a relatively high turbidity and extreme environmental conditions which limit their development. Coral reefs in Kuwait are either found as platforms, patches or fringing coral assemblages. The most developed coral reefs are those associated with Kubbar, Qaru and Um Almaradim islands. About 35 scleractinian coral species have been recorded in Kuwait, 29 species are hermatypic and 6 species are ahermatypic. About 124 species of coral associated fishes were recorded in the coral reefs; they constitute about 35 percent of the total number of fish species (337 species) recorded in Kuwait. Among the coral associated fishes there are a number of commercially important species. Environment Public Authority (EPA) has the mandate for the protection of the environment and the conservation of natural resources and biodiversity. EPA has recently proposed a legislation for designating a system of protected areas, among these areas are all the coral reefs in Kuwait. Kuwait Institute for Scientific Research (KISR) has been conducting coral reef researches and studies. EPA is currently in the process of building its capacity for coral reefs conservation, monitoring and management in cooperation with national, regional and international organizations and partners.

The Status of Coral Reefs in Brazil

Beatrice P FERREIRA, Mauro MAIDA, Tamara M D'AMICO, Ana P PRATES, Clovis B CASTRO, Debora O PIRES, Fabiana C CAVA, Sergio M REZENDE, Danilo MARX, Caroline FEITOZA, Fabiana B CESAR*

Av. Arquitetura s/n., Campus universitario, Recife, cep 29060-900, Pernambuco, Brazil
beatrice.ferreira@ibama.gov.br

Coral reefs in Brazil are distributed along 3,000 km of the Brazilian Northeastern coast, and represent the only coral reef ecosystem in the South Atlantic. In 2002, the Brazilian Institute of Environment funded a pilot project to assess the status of conservation of Brazilian reefs using the global methods of Reef Check. Six representative regions of Brazilian reefs, between latitudes 3° and 18°S, were chosen for the assessment, including four coastal areas, one oceanic island and one atoll. The selected reefs were located inside the boundaries of marine protected areas of the two main types established in Brazil: fully protected and of sustainable use, where extraction is allowed. Intensity of use in this last category was variable, largely depending on local conditions such as human population densities and management regimes. From March 2002 to April 2003 reef check surveys were conducted along 192 transects distributed in several areas and sites within this regions. A geographic information system was build using LANDSAT imagery. Reef check methods were adapted so to fit local requirements while permitting collection of the same basic data. Hard coral cover varied between 5 to 35%. Higher cover was found at Abrolhos reefs and in some areas of Fernando de Noronha. Specific hard coral composition varied between regions, with lower diversity of corals registered at northern reefs. Indicator species of fish, including Lutjanids, Scarids, Serranids and ornamental species were significantly less abundant in areas were fishing and collecting were allowed. The same pattern was observed for commercially exploited species of lobster and octopus. Larger species of groupers were generally absent of all areas with very few exceptions. In the summer of 2003 a synchronized event of bleaching was registered. This is the first large scale event registered and shows the importance of large scale monitoring in Brazil.

Management and Media

*Marcos GEKTIDIS**

28 D-91054 Erlangen Federal Republic of Germany
science@gektidis.de

Management and MEDIAManagement of coral reef ecosystems has one goal: To keep reefs healthy and alive. The ongoing destruction of nature has turned the protection of our natural resources into the most important task of this new century. If coral reef scientists and managers fight this war without public notice, they have lost it already. The publication of scientific papers is not enough any more. Public pays science - in times of low economies a hard job. But nature cannot wait for a positive market. The worst destructions of natural resources happened in times of recovering economies. The most powerful public media are visual media. Without doubt, television reaches more people than any other source of information. It is therefore a logical step to integrate television media in coral reef management. This talk will provide a media training for scientists, devoted to the management and protection of marine coastal ecosystems. Last years cruise of the german research vessel POLARSTERN to the endangered deep-water reefs off Ireland serves as an example of close cooperation between science and media. During three weeks of filming, enough footage was shot to produce 3 television shows and 3 movies for festivals. A one page story in a major german newspaper was another product of this cruise. Additionally, on request, all scientists on board were provided with footage for their personal use. The scientific struggle for the conservation of deep-water corals and their protection from trawling has been witnessed by millions of people. As a result, the implementation of one of the first deep-water marine sanctuaries by the EU is at hand. This is a direct result of the devotion of the leading scientist to this issue and their foresight to integrate media at an early stage of their project.

Status and Recovery of Palau's Reefs after the 1998 Bleaching Event

*Yimnang GOLBUU**, Lolita PENLAND, David IDIP JR., Steven VICTOR, Carol EMAUROS, Jim KOULECHAD, Masao UDUI, Ken OKAJI
P.O. Box 7086 Koror, Palau 96940 Republic of Palau
ygolbuu@picrc.org

Palau launched a nationwide coral reef monitoring program in 2001. The program consists of rapid assessment of reef habitats (spot checks) and detailed surveys of benthic organisms, fishes and coral recruitment. Spot checks were conducted at 217 sites around Palau to make qualitative record of coral cover, major lifeforms and bottom substrates. Detailed surveys were also conducted at 14 permanent monitoring sites. Geographic balance, reef type, and potential level of human impacts were considered in the selection of the sites. Data from the spot checks shows that 87 percent of the sites surveyed have *Acropora* cover in the range of 0-5%. For non-*Acropora* corals, 68 percent of the sites surveyed had coral cover lower than 25%. The results of detailed surveys show that inner fringing reefs had the highest coral cover and patch reefs had the lowest. This trend was evident at both 3 and 10-meter depth. For coral recruitment, outside exposed reefs seem to have higher level of recruitment than fringing or patch reefs. There is no correlation between coral cover and recruitment. Based on the data collected so far, recovery of reefs is occurring as evidenced by the presence of recruits and young juvenile corals at many of the monitoring sites. However, if we compare reefs that have pre and post-1998 data, it is evident that the reefs have not fully recovered in terms of percent cover and species diversity.

Status of Coral Reefs of India

*Mohamad Asarahul HAQUE**, Krishnamoorthy VENKATARAMAN, Jayakumar Balagurunathan ALFRED
PARYAVARAN BHAVAN, C.G.O. COMPLEX, NEW DELHI - 110003
haque@menf.delhi.nic.in

The major reef formations in India are restricted to the Gulf of Mannar, Gulf of Kachchh, Andaman and Nicobar and Lakshadweep Islands. These reefs are important to the local community only to the extent of sustenance fishing. Tourism is being developed at a few places which are not beneficial to the locals to the maximum extent. The reef condition is generally poor and declining in near shore waters and areas of high population density. The bleaching event of 1998 in India has been reported to have increased dead coral cover to about 70 + 10%. However, post-bleaching surveys in 2001-2003 have shown recovery of some of the coral reef fauna except Lakshadweep Islands. Impacts of bleaching on other reef organisms and reef fisheries have not been adequately evaluated. Sedimentation, dredging and coral mining are damaging near shore reefs, while the use of explosives and bottom nets in fishing are damaging off shore reefs in specific sites. Taking in to consideration ecological and economic significance of Coral reefs and the threat perceptions, Government of India has initiated measures for their intensive conservation and management. Capacity for survey and underwater studies has been increased using Aus-Aid India Australia Training and Capacity Building Project. International initiative on the GEF project on the Coral reefs of Gulf of Mannar has been functional by forming a Gulf of Mannar Trust. To protect the sovereign rights of the people of the country Biodiversity Act 2002 has been enacted in the parliament and by establishing National, State and Local Biodiversity Fund. Present paper deals with ecological status of Coral reefs in the country and various national and international initiatives as well as current efforts of Government of India along with gaps and future directions for their conservation and management.

Coral Reef Status in the Mamanucas Islands, Fiji: An Assessment of Three Years of Reef Check Data

*Simon P HARDING**, James COMLEY, Jean-Luc SOLANDT, Alastair R HARBORNE, Peter S RAINES
The Tower, 13th Floor, 125 High Street, Colliers Wood, London, SW19 2JG
United Kingdom of Great Britain and Northern Ireland
sph@coralcay.org

Since 2001, Coral Cay Conservation has undertaken an annual monitoring programme of the coral reef environment within the Mamanucas islands of Fiji using a modified Reef Check method. As well as recording the standard data required by Reef Check HQ, CCC divers collect further information on hard corals (to lifeform and selected target genera or species) and a number of reef fish and invertebrate families. CCC volunteer divers are able to undertake the more rigorous survey methods, through thorough training and testing before actual surveying begins. The data indicates that the region is continuing to recover from the 2000 bleaching event with an increase in total hard coral cover and a corresponding decrease in dead coral and reef rock substrata. A number of target groups have also been recorded often suggesting that the reef habitat is generally in a good condition. However, an assessment of new sites surveyed in 2003 suggest that tourist development may have impacted on shallow reef habitats around some of the smaller islands within the archipelago. The presence of dense beds of the macroalga *Gracilaria* may be related to elevated nutrient levels in nearshore waters. The potential causes of these extensive macroalgal beds are considered.

Status of Coral Reefs in the Mergui-Archipelago, Myanmar (Burma)

*Georg A HEISS**, Moshira HASSAN, Luca SCHUELI
5 A Bahgat Ali Street, Zamalek, Cairo Arab Republic of Egypt
georg.heiss@reefcheck.de

Reef Check surveys were carried out in the southern Mergui Archipelago in the Andaman Sea (Myanmar) in 2001, 2003, and 2004. Natural pressure on reefs is mainly from river influx. Human impacts are mainly fishing (including destructive fishing practices) and collection of sea cucumbers, human settlements are dispersed. Deforestation in the hinterland leads to increase of the already high sediment load of the rivers. Diving tourism is its early stages; a few dive boats per week enter the archipelago from Thailand. The high sediment and nutrient input from rivers results in high turbidity in the shallow near shore reefs. Nonetheless, coral cover is high and health of corals as well as coral coverage (up to 75%) is in general good. Low light levels are probably the cause for restricted growth of hermatypic corals below 9m water depth in many reefs. Large fish as well as invertebrates such as lobsters or sea cucumbers were rare. In some reefs we observed extremely high numbers of *Diadema* sea urchins (up to 300/100m²). Results of fish and invertebrate surveys show a dramatic impact of over fishing, often through destructive fishing methods. The waters of the Lampi National Park are no exception.

A History of *Acanthaster planci* in Onna-Vill

Akiyuki IRIKAWA*, Yoshimi HIGA

Environmental Assistance for Community & Culture Co.,Ltd. Japan
a.irikawa@eac-oki.co.jp

In Onna village the west side of Okinawa island, outbreak of *Acanthaster planci* of several times happened in the past 30 years, and scleratinian coral community have suffered serious damage. Extermination of *Acanthaster planci* has been recently performed over for 15 years in Onna village. Continuation of extermination showed that the density of a large-sized starfishes increase before an outbreak, that generating cycles differ on the 10km scale, and that specific coraline algae and scleratinian corals existed abundantly in the place shallower than the depth of 50m in the place where large-scale outbreak happens. Moreover, there is a tendency that the density of childish *Acanthaster planci* is higher in specific geographical feature, and it became clear that many wreckage of corymbose coral colonies are seen and the place where the density of childish starfish is higher. Now, in Onna village the trial which manages the density of *Acanthaster planci* by exterminating reproductible starfishes is kept continued.

Status of Corals in Korea

Jong-Geel JE*, Bon Joo KOO

Ansan P.O.Box 29, Seoul 425-600 Republic of Korea
jgje@kordi.re.kr

Jeju island (Jejudo) located in the southern tip of Korea has some distinct soft corals with tropical and subtropical elements because of a branch of warm current, Kuroshio, which passes mainly through the southern part of the Island, however, Korean waters do not have any typical coral reefs by reef building stony corals. There are varieties of soft corals with vertical zonation on volcanic rocks around three islets, Munseom, Bumseom and Supseom in the southern area. Jejudo is considered as an ecological refuge for the tropical and subtropical marine species and is northern edge of their distribution as well.

The soft coral communities have been under destruction since 1988. Major factors of threats on the marine life including corals are suspended material from coastal development, construction, land-based organic pollution including wastewater and unsustainable fishing. Recreational divers and the tourist submarine also sometimes physically impact the habitats of marine organisms, especially of soft corals on subtidal cliffs.

The first protected area was designated in Nakdong River Estuary as a Natural Monument Protection Area for migratory bird habitats in 1966. The first marine national park, the Hallyeosudo Marine National Park, was established in the South Sea of Korea in 1968. Natural Monument Protection Areas at Munseom and Bumseom of Jejudo designated in 2000 are the first protected areas for marine life including corals.

The southern coast of Seogwipo is also investigated for designation as a Biosphere Reserve Area by UNESCO and a Marine Protected Area by Ministry of maritime Affairs and Fisheries.

A network system is needed for all protected areas relating to marine ecosystems for efficient management and conservation through sharing information and experiences, as well as integrated management for coastal and marine ecosystems of the managed areas in Jejudo.

Status of Coral Reefs in Japan

Tadashi KIMURA*, Hitoshi HASEGAWA, Takeshi IGARASHI, Makoto INABA, Kenji IWAO, Fumihito IWASE, Kenji KAJIWARA, Takashi MATSUMOTO, Tatsuo NAKAI, Satoshi NOJIMA, Keiichi NOMURA, Masanori NONAKA, Katsuki OKI, Kazuhiko SAKAI, Kazuyuki SHIMOIKE, Kaoru SUGIHARA, Mitsuhiro UENO, Shinpei UENO, Hiroya YAMANO, Hiroyuki YOKOCHI, Minoru YOSHIDA

3-10-10 Shitaya, Taito, Tokyo 110-8676 Japan
tkimura@jwrc.or.jp

Although Japan is located at the northern edge of coral distribution of the Pacific Ocean, coral diversity is quite high at the latitude. Four hundred coral species have been recorded in Japan. Corals widely distribute from Ryukyu Islands to northern islands, Kyushu, Shikoku and Honshu.

Main disturbances on corals are crown-of-thorns starfish and bleaching. Outbreak of the starfish occurred around the Ryukyu Islands from late 1960's to 1990's. The outbreak finished in the middle of 1990's after destroying almost entire coral communities there. Most of the coral have been recovered gradually in 10 to 20 years after the outbreak. However, the number of the starfish has been increasing again.

The catastrophic bleaching event occurred in Japan in summer of 1998. Relatively small scale bleaching occurred in 2001, 2002 and 2003. On the other hand, coral coverage is increasing in the northern islands because of elevated water temperature in winter, which limits coral distribution in the area. Soil runoff by the coastal development is still the major threat on the reefs. Large numbers of corals were killed by sedimentation after heavy rain in Ishigaki and Shikoku in 2001.

The corallivorous gastropod *Drupella* is also one of the main disturbances on corals in northern islands. *Drupella* outbreaks occurred in Shikoku and Kyushu from late 1970's to 1990's. Some of the areas still have a large number of *Drupellas*.

However, these threats and disturbances involve the general people to pay their attention toward the marine environment and coral conservation. There are some management practices conducted in the local communities to control the disturbances. The government also starts considering integrated coastal management for coral conservation involving different stakeholders as well as implementing individual activities.

The Status of Coral Reefs and the 2003 Mass Fish Deaths in Kiribati : Climate Change? Are Livelihoods at Stake

Taratau KIRATA*, Reuben SULU

Tarawa, Kiribati Kiribati
TaratauK@mnr.gov.ki

The status of coral reefs in Kiribati is generally unknown. A few anecdotal studies exist, however no permanent monitoring programme is in place. This paper presents results of some monitoring initiative in Kiribati in 2004 and some unusual mass fish deaths, which occurred between October to December 2003

The Status of Brazilian Coral Reefs since 5000 Years Ago

*Zelinda M LEAO**, *Ruy K P KIKUCHI*, *Leo X C DUTRA*, *Saulo SPANO*,
Marilia D M OLIVEIRA, *Igor C CRUZ*

Rua Caetano Moura 123, Federacao, Salvador, Bahia, Brasil
zelinda@ufba.br

Holocene reef growth in Brazilian waters began after 8000yrs BP. Until 5000yrs BP reefs developed upward to catch-up a transgressive sea, exhibiting a framework mainly composed by the endemic coral *Mussismilia braziliensis*, which colonies reached up to 1m diameter. A 5m sea-level lowering that occurred after 5000yrs BP, exposed nearshore reefs to solar radiation and influx of terrigenous sediment, causing a catastrophic coral cover decline, from about 20% in fossil reefs to less than 8% in living reefs. Nowadays, a sediment accumulation rate over 10mg.cm⁻².day⁻¹ seems to be critical for the vital condition of this low diversity coral fauna, because there is an inverse relationship with respect to some of their biotic parameters. Bleaching events registered in 1993, 1994, 1997/98 and 2003 did not cause mass mortality; all bleached corals recovered after 6 months. The results of three years (2000, 2001, 2002) monitoring the offshore reefs of Abrolhos National Marine Park, applying the AGRRA (Atlantic and Gulf Rapid Reef Assessment) protocol, are: a) benthos surveys indicate that fringing reefs of Abrolhos Islands show some reef damage in sites where intensive diving is permitted; b) giant offshore pinnacles rate as well preserved in terms of density and health of large stony corals, recruits density and macroalgae scarcity, c) pinnacles microtopographic complexity may enhance fish species diversity in relation to fringing reefs, where tourists or artisanal fishers (night illegal fishing) may have been reducing the density of carnivores, and d) no signs of disease or coral plague are seen in any stony corals. Sea-level rise may favor nearshore reefs in Brazil, while global warming seems not to be an important threat to this selected robust coral taxa. Management strategies for establishment of no-take reef areas need to be implemented in Brazil, for minimizing human impacts and ensure long-term protection of coral reefs.

The Jamaica Coral Reef Monitoring Network (JCRMN): Facilitating Increased Monitoring of Jamaican North and South-coast Reefs

*Dulcie M LINTON**, *Peter E EDWARDS*, *George F WARNER*

Mona, Kingston 7, Jamaica
dulcie.linton@uwimona.edu.jm

The JCRMN was launched by the Caribbean Coastal Data Centre (CCDC), Centre for Marine Sciences, University of the West Indies in June 2003 at the Discovery Bay Marine Laboratory. Seventeen individuals representing academic, governmental and non-governmental organizations and institutions participated and agreed on priority areas for coral reef monitoring in Jamaica. Through this collaborative effort, resources are shared and a growing volunteer group of divers have been trained through a series of training workshops in coral reef monitoring organized by the CCDC. Data have been collected on the status of corals, selected invertebrates and fish on a number of reef sites in Jamaica, particularly on the south coast, where coral reef data is scarce. Preliminary results indicate that south coast reefs generally have better hard coral cover than north coast reefs, suggesting that the impacts of sedimentation, pollution and over-fishing may not be as pronounced as on the north coast. Reef fish population is low at all reef sites while diadema showed some spatial pattern to its distribution, suggesting that the recovery of diadema populations may be facilitated more at some sites than at others.

Reef Check in Japan

*Yasuaki MIYAMOTO**

1-32-13-405, Unomori, Sagami-hara, Kanagawa, Japan
miyamoto@hs.st41.arena.ne.jp

We, Coral Network, have been supporting Reef Check surveys in Japan. I will show Reef Check results and how we successfully increase survey teams.

Status of Coral Reefs in Tanzania

*Mohammed S MOHAMMED**, *Christopher A MUHANDO*, *Haji M ALI*,
Carol DANIELS

Livingstone House, P.O. Box 774, Zanzibar - Tanzania
mohammed_sule@hotmail.com

Coral reef recovery after the 1998 bleaching event in Tanzania is significant, despite the occurrence of a minor coral bleaching episode in April 2003. The live coral cover on Unguja (Zanzibar), Tanga, Dar es Salaam, Songo Songo, and Mtwara reefs was medium (20-35 %) to good (35-55 %). However, recovery is very slow and macroalgal abundance is high in sites that were severely hit (70-80 % mortality) by the 1998 bleaching event, e.g. in Kitutia (in Mafia). Recent reef studies have indicated a slight change in coral species composition and an increase in settlement and recruitment rates in 2003 compared to 1999 years. The density of reef fish has shown a slight decline in unprotected areas and a slight increase in protected areas (e.g., Mafia Island Marine Park and Chumbe Island Marine Sanctuary). Similarly, some changes in reef fish composition, in favour of herbivores have been observed in some Unguja reefs. The densities of macro-invertebrates have fluctuated up and down over the past five years, e.g., increased in Pemba and declined in Mafia, depending on exploitation levels and recruitment success. The use of destructive fishing practices, overfishing, sedimentation and pollution are the main anthropogenic threats to coral reefs in Tanzania. Algal competition and to a less extent, crown of thorn starfish predation (in Unguja) also contributed to slow recovery of coral reefs. Environmental education, community resource monitoring programmes as well as establishment of more marine protected areas are some of the efforts taken to enhance sustainable coral reef exploitation.

Coral Reef Monitoring for Management in Central Sulawesi, Indonesia

*Abigail M MOORE**, *Sofyan A YOTOLEMBAH*, *Samllok NDOBE*,
Harto DARWINTO

Jl Tendeang No 7, Palu 94111, Central Sulawesi Republic of Indonesia
abigailyacl@yahoo.com

Yayasan Adi Citra Lestari (YACL) is a local NGO based in Palu, Central Sulawesi, a Province with over 2000 km of coastline and many small islands, most fringed by coral reefs, with numerous barrier reefs and atolls. In 2000, when YACL was a local partner in Reefs at Risk SE Asia, there was little or no data for most reefs, and no locally based monitoring capacity. YACL initiated a capacity-building programme for coral reef monitoring, including training in SCUBA and GCRMN methods (Manta Tow, Reef Check and LIT). Supported by The David & Lucille Packard Foundation, UNEP EAS/RCU, NOAA, PADI Project AWARE and the Reef Check Foundation, the result is a capable survey team recruited from the local community, with strong commitment to coral reef conservation. Data collected has been submitted to local, national and international stakeholders. Fourteen permanent transects at four long-term monitoring sites are regularly surveyed: two protected areas with marine components, Pulau Pasoso Provincial level Game Reserve and Tanjung Api Strict Nature Reserve; Palu Bay (YACL base and main training area); and Labuana (community awareness programme site, including ecotourism). Additional sites surveyed include a control area for Tanjung Api and locations where data is required for planning purposes, in collaboration with other projects and organisations. Applications include: planning a support programme for Pulau Pasoso, community development & extension activities, and production of a variety of training and awareness materials (YACL); input to the Marine and Coastal Resources Management Project (local Government and ADB); decision support for MPA creation or status change in the Togeang Islands, Banggai Archipelago, Pulau Pasoso (National programme). In addition to providing data and data-related products, involvement in education, community outreach, and coastal resource management is expected to increase in 2004/2005.

Status Report on Coral Reefs in the Philippines

*Cleto L NANOLA**, *Angel C ALCALA*, *Porfirio M ALINO*, *Hazel O ARCEO*,
Wilfredo L CAMPOS, *Edgardo D GOMEZ*, *Wilfredo Y LICUANAN*,
Miledel C QUIBILAN, *Andre J UYCHIAOCO*, *Allan T WHITE*

Bago Oshiro, Tugbok District, Davao City 8000, Philippines
tingnanola@yahoo.com

Regular update of the status report on coral reefs has been ongoing for more than two decades. Initial report indicated that only 5 percent were in excellent condition. Through the years this state has declined. Various management interventions were conducted in various forms such as establishment of marine protected areas and strict enforcement of the law on destructive and illegal fishing methods. Based from the year 2002 monitoring report, 24 percent of the studied reefs through time showed an increasing trend on hard coral cover, 17 percent were stable and 20 percent were decreasing. Fish abundance indicates that 17 percent were increasing, 5 percent were stable and 18 percent were decreasing. At present, most of these areas being monitored are being managed and thus may indicate a relatively optimistic outlook than what is prevalent. The most prevalent threats to reef health remain to be overfishing and its resultant associated destructive fishing. Sedimentation though pervasive and can be detected through many of the condition indices of reefs, does not seem to be as widespread especially in areas which are less accessible and far from river runoff areas. Storm damage and wave surge are also important forcing factors, though these associative relationships are derived from more refined community benthos and fish correlation analyses. Previous distinct stress (e.g. coral bleaching in 1998) from El Nino associated events has not been as discernible in this recent update. Additional information from areas monitored through time (2002 to 2004) derived from managed areas suggests that there are increases in more areas than before. Although these results may be encouraging, present simulation studies indicate that it may take more than a hundred years for reefs to recover from the prevailing stresses unless enhancement measures are improved and with more areas being managed more effectively.

The Current Ecological Status of Coral Reef Ecosystems in Mnazi Bay - Ruvuma Estuary Marine Park

David OBURA, *Redfred NGOWO**, *Julie CHURCH*, *Mohammed NUR*,
Nsajigwe MBIJE

P.O.BOX 845, MTWARA, TANZANIA Republic of Kenya
MBREMP@MAKONDENET.COM

The Mnazi Bay-Ruvuma Estuary Marine Park, located at the extreme south of Tanzania's coastline (40°23'E, 10°18'S), includes a complex of outer fringing reefs, channel fringing reefs, lagoon patch and platform reefs over an area of approximately 150km². A biodiversity inventory and habitat assessment conducted in late November 2003 updated information on the area from previous studies in the mid-1990s. A total of 258 species (59 genera/15 families - the highest number recorded for a site in East Africa) of reef building corals and 369 species of reef fish (146 genera/47 families) were identified. The coral reefs showed evidence of having suffered major coral mortality in the El Nino of 1998, but recruitment and re-growth of hard and soft corals was high, and hard and soft coral cover were estimated at an average of 30% and 18% respectively. The impacts of destructive and excessive fishing pressure on the reefs were high. Dynamite fishing was stopped in 1998, but craters and damaged corals were abundant in all sheltered and shallow areas. Continuing damage to the benthos from drag nets is likely until proposed management regimes are implemented. These, together with pressure from the large artisanal fishery in the area have resulted in a near-total absence of not only the preferred higher predators (groupers, emperors, snappers), but also of herbivores (parrotfish, surgeonfish, rabbitfish). Nevertheless, the high ecological resilience of the reef system, suggested by the massive recruitment and high recovery rates of hard and soft corals observed, suggest that the proposed management of fishing and other pressures could result in rapid and successful return of the reef ecosystem to a less damaged state.

Data and Information Standards for Coral Reef Monitoring and Status Reports

*James K OLIVER**, *Marco NOORDELOOS*

PO BOX 500, 11680 Bayan Lepas, Penang Malaysia
j.oliver@cgiar.org

Management and sustainable development of coral reefs are ideally based on a sound understanding of marine and coastal processes and resources. Reef monitoring programs play an important part in this, as they regularly generate important volumes of data and information on coral reef parameters. However, standardized and easily accessible data and information from these programs is often lacking. As a result, global, regional and in some cases even national coral reef status reports of the Global Coral Reef Monitoring Network (GCRMN) do not always make use of the full range of data which has been collected through these programs. Similarly, although ReefBase is the official data repository for the GCRMN, to date only a small proportion of the available data is lodged there. Sensible standards and guidelines for reef monitoring reporting structure and formats could help to bridge the current reef information gaps, and enable production of essential statistics, indicators, and status reports at national, regional, and global scales. The recent *International Workshop on Coral Reef Monitoring Data* addressed a range of ideas and suggestions on how national, regional and global coral reef status reports could be structured and presented as part of the GCRMN. An important goal was to produce guidelines for GCRMN reports that would make effective use of the data that is currently being collected around the world on coral reef condition, and threats. Additionally, the workshop aimed to provide guidance on how data collection might be better focused and standardized to enable specific questions to be addressed and comparisons made. This paper discusses reef data and information reporting standards, and how they could facilitate better sharing of results from multiple monitoring programs into an unprecedented public knowledge base on the status of coral reefs.

Taking Two Steps Back with Each Step forward: Seychelles Coral Reefs Remain at the Mercy of Bleaching Events

Rolph A PAYET, *Jude BLIOUX**

P.O. Box 677, Victoria, Mahe, SEYCHELLES Republic of Seychelles
rolph@seychelles.sc

Coral reefs around the Seychelles inner granitic islands suffered extensively from the mass coral bleaching event of 1998. Many reefs were reduced from a more or less pristine state to less than 10% live coral cover. Extensive monitoring of reefs has been undertaken from the year 2000 on a 6 months basis. During this period 2 additional coral bleaching events were recorded, which further impacted the recovering reefs. A number of factors are known to be affecting recovery of many reefs in the Seychelles. We hypothesize that recurring coral bleaching events remain the most important factor limiting coral recovery. Data on trends in recovery and reduction in live coral cover caused by bleaching events are presented to support this hypothesis along with extrapolation of expected coral cover in the absence of new bleaching events. It was concluded that renewed coral bleaching event remains the single most important factor limiting recovery of coral reefs around the Seychelles inner granitic islands. We further concluded that live coral cover on many reefs around the Seychelles inner granitic islands will increase from about 10% to 40% in 5 years in the absence of renewed coral bleaching event.

Effects of Environmental and Biological Factors on Juvenile and Adult Coral Communities in Kuwait Off-shore Reefs

*Michel PICHON**, *Francesca BENZONI*, *Shakier ALHAZEEM*

66860 PERPIGNAN Cedex. FRANCE French Republic
pichon@univ-perp.fr

The Arabian Gulf is a shallow sedimentary basin where environmental conditions can be limiting for coral reef growth. Such conditions include, among others, extremes (both high and low) in seawater temperature regime and the Shatt al Arab freshwater input, a waterway into which the Tigris, Euphrates and Karun rivers discharge their waters. Coral reefs fringing the off-shore islands of Kubbar, Qaro and Um Al Maradeem off the southern shores of Kuwait are the most northerly reefs in the Arabian Gulf. These shallow high-latitude reefs are characterized by a low coral species diversity, and a relatively high cover dominated by *Acropora* spp. and *Porites* spp. paucispecific assemblages, a typical condition in other high-latitude reefs in the Arabian region. In late 2003 a survey of kuwaiti off-shore coral reefs was carried out in order to assess coral community structure, and adult and juvenile coral diversity and distribution. A survey of the abundance and distribution of the sea urchin *Echinometra mathaei* was also conducted in order to investigate possible relationships between the density of coral juveniles, and grazing sea urchins. Coral reefs at Kubbar, Qaro and Um Al Maradeem were surveyed at sites with different exposure to the Shatt al Arab input, to predominant hydrodynamic actions and at different depths (1-3 m and 5-8 m). Although coral cover showed no significant differences between sites or depth, and between islands, significantly lower species diversity was found at exposed sites. Coral juveniles density was significantly higher in sheltered sites, and at deeper depth, whereas *Echinometra mathaei* density showed an opposite pattern, being significantly higher at exposed sites, and at shallower depth. Our results suggest that the Shatt al Arab water input influences the coral diversity and juvenile coral abundances in the reefs of the northern Arabian Gulf.

Status of the Coral Reefs in Wallis Island (French Overseas Territory of Wallis & Futuna)

*Michel PICHON**, *Claude PAYRI*, *Francesca BENZONI*, *Paino VANAI*

Service de l'Environnement, Administration Centrale, Mata Utu, Ile Wallis, Wallis & Futuna
pichon@univ-perp.fr

Wallis Island (French Overseas Territory of Wallis & Futuna) is an almost-atoll with a 155 m high central island, encircled by a 63 km long barrier reef. The central island, and smaller high islands present in the lagoon are lined with fringing reefs. Numerous patch reefs and pinnacles also occur in the lagoon. The coral reefs of Wallis Island have not been affected in the recent past by severe disturbances such as cyclones, Acanthaster infestations or significant bleaching episodes. A detailed survey of coral and algal species diversity and community structure was carried out in 2002. This survey revealed a high coral and algal diversity (including encrusting coralline algae) on the outer slopes of the barrier reef, lagoon reefs and fringing reefs, with up to 160 scleractinian coral species and 216 species of algae and seagrasses. Conversely, the barrier reef flat is largely covered by carbonate sediments, with very low coral cover except for the back reef margin. This situation can be explained by the fact that, in geological terms, the coral reefs of Wallis Island have reached a stage of maturity with respect to the present sea level, rather than as a result of anthropic pressure. Degradation of coral reef communities, presumably as a result of dynamite fishing was observed in a number of areas of the barrier reef flat. The effects of anthropic disturbances were also observed near the harbour area, where large brown algae (*Sargassum polycystum*) were conspicuous, and on some fringing reefs along the mainland shores. The coral reefs of Wallis Island are noteworthy by the richness of the barrier reef slope communities, particularly the lower slope communities, between 25 and 40 m, and the occurrence, sometimes in high abundance of coral species which are relatively rare, or with a very restricted geographical distribution range.

Status of the Coral Reefs of Mayotte Island (SW Indian Ocean) Five Years after the 1998 Bleaching Event

*Michel PICHON**, *Fany SEGUIN*, *Stephanie HERNANDEZ*, *Bernard THOMASSIN*, *Dhahabia CHANFI*, *Spem DAF*

EPHE Université de Perpignan, Perpignan, France French Southern Territories
pichon@univ-perp.fr

The scleractinian coral fauna of the barrier reef encircling Mayotte Island (SW Indian Ocean) was severely affected by the 1998 bleaching episode. Between 0 and 6 m depth, coral mortality was higher than 90%, affecting mostly the Pocilloporidae and the genus *Acropora*, which were overwhelmingly dominant on the upper outer reef slopes. Below ca. 6 m, the coral fauna was little affected by the bleaching event, with no evidence of mortality, or only partial mortality observed during surveys carried out in 2000 and 2002. Limited recolonization, mostly by species of *Acropora* was observed on the upper slope in December 2002, with up to 14 colonies per square metre, belonging principally to the humilis and the robusta groups of species. The average colony size ranged between 10 and 15 cm. Conversely, only a few Pocilloporidae, which were present before the 1998 bleaching event, had re-established almost 5 years later. Detailed surveys carried out in 1989 and 1997 on the fringing reefs indicate an average decrease in coral cover of 5-10% over the 8-year period, and recent evidence suggests an on-going trend of degradation. In contrast to the situation observed on the barrier reef, corals on the fringing reefs were not affected at all by the 1998 bleaching event. This situation can be explained by the fact that fringing reefs experience more extreme environmental conditions in particular in terms of seawater temperature and salinity variations, as well as heavier loads of nutrients and silt from terrigenous runoff. Corals on the fringing reefs would therefore have adapted to harsher conditions and become more tolerant, in particular to above normal temperature increase in summer. It is further hypothesized that recolonization by corals of the barrier reef after the bleaching event results from the settlement of propagules originating from the more resistant fringing reefs.

A National Status Report for Coral Reefs in Bermuda

Joanna M PITT*, Samantha J DE PUTRON, Alexandra AMAT, Thaddeus MURDOCH, Brian LUCKHURST

17 Biological Station Lane, St. George's GE01, Bermuda
jopitt@bbsr.edu

The high latitude coral reefs of Bermuda have not escaped impact but are generally healthy. Coral cover varies greatly between reef zones, but appears stable within zones over recent years. Highest cover is found on the terrace reefs, followed by the rim reefs. These areas are comparable to healthy Caribbean reefs. Patch reefs have lower cover but greater species diversity. Species richness is restricted by distance from the Caribbean and the stress of low winter temperatures. Differences in breeding season and fecundity compared to the Caribbean have implications for Bermuda coral populations. Photosynthetic capacity and calcification rates show little spatial but large seasonal variation. In 2003, widespread bleaching affected a variety of species and impacted photosynthetic and calcifying performance. The fire coral, *Millepora alcicornis*, experienced high mortality, but overall mortality was low as scleractinians recovered in the lower seawater temperatures brought about by Hurricane Fabian. No significant hurricane damage to reef communities was observed. Incidence of coral diseases is low. Most families of reef fishes are relatively abundant and stable. The 1990 ban on fish traps has resulted in a significant increase in the biomass of parrotfishes (Scaridae). Some carnivores targeted by the fishery are still depleted although black grouper, *Mycteroperca bonaci*, have increased in abundance in response to management measures. The 29 small no-take Marine Protected Areas do not yet appear to have made a significant contribution to the enhancement of fish stocks. Surveys of juvenile fishes show that common species are recruiting well, although juveniles of depleted species are still rare. Distinct spatial patterns indicate a need for protection of recruitment habitats. Maintaining the current status is the most realistic prediction for the next ten years. An ideal scenario would see a wider range of habitats and species placed under a greater variety of protective measures.

Programs and Legal Instruments for the Conservation of Coral Reefs in Brazil

Ana Paula L. PRATES*, Beatrice Padovani FERREIRA

Esplanada dos Ministerios, Bloco B, Sala 731, Brasilia/DF, 70.068-900, Brazil
ana-paula.prates@mma.gov.br

In Brazil the marine and coastal zone encompasses three million squared kilometers. Along the northeast and north parts of the coast, warm currents give support to a great variety of ecosystems including mangroves, coral reefs, dunes, sandbanks, sandy beaches, islands, lagoons and estuaries. Coral Reefs, in Brazil, are distributed along 3,000 km of the Brazilian northeastern coast, the only reef ecosystem in the Atlantic South. The establishment of protected areas is considered one of the main strategies for conservation of the biodiversity. In Brazil, up to now, nine protected areas have been created over coral reef ecosystem including some international protected areas (Ramsar and Natural World Heritage sites), several other measures were taken in order protect coral reefs, including a significant number of conventions, laws, norms and procedures. In 1992, Brazil was the first country to sign the Convention of the Biological Diversity and this commitment has stimulated a series of conservation measures. In this context, the Law of Environmental Crimes and the Law of the National System of Conservation Units were of special significance. In addition, the Ministry of the Environment in partnership with other institutions has created a number of programs. Some examples are the Atlas of Coral Reef Protected Areas in Brazil, developed to map and assess the representativeness of existing MPAs; the Coral Reefs Conservation Campaign developed to increase public awareness; and the Brazilian Coral Reef Monitoring Program, developed to monitor coral reefs health through the implementation of Reef Check. This paper will bring together the main strategies established for the conservation of coral reefs in Brazil, describe the legal instruments and the most relevant programs aimed to the conservation as well as the threats to their success.

Papua New Guinea's Participation in a Global Assessment of Human Effects on Coral Reefs, 1998 to 2000

Norman J QUINN*, Rebecca SAMMUEL, Barbara L KOJIS

PO Box 35, Discovery Bay, St. Ann Jamaica
norman.quinn@uwimona.edu.jm

The transformation of Papua New Guinea's economy has altered the use of coral reefs. Today reefs are increasingly fished commercially, visited by tourist divers, and impacted by resource exploitation. The impact of these activities on the reef ecosystem needs to be assessed. Using the Reef Check protocol, University of Papua New Guinea students conducted surveys on reefs in Kavieng, Kimbe Harbour, Tufi, Madang and the Papuan Lagoon from May 1998 to June 2000. Students were taught scuba skills and marine survey techniques. From an initial group of 32 students, 15 students successfully completed PADI open water dive certification and 11 participated in Reef Check surveys. Survey results indicated that offshore reefs still retained large fish populations as exemplified by the large schools of Maori wrasse within 15km of Port Moresby. Tridacna clams, lobsters, and Triton shells (*Charonia tritonis*) were very rare. Butterfly fish were common on most reefs. Also, coral cover was high and there was no evident of recent deaths either by bleaching or *Acanthaster planci*. There was no evidence that dynamite or poison was used on any reefs. The PNG Dive Operators Organization supports a mooring program which reduces the damage caused by anchors on reefs used by tourist boats. None of the reefs had any noticeable anchor damage or trash. The provincial towns close to the reefs surveyed were small and sewage discharge did not impact surveyed reefs. The main human impact on PNGs reefs is from coastal artisanal fisheries. Subsequent to these surveys a fish processing plant has opened in Madang with reports of foul smelling discharges into the sea. The Madang reefs should be resurveyed to ascertain any impacts from the fish processing plant and to determine if any recommendations need to be submitted to the local or national government of PNG.

Status, Diversity and Threats to Branching Corals (Scleractinia) of Gulf of Mannar Marine National Park

Kosalai Pargunam RAGHURAM*, Krishnamoorthy VENKATARAMAN

130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
dugong@md2.vsnl.net.in

Gulf of Mannar Marine National Park is situated at southeast coast of India. There are 21 islands surrounded with fringing reefs. In the recent times the GoMMNP reefs are under intense human pressure. Impact of anthropogenic disturbances on the status and diversity of branching corals in the Gulf of Mannar were studied. The LIT (Line Intercept Transect) shows ACT 1%, ACB 1%, CD 11%, CB 4%, CF, 3%, CE 12%, CM 68%. In Gulf of Mannar, Pillai (1983) reported 12 species of *Acropora* out of which only 5 were observed (*Acropora muricata*, *A. hyacinthus*, *A. millepora*, *A. humilis* and *A. cytherea*). The genus *Acropora* forms a major branching corals in Gulf of Mannar. The genera *Acropora* and *Pocillopora* were severely affected by boat anchoring, net entanglement, induced sediment settlement due to seaweed plucking and coral mining. Selective mining of species like *Pocillopora damicornis* had depleted their population in Gulf of Mannar. Recruitment rate of branching corals is very low due to seaweed plucking, shoresine operation, blast fishing and other anthropogenic disturbances.

Status of Coral Reefs in Sri Lanka

Arjan RAJASURIYA*

Crow Island, Mattakkuliya, Colombo 15 Democratic Socialist Republic of Sri Lanka

arjan@nara.ac.lk

Coral reefs habitats in Sri Lanka are patchy, the majority occur as fringing reefs. There are well-developed offshore patch reefs in the Gulf of Mannar. Sandstone/limestone platforms are abundant and are the most common form of substrate for reef development. Coral reefs were severely bleached in 1998 during the coral-bleaching event in the Indian Ocean. There is little recovery among inshore coral reefs along the west coast. In the southern coast there is rapid colonisation by branching *Acropora* species at Weligama whilst *Montipora acutuberculata* is the dominant coral species among other southern coastal reefs. In the Gulf of Mannar, new coral growth has been recorded from the Bar Reef Marine Sanctuary and other nearby patch reefs. Some individual patches contain more than 50 percent live coral, dominated by tabulate *Acroporids*. Shifts from newly growing coral to algal banks have been observed. In the east coast there is good coral growth and healthy coral habitats in the Pigeon Island National Park and at Punnakuda near Batticaloa. Results from monitoring have indicated changes in coral and fish communities. Low abundance of *Chaetodontids* and other coral dependent species on most shallow coral habitats reflects the impact of loss of live coral coverage on reef fish species. Special Area Management Programmes are active at the Bar Reef Marine Sanctuary and in two coral reef areas in the Southern Coast to better manage and protect coral reef resources. Two new marine protected areas have been declared in 2003 bring the total up to 4 coral reef marine protected areas for Sri Lanka. However, management of reef fisheries and other extractive uses is poor and an overall decrease in fish communities on most reefs is evident. The current status of the coral reef habitats, their management issues and results from recent monitoring are highlighted.

Changes in Coral and Reef Fish Communities in Sri Lanka; five Years after the Major Bleaching Event in 1998

Arjan RAJASURIYA*, Nishan PERERA, Chaminda KARUNARATHNE

Crow Island, Mattakkuliya, Colombo 15 Democratic Socialist Republic of Sri Lanka

arjan@nara.ac.lk

Coral reefs in Sri Lanka are limited to shallow water and occur as fringing and offshore patch reefs. The 1998 major bleaching event had serious consequences for coral reefs around much of the country except in the northeastern coastal waters where some reefs escaped bleaching. Recovery of bleached reefs has been variable; several offshore patch reefs have shown better recovery comparatively to inshore shallow coral habitats. In the south a shift in the coral diversity has been recorded where previously *Acropora* dominated fringing reef habitats are now dominated by *Montipora*. In one of the monitoring sites there was rapid recovery of branching *Acropora* after the bleaching in 1998. In the northwest many patch reefs are in poor condition with little live coral on them. However some individual patches support more than 50 percent live corals and indicate good recruitment and recovery. However a shift has been observed in composition and abundance from branching *Acropora* and *Echinopora lamellosa* to tabulate *Acropora* species. Numerous small colonies of *Faviidae*, *Siderastreae* and *Poritidae* are present in degraded reefs indicating that the mass coral mortality in 1998 has created an opportunity for many species to colonise. Other reef patches indicate that the presence of new coral growth may not always guarantee complete recovery in the short-term. Coral banks that showed recovery in 2002 has been smothered by *Halimeda* species one year later. In the east coast at Pigeon Island there was no evidence of bleaching in 1998 and recent surveys indicate that there is little change in species composition. Monitoring results indicate that the amount of live corals determines the species diversity and abundance of *Chaetodontids* and many other reef fish that are dependent on live coral habitats. This paper discusses the impact of reef degradation and recovery on fish communities on coral reef habitats.

Reef Fish Assemblages of Three Colombian Caribbean Sites: Status and Spatial and Temporal Trends

Maria C REYES-NIVIA*, Alberto RODRIGUEZ-RAMIREZ, Jaime GARZON-FERREIRA

A.A 1016 Santa Marta Republic of Colombia

catareyes@invemar.org.co

Reef fish assemblages were surveyed annually (1998-2003) to know its status and to explore spatial and temporal trends at three Caribbean sites (Chengue bay, Rosario island and San Andres island) through the National Monitoring System for the Corals Reefs of Colombia "SIMAC". Within each site, two reefs were evaluated at three depth levels. The Roving Diving Technique was used to assess the richness and relative abundance of species. From this data, a comprehensive species list (200) with 5-11 new records for each site was compiled. At Chengue 150 species were registered, at San Andres island 140, while in Rosario island there were 129 species. These results show that there is a high richness of fish in the evaluated areas, even though we only surveyed two stations and one type of environmental reef. In general, at the three sites there is a low representation or scarcity of species of commercial importance due its low sighting frequency and a low relative density of individuals. To identify the general spatial trends of the fish assemblages, a classification analyses was carried out, which identified four different groups. In general, the analyses showed that the stations within any locality tended to group within the same cluster. Inside each area, the groups formed through the multidimensional scaling ordination generally showed the influence of the depth level in spatial distribution of the fish community composition. The cluster showed a particular community structure at shallow level and another at "mid-depth" level. With regards to the temporal trends, no considerable changes in the assemblages of fishes have been observed over the years of monitoring in accordance with the information shown by the multivariate analyses.

Status and Recent Dynamics (1998-2003) of the Coral Reefs of Colombia

Alberto RODRIGUEZ-RAMIREZ*, Carlos CARO-ZAMBRANO, Jaime GARZON-FERREIRA

A.A. 1016 Santa Marta, Colombia

betorod@invemar.org.co

Through the National Monitoring System for the Coral Reefs of Colombia (SIMAC), three areas of the Caribbean and one in the Pacific were evaluated annually (1998-2003), in order to determine their recent dynamics and status. The information was obtained over permanent chain transects of 10 m of length, established at different depth levels. The average of live coral cover ranged between 20% and 35% and the algal cover between 35% and 43% in the Caribbean localities, whereas in the Pacific, live coral cover reached 60% and the algal cover 28%. In the context of the Great Caribbean, the monitored coral reefs of Colombia have a similar status to other areas. This means that algae are the dominant component of the reef surface. In contrast, in the tropical eastern Pacific (TEP), the monitored locality is characterized by its high live coral cover. Multivariate analysis indicates that there are no considerable changes in reef structure at any of the monitored localities between 1993 and 2003. Nevertheless, repeated measures analysis done with coral, algal and principal coral species covers, showed some trends of significant change in some localities and depth levels. For example, live coral cover has only decreased in one of the Caribbean localities (Chengue Bay) at the shallow reef zone, and in the Pacific reef (Gorgona Island) coral cover declined (~14%) at the shallow reef, but increased (~8%) at the middle reef zone. The reductions were not associated with anthropogenic impacts but natural disturbances such as hurricanes (in the Caribbean) or low extreme tides (in the Pacific) and only a few coral species were affected. As a consequence, our research showed stability for all monitored localities in terms of their coral reef communities, but some temporal variability on a local scale depending on the component of the reef considered.

Status and Threats of Coral Reef in Menai Bay Conservation AreaSalim A SAAD*

P.O.Box 774 - Zanzibar, Tanzania

salimamar@yahoo.com

STATUS AND THREATS OF CORAL REEF IN MENAI BAY CONSERVATION AREA ABSTRACT Menai Bay Conservation Area is in the South western of Unguja Island, is a popular for traditional fishing and tourism. The area is known for its productive resources resulting from scattered coral reefs and dense seagrass beds. These reefs are increasingly under threats due to destructive fishing practices such as beach seines, dynamite, noxious material and anchors. Coral reefs survey conducted in 1994 shows coral reefs were heavily degraded suffering from human sources such as beach seine, dynamite and anchoring. In 2000 another survey was conducted in different reefs within conservation area like Tindiji reef, Pungume, Kwale, Kizimkazi, Ukombe reef, and Komonda. Line transect, manta tow and SCUBA diving were used in the survey. The results show high percentage of hard coral cover within the area; high levels of damage to coral reefs in all sites and smothering by brown algae as a consequence of dying coral; extensive damage from the coral bleaching event of 1998. At present, low recovery, over-harvesting of reef fish and reef invertebrates are the obvious threats to the reef communities. Establishment of no take zones in critical sites like Kwale west, Pungume sand bank, Pungume west, Kizimkazi reef and Ukombe reef is important for the well being of the Bay. Establishment of mooring buoys for tourist boat instead of anchoring can reduce anchor damages. Environmental education for fishermen and other users of marine resources can also reduce human induced degradation. It is also proposed that coral reef monitoring should be conducted annually to sea changes over time and help in management decision.

The Status of Coral Reefs of Samoa: 2004Joyce SAMUELU*, Anama SOLOFA, Antonio MULIPOLA, Nofoaiga TAUSA

Apia Park, Samoa American Samoa

joylarkam10s@yahoo.com

Coral reefs are slowly but surely degrading due to the huge dependency of the Samoan people for their livelihood everyday. The evolution of technology and also the increase of population have produced all sorts of problems to the coastal environment and especially the coral reefs. Coral reef monitoring has become an important role by the Fisheries Division since 1997. The Fisheries Division has undertaken conservation and management efforts with the establishment of Marine Protected Areas (MPAs) in local communities and having them actively involve in the management and monitoring. The joining of Samoa into the Global Coral Reef Monitoring Network (GCRMN) further addresses the intention of our Government to enforce on our coral reef management and monitoring. Currently, 57 communities have established MPAs under the Fisheries Extension Programs and also 10 permanent sites for the GCRMN. The outcomes of monitoring from the January-November 2003 time period show an overall dominance of the live corals together with the abundance and diversify population of fish and invertebrates. All Islands of Samoa were hit by the latest cyclone Heta (2004) and overall damages show an average of 30%. More over there are ongoing anthropogenic activities that still pose threats to the Coral reefs ecosystems. The local staffs have been train in the Australian Institute of Marine Science on monitoring methodology but still a need for more trained marine biologists, taxonomist's ecologists and managers to compliment conservation and monitoring efforts.

Status of Fishery Target Species on Coral Reefs of the Marianas ArchipelagoRobert E SCHROEDER*, Michael S TRIANNI, Kate A MOOTS, Brian J ZGLICZYNSKI, Joseph L LAUGHLIN, Brent R TIBBETTS, Mark K CAPONE

NOAA Fisheries, PIFSC, Kewalo Research Facility, Coral Reef Ecosystem Division, 1125B Ala Moana Blvd. Honolulu, HI 96814 United States of America

Robert.Schroeder@noaa.gov

Large coral reef fish were surveyed throughout the Marianas Archipelago in August-September 2003 to assess their status as fishery targets. Three underwater visual survey methods were used: belt transect (for fish >20cm TL), stationary point count (for fish >25cm), and towboard count (for fish >50cm). Fish sizes were estimated and numerical and biomass densities quantified at 14 islands and 6 shoals. Coincident habitat data were also collected. In general, all three survey methods indicated that large fish (all taxa pooled) occurred in relatively higher densities around the northernmost islands of the archipelago (e.g., Uracas, Maug, Asuncion). Similar trends held for sharks, jacks, and snappers, considered independently. In contrast, large fish densities were generally lowest at the southernmost islands/shoal (e.g., Saipan, Tinian, Aguijan, Rota, Guam, Santa Rosa), with a few exceptions (e.g., moderate-high densities of parrotfishes, wrasses and/or emperors, at Rota, Tinian and/or Aguijan). Along the western chain of shoals (e.g., Stingray, Pathfinder, Arakane), sharks, groupers, and jacks had high densities. At most Marianas reefs, total large fish densities were lower than those found at some other U.S. island chains (e.g., the Northwestern Hawaiian Islands and the U.S. Line Islands). A few surveys from the mid-1990s have indicated that fishing pressure in the northern Marianas islands is much less than around the inhabited islands of the south. However, since then there have been an estimated 50-100/yr large vessel fishing trips to the north and few venturing to the western shoals. Anecdotal information suggests that large target species were more abundant in the northern islands 6-8 yr ago than what these surveys found. Based on various intelligence sources, the USCG believes there are ~30-45/yr encroachments by foreign fishing vessels into the Marianas EEZ, but surveillance effort is currently insufficient to document any direct poaching activity

Northern Persian Gulf Coral Reefs Status and their Changes from 1990 to 2001 Using Remotely Sensed Satellite Images (TM and ETM) and Under Water SurveyOmid SEDIGHI, Hamzeh VALAVI, M MORADI, M R VARASTEHE, A SAFFARIAN*187, Nejatollahi Ave., 15187., P.O. Box 5181., Tehran Islamic Republic of Iran
osedighi@hotmail.com

In this study the distribution of coral reefs and their areas in the northern Persian Gulf (from Strait of Hormuz to the northern part, Khark and Kharkoo Islands) were studied. The Landsat- 5 TM and Landsat- 7 ETM data path (images) covering study area on 1987-1990 and 2001 respectively were used. Geometric and radiometric correction, evaluation of proposed model and accuracy estimation was carried out. The overall accuracy of classified coral map is equal to 89.85%. The biggest and best-developed coral areas were found around Kharkoo Island with approx. area of 310 ha in 1990 decreased to 266 ha in 2001, followed by Khark Island With 250 ha in 1990 decreased to 188 ha in 2001 and Nayband bay with area of 181 ha of coral reef in 2001. The smallest area of coral reefs were also found around Bani-farour and Abu-Musa Islands with a 2.5 ha and 11 ha of coral coverage in 2001, respectively. Change detection survey by comparing two periods of 1990 and 2001 showed significant decrease of coral reefs in many parts of the northern Persian Gulf. The field under water survey indicated that best-developed coral reef coverage are located at Kharkoo followed by Nayband bay and Khark, which approve remotely sensed images results. The highest live coral coverage was 32% at Kharkoo Island and lowest in Kish Island with 10% while the highest diversity was found in Kish Island. The most abundant frequently occurred family with highest coverage was Poritidae. Despite recent growth and development of Acropora in shallow waters of Kish Island and some other parts, its high coverage and abundance has been decreased to minimum in shallow waters of many fringing Islands caused by anthropogenic and natural impacts and stresses.

The Qatar Coral Reef*Saif SHANDHOUR**

P.O. Box 7634., Doha State of Qatar

alali@mmaa.gov.qa

Qatar is a peninsula situated in the middle of the western coast of the Arabian Gulf. It covers more than 11,000 km² which includes a number of islands. It has a very long coastline extending over 700 km - approximately 23% of the total Gulf Coastline. The capital and most prominent city of Qatar is Doha, located on the middle of the Eastern coast of the country. In addition to Doha, there are also many small cities that outline the Qatari coast, e.g. Al-Khor, RasLafan, Al-Wakra, Umm Saeed. Generally, the peninsula has a flat desert landscape, except certain parts of it on the Western coast, which contain hills and valleys. Sabkhas (salt marsh) sand dunes and mangroves can be found as well. Tourists tend to be attracted to sand dunes due to the beauty of their nature. Also, they are keen to visit the coral reef. The coral reef can be found in several parts of the coast including some islands. In 1998 the rise in water temperature in the Arabian Gulf caused many parts of the reef to die off. At present, there are regulations to protect and maintain the reef and what it contains. The Supreme Council for Environment and Natural Reserves, Coast Guard and the Fisheries Dept are all responsible for enforcing these regulations. In the near future The Supreme Council for Environment and Natural Reserves, plans to launch a project for the purpose of monitoring the Coral Reef in all Qatari water.

The Coral Reefs of Cambodia: Present State of Information and Management Capacity*Kim SOUR*, L M CHOU, K P P TUN*

186 Norodom Blvd., P.O. Box 582, Phnom Penh, Cambodia Kingdom of Cambodia

catfish@camnet.com.kh

much is known about Cambodia's coral reefs because of a lack of research capacity. Coral reef sites have not been completely identified although they are distributed in various localities, generally associated with offshore islands and rocky beds. Diversity studies to date indicate 111 hard coral species, 6 soft coral species and 9 species of sponges and seaweeds. Recent surveys of coral reefs in the Koh Sdach islands showed live coral cover ranging from 4 to 72% with the poorer reefs showing signs of bleaching impact. The reefs are exposed to anthropogenic pressures including coastal development, coral collecting and destructive fishing. There is a general lack of public awareness on the significance of coral reefs. Additionally, the absence of policies and laws relevant to coral reef management, coupled with the lack of enforcement all point to an urgent need to enhance management and research capacity. In recent years, this capacity has slowly expanded through the facilitation of bilateral and regional initiatives.

The Impacts of Climate Change on Cosmoledo Atoll, Southern Seychelles*David SOUTER*, Olof LINDEN, David OBURA, Rolph PAYET, Matthew RICHMOND, Charles SHEPPARD, Dan WILHELMSSON*

391 82 Kalmar Kingdom of Sweden

david.souter@cordio.org

Coral and fish populations were surveyed at several permanent sites at Cosmoledo Atoll in the southern Seychelles to determine their status and monitor future changes. Mortality of coral in the lagoon and on seaward slopes was severe to a depth of 10 m with only a few *Porites* colonies surviving. Beyond 10 m, survival was greater. Deeper reef slopes supported 20-25% live coral cover. Coral diversity was high with 120 species from 15 families and 45 genera recorded. The most speciose genera were *Acropora*, *Montipora*, *Favites* and *Porites*. *Favia*, *Fungia*, *Pavona*, *Millepora*, *Alveopora*, and *Goniopora* were poorly represented. The average number of coral recruits ranged between 5 and 6.7 m² on the slope and 6.8 m² in the lagoon. On reef slopes, recruitment was higher at 20 m than 10 m. Faviids were most common at 20 m, while pocilloporids dominated at 10 m. The species composition of recruits differed from the pre-bleaching adult community. In the lagoon, *Porites* and *Fungia* recruits were most common while previously dominant acroporids were rare. The large reservoir of surviving adult corals at depth seems to be assisting recovery but a shift in species composition is underway. The prognosis for Cosmoledo's reefs is good, provided further warming does not kill colonies surviving at depth. More than 200 species of fish were recorded. Acanthurids were common, large and medium sized serranids were recorded at all sites and lutjanids and lethrinids were frequently sighted. Obligate corallivores *Chaetodon trifascialis* and *Chaetodon trifasciatus* were rare even at depths where coral cover was greater. Not a single shark was sighted. Temperature loggers were deployed at 4 sites to determine flow and residence time of warm water masses in the lagoon and on the reef slopes to examine vulnerability of different coral communities to climatic changes.

Status and Management of Coral Reefs in Indonesia*Suharsono SUHARSONO**

Jl. Raden Saleh No. 43 Jakarta 10330 Republic of Indonesia

shar@indo.net.id, harsono@coremap.or.id

The coral reefs of Indonesia especially in the central and east regions are the most diverse in the world, with 82 genera and 590 species of corals. The Indonesian archipelago contains the greatest recorded diversity for the genus of *Acropora* (91 species) worldwide. The world highest diversity *Acropora* for a single restricted locality *Acropora* (78 species) was recorded at Togian Islands (178 species), central Sulawesi, while Raja Ampat Islands had the highest coral diversity ever recorded (456 species). Results of the monitoring from 57 different localities throughout Indonesia show that 31% of coral reefs are classified as being in poor condition and 32% in excellent and good condition. Several areas show that coral reefs are improving, while other locations become worse. Anthropogenic threats are severe including runoff and sediments from land based activities, destructive fishing practice. Blast fishing in the main caused coral mortality. The Indonesian government has launched a coral reef rehabilitation and management program in order to manage coral reefs since 1999. The results of these programs are increasing the awareness of the coastal communities. A policy and strategy to manage and protect coral reefs has been set up. A manual for data base, monitoring, and information system established. There have been more than 15 provincial and district regulations established and the law enforcement has been implemented and destructive fishing practice has been significantly reduced. Establishment of village community groups for implementing alternative income generating activities using a village grant, there has been more than 74 different topics of training with more than 12,000 people trained to manage coral reef in effective way.

Diversity and Status of Alcyonacean Fauna in Nallathanni Island, Gulf of Mannar Marine National Park, India

*Chellasamy SURESHKUMAR**, *Krishnamoorthy VENKATARAMAN*
130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
dugong@md2.vsnl.net.in

Nallathanni is one of the island of Keelakarai group in Gulf of Mannar National Park. Soft corals come under the Phylum Coenterata, Class Anthozoa and Order Alcyonacea. It is second largest group of organisms in the coral reef environment and play significant role in the coral reef ecology, provide food and shelter to other coral reef animals. The species richness and the abundance of the Alcyonacean fauna were well known from the earlier reports. Very few studies were conducted in Gulf of Mannar coral reef environment about soft corals. The present study was conducted in Nallathanni island of Gulf of Mannar Biosphere Reserve. The diversity of Alcyonacean fauna in the present study in Nallathanni Island shows the occurrence of 7 species under 2 genera and one family. The species such as, *Lobophytum crassum*, *Lobophytum latilobatum*, *Sarcophyton glaucum* and *Sarcophyton crassocauleis* abundant in this island. Status survey of Alcyonacean fauna in Nallathanni islands was conducted from the shoreline to back reefs using Line Intercept Transect method. The status survey results show 12 % occurrence of Alcyonacean fauna in the Nallathanni Island.

Coral Reefs of Vietnam: Recent Status and Conservative Perspectives

Vo S TUAN, *Hoang X BEN*, *Nguyen V LONG**, *Phan K HOANG*
01 Cau Da, Nha Trang city, Vietnam
thuysinh@dng.vnn.vn

The surveys during 2002 - 2003 provided more information to confirm high biodiversity of coral reefs in Vietnam with the records more than 300 reef building coral species in some areas in the south coastal waters. The results of coral reef monitoring at 10 sites, however, showed a negative figure of coral reef status. Data obtained by Reef Check and AIMS techniques presented the dominance of reefs with poor and fair conditions of coral cover (18% and 30% respectively at 48 monitored reefs). Abundance of invertebrate and fish indicators also showed poverty of reef economical organisms. Positive figure was only recorded at some reefs in Ninh Thuan, Phu Quoc, Nam Du. As presenting in previous status report, main threats to coral reefs included over-catching and destructive fishing... Moreover, there were some abnormal phenomena happening during 2002 - 2003. Meanwhile coral bleaching did not occur extensively as in 1998, there was the serious outbreak of Crown of thorn starfish in Khanh Hoa coastal waters. Environment risk caused by algae bloom killed almost coral reefs in Ca Na bay and the recovery is occurring slowly after the event. Sedimentation is continuously considered as a strong impact in Ha Long - Cat Ba islands with extensive threats to coral reefs. Recently, Vietnam government and oversea agencies have supported to develop a network of marine protected areas. Preliminary results of Hon Mun pilot marine protected project and initial activities of some new National Parks are creating perspective to manage MPAs with coral reefs as a target ecosystem. Local governments at number of sites are encouraging to build different models suitable to their practices in coral reef management and wise use. National action plan for coral reef management is also developing in the framework of UNEP GEF / SCS project and will be approved by authorization.

How Much Reef Check Survey Method Is Important for India?

*Krishnamoorthy VENKATARAMAN**
130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
dugong@md2.vsnl.net.in

Coral reefs are one of the most ancient, important, rich and dynamic ecosystems of India. They not only provide a sanctuary to a myriad of marine life but also play a key role in protecting the coastline from erosion. In addition, people living along the 8000 km long coastal stretch depend on coral reefs for their livelihood. The total area of coral reefs in India is estimated at 2,375 sq km. Unfortunately these are also some of the most threatened and little known coral reefs of the Indian Ocean. There are 208+ species of hard corals have been reported so far within four major coral reefs of India viz. Gulf of Mannar and Kachchh, Lakshadweep and Andaman and Nicobar Islands, and as research continues, many more are expected to be discovered in the coming years. So far, only scientists were conducting the status surveys on coral reefs. There is very little participation of volunteers to conduct surveys. Reasons may be due to very little awareness created among the general public, lack of willingness and motivation due to various reasons and duplication of scientific works. Conservation of coral reefs are not given the top priority. Many scientific training programmes are only directed towards the scientific community. Remedial measures such as the capacity building and awareness programmes directed towards the common public as well as the policy makers should be the top priority. This may form the basis for conservation of coral reefs as well as the resources associated in the country. The reasons why simple methods such as Reef Check (RC) for status survey is necessary for India, the level of international support needed to introduce and conduct the surveys with NGOs and public are discussed in this paper.

Status of Coral Reefs of Gulf of Mannar Biosphere Reserve, India

*Krishnamoorthy VENKATARAMAN**, *Jayakumar Balagurunathan ALFRED*
130, SANTHOME HIGH ROAD CHENNAI, 600 028 INDIA
dugong@md2.vsnl.net.in

The Gulf of Mannar Biosphere Reserve (GoMBR) was established in 1989 and it encompasses 21 coastal islands located between 8°49' to 9° 15' N latitude and 78°11' to 79° 15' E longitude on the southeast coast of India. It is one of the richest coastal regions in India. A total of 82 species of corals belonging to 27 genera and 13 families have been reported from this area and the coral reefs are mostly of fringing type. During 2001 to 2003, Line Intercept Transect surveys had been conducted in all the 21 islands to estimate the present status of the coral reefs of this region. For the purpose of the survey GoMBR was divided into three island groups such as Mandapam, Keelakarai and Tuticorin, each group consisting of seven islands. The overall percentage of coral life forms amounted to 43.3% live coral; 44% dead coral and 11.3 % sand. Among the three groups of islands, Keelakarai had a higher percentage of live coral cover (49%) than the other two groups Mandapam (46%) and Tuticorin group (35%). The reason for the dominance of massive corals over the other groups in GoMBR may be explained by the 1998-bleaching event. During the March 2003 a mild bleaching was noticed and the coral bleached recovered from the effect. The fragile and sensitive branching coral was the most affected life form group as a result of bleaching in this region is slowly recovering in all the island groups. The recovery of corals from the 1998 bleaching and the changes in the status of the live coral cover in the GoMBR, level of threat to coral reefs, other major developments on the capacity to conduct the studies, conservation and management measures taken by the government, the status of the associated fauna are discussed.

Status of Coral Reefs in New Caledonia in 2004

Laurent WANTIEZ*, Francois DEVINCK, Claire GARRIGUE, Sabrina VIRLY
BP 4477, 98847 Noumea cedex New Caledonia
wantiez@univ-nc.nc

A monitoring initiative was launched in 1997, using Reef Check methods adapted to the local context. This program contributes to the Reef Check network. The study area was limited to the Southern Province of New Caledonia, which funded the program. Surveys were completed in 1997, 1998, and 2001. In 2003 IFRECOR (French Initiative for Coral Reefs) funded a new phase of the program for 3 years, and the sampling zone has been extended to all New Caledonia reefs. The monitoring is now conducted by local communities, NGO and volunteers. Two facilitators have been employed to reinforce capacities and willingness for monitoring on a long-term basis, as resource persons for training and data processing. The analysis of the data collected in 2003 is not finished yet. This abstract will be updated when the analysis is completed. The results presented at the present state of knowledge concerned only the South Lagoon Marine Park. Inside the marine protected areas of the Park butterflyfishes and commercial fishes (groupers, parrotfishes, surgeonfishes and rabbitfishes) were present and common. Fish densities remained relatively stable over the years with the exception of irregular grouper and rabbitfish aggregations, which were not always recorded. Commercial invertebrates (giant clams, trochus, sea cucumbers) were also common inside the protected areas, and crown-of-thorns were recorded in some locations. The density of these invertebrates remained relatively stable since 1997. A significant decrease in coral cover was recorded on some stations since 1997. These modifications were attributed to spatially limited crown-of-thorn outbreaks in 2000 and 2001. On the other stations, after a decrease recorded in 1998, coral cover remained stable or increased notably. These results indicated that the status of New Caledonian coral reefs was satisfactory in 2001 in the South Lagoon Marine Park.

Status of the Coral Reefs of the Semporna Islands (Sabah, Malaysia) and Development of an Interactive Map-based Information System for Management Purposes

Elizabeth M WOOD*, Andrew N DAVIES, Frances DIPPER
Hollybush, Chequers Lane, Eversley, Hook, Hants, RG27 0NY United Kingdom of Great Britain and Northern Ireland
ewood@globalnet.co.uk

The Semporna Islands are situated on the fringes of the Philippines-Indonesia-Papua New Guinea triangle which is acknowledged as having the highest diversity of marine species throughout the Indo-Pacific. The Semporna Island reefs are very varied in their structural diversity, include a wide range of habitats and exhibit high species diversity. The area is of significant biological and economic value, but is faced with a number of problems. The main impacts are from over-exploitation of reef resources, fish blasting, cyanide fishing and predation by crown-of-thorns starfish. There has also been some damage from coral bleaching and pollution. The 350 sq km area, including over 100km of reef front, is scheduled to become a Marine Park and a management plan has been prepared. Large amounts of data have been collected over the past 5 years, and it is vital that this information is readily available so that the area can be effectively managed. A map-based, electronic information and planning system has been developed, the aim of which is to provide a logical and organised system in which biological, physical, socio-economic and other features of the area are stored and linked together. The system can be easily interrogated and updated, and will help to inform and guide managers. The information system includes the following: a) Details of survey and monitoring sites, with summary information on reef profiles and features, b) type and distribution of reef biotopes (habitats and their associated communities of species), c) distribution and abundance of key species, d) resource use and socio-economic data, e) evaluation of reef sites based on criteria including biodiversity, rarity (species, communities or habitats), f) existing or potential value (extractive and non-extractive uses) impacts and overall health, g) Management needs and goals.

Status of Coral Reefs in Thailand

Thamasak YEEMIN*
Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240 Kingdom of Thailand
thamasakyeemin@hotmail.com

There are an estimated 153 km² of coral reefs along the total coastline of 2,614 km and around 300 islands in Thai waters. These are classified in 4 distinct areas with different oceanographic conditions: the inner part of the Gulf of Thailand; the east coast of the Gulf of Thailand; the west coast of the Gulf of Thailand; and along the coastline of the Andaman Sea. Three reef types can be recognized: coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs. Several comprehensive reef survey programs covering over 400 sites in the Gulf of Thailand and the Andaman Sea were carried out by governmental institutions and private agencies. In general, most reefs were rated good, fair or poor. Relatively small areas were classified as excellent or very poor. Monitoring of reef fish was less extensive and needed more effort in order to provide clear patterns and trends. The first extensive coral bleaching phenomenon in the Gulf of Thailand occurred in April-June 1998 and was the major cause of coral reef degradation. The mild coral bleaching in 2003 was also clearly observed in the Gulf of Thailand and the Andaman Sea. Adaptation to bleaching of several coral species was evident. Continued studies on coral recruitment are required to predict recovery potential. The reefs support a variety of human activities, especially tourism and fisheries-related uses. Tourism activities, sedimentation and wastewater pollution associated with rapid coastal development are recent and increasing severe problems for the next decade. Marine National Parks will play a major role for coral reef management and conservation.

Coral Reef Monitoring for Management in Central Sulawesi, Indonesia. Summary of Results 2000-2003

Sofyan A YOTOLEMBAH*, Abigail M MOORE, Samliok NDOBE, Harto DARWINTO
JI Tendean No 7, Palu 94111, Central Sulawesi Republic of Indonesia
abigailt@plasa.com

Yayasan Adi Citra Lestari (YACL) is a local NGO based in Palu, Central Sulawesi, a Province with over 2000 km of coastline and many small islands, most fringed by coral reefs, with numerous barrier reefs and atolls. In 2000, when YACL was a local partner in Reefs at Risk SE Asia, there was little or no data for most reefs, and no locally based monitoring capacity. YACL initiated a capacity building programme for coral reef monitoring, including training in SCUBA and GCRMN methods (Manta Tow, Reef Check and LIT). Supported by The David & Lucille Packard Foundation, UNEP EAS/RCU, NOAA, PADI Project AWARE and the Reef Check Foundation, the result is a committed survey team recruited from the local community. Data has been collected and submitted to local, national and international stakeholders. A summary of data collected over the period 2000-2003 is displayed, in map and graphic formats together with examples of data application. The data show: (i) most reefs in average to poor condition, (ii) threats increasing in most areas, (iii) most reefs capable of natural recovery if destructive actions cease, (iv) regional variations in both natural conditions and major threats. Time-series data from fourteen permanent transects installed at four long-term monitoring sites is presented: two protected areas with marine components, Pulau Pasoso Provincial level Game Reserve and Tanjung Api Strict Nature Reserve; Palu Bay (YACL base and main training area); and Labuana (community awareness programme including ecotourism). Major changes are highlighted, together with likely causes. Base-line survey data for Tete B (a control area for Tanjung Api Reserve) and locations where data was required for planning purposes in collaboration with other projects and organisations is summarised, and regional variations highlighted.

Status of Coral Reefs of Southwest Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands Tuvalu & Vanuatu in June 2004

*Reuben SULLU**

Laucala Bay Road, Suva, Republic of Fiji

sulu_r@usp.ac.fj

Significant efforts are underway in the Southwest Pacific GCRMN node to mitigate current threats to coral reefs. This paper provides a snap shot of the status of coral reefs in these countries as at June 2004 and a summary of the initiatives undertaken by various communities, governments, organisations and agencies to protect and conserve coral reefs.

Status of Coral Reefs in Micronesia

*Jason KUARTEI**

PO Box 1811 Republic of Palau

jkuartei@yahoo.com

The US Affiliated and Freely Associated islands of the tropical Pacific include American Samoa and the islands of Micronesia (excluding Kiribati). Most lie north of the equator, except American Samoa, which is considered part of Polynesia, but has the high coral diversity and cultural dependence on coral reefs similar to Micronesia. Micronesia is made up of a group of small tropical islands and atolls in the central and Indo-west pacific, and encompasses an area of approximately 11.6 million km². The vast majority of their area is ocean, with a landmass just over 3000km². From east to west, the US affiliated and Freely Associated states include: American Samoa, the Republic of the Marshall Islands, the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, Guam, and the Republic of Palau. As a region, Micronesia possesses a high diversity of corals and associated organisms and the human population is heavily dependent on coral reefs and related resources both economically and culturally. The coral reefs of American Samoa and Micronesia range in condition from nearly pristine to seriously damaged by human disturbance and climate change. The human impacts include overfishing, ship groundings, sedimentation and coastal pollution. In the past, human impacts were largely related to the size of the resident populations, however fishing fleets from other nations have taken their toll on even the most remote islands and atolls. Micronesia is a highly rated scuba diving destination and rapid tourism development including new roads, hotels, golf courses and personal watercraft, is having substantial effect on coastal reefs on some islands. In the last two years, there have been monitoring activities in the islands north of CNMI by the National Oceanic and Atmospheric Association (NOAA) and new information is now being collected for this area.

Regional Coral Reef Monitoring Program and Status Report in the South East Pacific Countries, GCRMN Polynesia Mana Node

Caroline VIEUX, Dave FISK, Peter PETELO, Taratau KIRATA, Brendon PASISI, Antoine NIA, Annie AUBANEL, Mary POWER, Bernard SALVAT*

B.P. 1013, Moorea, French Polynesia

criobe@mail.pf

The Cook islands, French Polynesia, Kiribati, Niue, Tokelau, Tonga and Wallis and Futuna progress in order to assess coral reef health and exploitation on a regional basis (Polynesia mana node). The 7 independent or autonomous countries or territories including 347 islands with coral reefs are half a million inhabitants whose 80% are concentrated in 7 islands urban centers. Monitorings programmes are effective or on the way in French Polynesia, Wallis and Futuna, Cook islands, Tonga and Tokelau and will be developed in other islands. A major bleaching event occurred in 2002 with up to 50% coral mortality in Tokelau but minor one in French Polynesia. This bleaching has also been reported in Kiribati in the Tarawa lagoon but its extent is unknown. In Tokelau, overfishing has depleted most of the lagoon and slope areas in reef fishes and giant clams. Touristic development in Kiribati (Christmas Island) and land reclamation for building in Tarawa are a threat for reef health in Kiribati and are to be monitored. Niue has been struck by the cyclone Heta early this year and 90% of the corals have been devastated on the west coast. Rarotonga (Cook) is facing a COT outbreak affecting hard corals. Marine protected areas are planned in many islands of the Polynesia mana node and reef monitoring will be developed in these areas. Only French Polynesia has taken part to the Reef Check program in the node with 13 sites monitored in Bora-Bora and Moorea. The GCRMN node Polynesia mana, South East Pacific, plan to set up a regional database under coordination and/or cooperation with the South West Pacific node (University of South Pacific coordination), the South Pacific Regional Environment Programme (SPREP), The International Coral Reef Action Network (ICRAN, ICRI) and Reefbase of the World Fish Center (WFC).

Consolidation of the STA-GCRMN Regional Node and Status of Coral Reefs in Southern Tropical America

Jaime GARZON-FERREIRA, Jorge CORTES, Aldo CROQUER, Hector GUZMAN, Zelinda LEAO, Alberto RODRIGUEZ-RAMIREZ*

Cerro de Punta Betin, Zona Portuaria, Santa Marta Republic of Colombia

jgarzon@invemar.org.co

Since 1999 five countries (Brazil, Colombia, Costa Rica, Panama and Venezuela) are cooperating for developing coral reef monitoring in Southern Tropical America (STA) under the framework of GCRMN, the support of UNEP-CAR/RCU and the coordination of the Institute for Marine and Coastal Research (INVEMAR, Colombia). Several actions have been carried out that have conducted to the consolidation of the STA Node: (1) a study of the capacity and needs for reef monitoring; (2) establishment of formal agreements between INVEMAR and the other institutions; (3) support of monitoring activities during 2000, 2002 and 2003; (4) expansion of monitoring programs in all countries; (5) preparation of regional reef status reports and contribution to the global reports published in 2000 and 2002; and (6) production of a strategic plan (2004-2013) and a 5-years project proposal. The STA region includes reefs in Pacific, Caribbean and Atlantic waters, and most of them are strongly influenced by continental runoff. There has been major damage to coral reefs of this region in the last 35 years that has been caused by a mix of natural agents and direct human impacts. Nevertheless, significant coral cover can still be found at several reef locations of both Caribbean and Pacific coasts. Monitoring data suggest that reefs of the STA region have not undergone noticeable changes or damages during the last two years (2002-2003). Live coral cover in the Caribbean averaged between 1.4% (Playa Caiman) and 50.3% (Cayo Norte) in Venezuela, between 18% (San Andres) and 41% (Uraba) in Colombia and between 8% (Manzanillo) and 26% (Cahuita) in Costa Rica. Pacific reefs showed both low and high levels of coral cover, ranging between 57% (Utria) and 75% (Gorgona) in Colombia, between 6% (Coco) and 8% (Ballena) in Costa Rica, and between 2% (Canal de Afuera) and 54% (Iguana) in Panama.

Report on the Activities of the GCRMN Northern Caribbean and Atlantic (NCA) Node in 2003

Dulcie M LINTON, *Loureene A JONES**, Peter E EDWARDS

Mona, Kingston 7, Jamaica,
dulcie.linton@uwimona.edu.jm

Through funding from the ICRAN project (UNEP-CEP) the CCDC has been actively encouraging greater coral monitoring and reporting among node countries. A survey of institutions identified financial and human resource limitations as the main constraints to sustained monitoring. A draft document for sustaining the node over a five-year period has been produced. The CCDC spearheaded the formation of the Jamaica Coral Reef Monitoring Network (JCRMN) on June 27, 2003. Seventeen individuals, representing 12 organizations agreed on the development of an organized approach to monitoring of coral reefs in Jamaica, with south coast reefs as priority. Reef Check training and data collection workshops were conducted during September and November in Negril and in Port Royal, Jamaica. Approximately 30 individuals representing a number of different institutions and organizations participated. A similar Reef Check training and data collection workshop was held in Haiti. Data from these surveys have been submitted to Reef Check and preliminary reports produced. JCRMN activities climaxed with a survey of the reefs of Portland Bight Protected Area, Jamaica. Twenty-five participants collected data from 6 reef sites during a 4-day exercise from December 4-7, 2003. This initial survey will be followed up in 2004 with more detailed surveys of these reef sites as well as of others in Jamaica and other node countries. Project funding is being sought to continue activities in node countries such as Haiti, the Dominican Republic, the Turks and Caicos islands, where coral reef monitoring data is scarce. Additionally, if funding is available, it is envisaged that a workshop of NCA node participants will be conducted in 2004 to allow sharing on best practices in coral reef monitoring and to encourage collaboration and agreement on building capacity to monitor reefs within node countries.

Status of Coral Reefs in the Red Sea

Moshira HASSAN*, Georg A HEISS, Mohammed M A KOTB

The American University in Cairo, Biology Dept., Cairo 11511 Arab Republic of Egypt
moshira@reefcheck.de

The status of coral reefs bordering the Red Sea and Gulf of Aden is generally good, with live hard coral cover averaging 20-50%. However, data show recent decreases in live coral cover. The highest average live hard coral cover was recorded in Yemen (53%), despite the poor development of reefs, compared to more complex reefs in the Central and Northern Red Sea. Edible sea cucumbers are currently being fished in most countries (legally as well as illegally) for export to Southeast Asia. Density reached from almost zero in Egypt and Sudan up to 3 individuals per 100m² in Yemen. Fish populations have declined slightly and several outbreaks of COTS were reported. Some local bleaching events and an increase in bioeroding organisms such as the urchin *Diadema setosum* and the coral eating gastropods *Drupella* sp. and *Coralliophila* sp. have been reported from several areas. Some of the most damaged reefs were seen in Yemen and Djibouti in the Southern Red Sea. The highest numbers of butterfly fish were found on Egyptian Red Sea reefs (>8/100m²). In general, the Red Sea shows comparatively low levels of human impact, as most of the coastline is sparsely populated. Threats to coral reefs differ within the region, and are continuously increasing with the increasing rate of coastal development. The impacts are most obvious around the larger ports and major tourist resorts. The major threats are land filling, dredging, sedimentation, sewage discharge and effluents from desalination plants. In tourism areas, there is physical damage by tourists and boat anchors as well as other impacts related to urbanization. Fishing pressure is constantly increasing throughout the region to satisfy demands of growing and more affluent populations. Deterioration was also found away from coastal developments, where it is probable that COTS and other natural disturbances have damaged the reefs.

Status of Coral Reefs in Iranian Coastal Area

A. MAGHSOUDLOU, P. EGHTESEADI*

No.9., Etemaadzadeh St., Fatemi Ave., Tehran, 1411813389 Islamic Republic of Iran
eghtesadi@inco.ac.ir; Wahab@inco.ac.ir

Persian Gulf is one of the most extreme environments for coral growth with an impoverished reef biodiversity compared to Indian Ocean. Coral reefs in the Iranian coastal waters are found around 16 islands from the northwest to the southeast and also some limited areas around Nayband Bay. The islands located near the Straits of Hormuz are influenced by less saline, nutrient-rich upwelled waters of the Gulf of Oman. The Inner Islands tolerate the most saline conditions and coral communities growing around these islands are mainly in shallow waters and protected areas. In this report, general patterns of coral distribution as well as the health status of them with emphasis on results of INCO's current yearly monitoring will be discussed. The coral types characteristic along much of the Iranian coasts are fringing reefs although some patchy corals are found in some of the more sheltered bays in the Gulf of Oman. According to available data the Khark and Kharku and Larak islands have a relatively high coral coverage. There are about 30 species of hard coral in this region, avidiidae with 6 genera and 8 species is most diverse, and Acroporidae is the most abundant among scleractinian coral. During the El Nino of 1998 mass mortality had occurred in coral species particularly in the Kish Island. Fortunately, recovery through coral growth has already started at Kish Island mainly for Acropora species, which were damaged during the above phenomenon. A moderate state Yellow-Band Disease was observed for the first time at Farur Island in the year 1995. In the following year, a low incidence of the disease was also observed in Kish Island. Among other natural impacts, *Acanthaster planci* had some little effects on coral, particularly in Larak and Lesser Tonb Islands. Key words: Coral Reefs, Iran, Status,

Status of Coral Reefs in East and North Asia (China, Taiwan, Korea and Japan)

Tadashi KIMURA*, Put O ANG, Chang-Feng DAI, Huang HUI, Jong-Geel JE
3-10-10 Shitaya, Taito, Tokyo 110-8676 Japan
tkimura@jwrc.or.jp

China, Korea and Japan belonging East and North Asian are located at the north edge of coral distribution of Pacific. Because of connectivity with the Philippines by the flow of the Kuroshio Current, coral diversity is quite high in Japan. On the contrary, there are patchy distribution of coral communities along China and Korea where some branch flows from Kuroshio Current. Coral reefs well develop from Nansha Island to Hainan in the South China Sea. Coral reefs also develop along the southern coast of Taiwan comparing with northern coast, which has patchy coral communities. In the north of this region, soft corals are dominant with a few stony coral species around the Jeju Island at southern coast of Korea.

Major threats on Japanese corals are crown-of-thorns starfish, bleaching, *Drupella*, and soil runoff from land. A large number of corals were killed by sedimentation after heavy rain in 2001 and the starfish is increasing in number since 2000. China and Korea also have serious disturbances of environment by marine tourism and coastal development. Destructive fishing practice and soil runoff are major causes of coral disturbance in Hainan Island and Taiwan. Coral destruction by tourists is another threat in Hainan Island and Korea.

Against these threats, China, Korea and Japan begin to grapple with the integrated coastal environment conservation including coral ecosystem. Moreover, paying attention to marine protected area, that number is increased gradually to use it as an important tool for the coastal management in China, Taiwan and Korea. For exchange of own experiences and information, cooperation among the countries of this region is being expected to be made more active with becoming more strong, however, there are still issues remained on establishment of local network system and effective management practice to utilize protected areas in these countries.

Coral Reefs of Southeast Asia: 2004 Status Report

*Karenne P P TUN**, A. CABANBAN, L M CHOU, Sour K PHILREEFS, Vo S T SUHARSONO, T. YEEMIN

PO Box 500, GPO, 10670 Penang, Malaysia

karenne@ecounlimited.com

National reef monitoring programmes continued throughout the region and were maintained at previous levels or expanded. Capacity transfer was increased to countries or provinces to involve them fully in regional reef status assessments. Various bilateral and major regional initiatives in recent years helped to enhance monitoring and management capacity. These include the ICRAN project, which focuses on the transfer of reef management capacity from successful demonstration sites to target sites in need of such capacity in the region. The region's coral reefs continue to face widespread impacts from human activities and are clearly in need of greater management. Monitoring data indicate significant improvements in the condition of reefs under effective management by government agencies or communities. Public education, awareness raising and community involvement remain important activities that contribute positively to reef protection.

Coral Reef Monitoring in the South Western Indian Ocean Islands "COI/GCRMN" Node - Year 2003 Results and First Trends

Lionel BIGOT, Said AHAMADA, Jude BLIJOX, Meera KOONJUL, Tara LYNCH, Jean MAHARAYO, Sabrina MEUNIER, Marylene MOYNE-PICARD, Jean Pascal QUOD*

ARVAM - 14 rue du stade de l'Est - 97490 Ste Clotilde - La Reunion - FRANCE French Southern Territories

bigot.arvam@wanadoo.fr

A regional monitoring network of the GCRMN was set up for the South Western Indian Ocean islands (Comoros, Madagascar, Mauritius, La Reunion and Seychelles) in 1998 coinciding with the circum-tropical mass coral bleaching event. The ongoing 3 years regional project which is financed by the Global Environment Facility (World Bank) and the European Union aim to :- increase coral reef monitoring in the SWIO islands,- strengthen the capacity of national networks to provide data,- advice stakeholders for marine resource management. Principal objective of 2003 annual network report are to recapitulate the annual regional activities linked to reef monitoring. More precisely, it aims to analyse actual coral reef health situation on reference sites and general trends (1998-2003) of coral reef recovery and take stock of the various regional and national actions carried-out by the networks. The number of monitoring stations covered by this project has increased from 43 stations in 1998 to 88 stations in 2003, with more than 20 stations located in Marine Protected Areas. Data (benthos, fish, etc) are processed with a database system called "COREMO II" used by all technical stakeholders. This software is flexible to cater for various methodological protocol (Reef Check, GCRMN, "expert" level) and allow several possibilities (screen consulting, printing of graphics, export data, etc). It has been recognized by Reef Base as a powerful and evolutive tool for monitoring and help decision making. On many sites, first trends show spectacular increase of coral cover recovery, particularly in Comoros (Moheli island). More often, situation is gradual with slow increase (Seychelles, Madagascar), or show a good stability of coral cover (Reunion, Mauritius). Information gathered under this programme is helping Coastal Zone managers to conceive concrete actions in conservation, management and sustainable use of the Indian Ocean reefs.

Status and Management of South Asian Coral Reefs

*Arjan RAJASURIYA**, K VENKATARAMAN, Hussein ZAHIR, J R B ALFRED, M A HAQUE

Crow Island, Mattakkuliya, Colombo 15 Democratic Socialist Republic of Sri Lanka

arjan@nara.ac.lk

Coral reefs in South Asia were severely damaged due to the 1998 coral-bleaching event in the Indian Ocean. Post bleaching recovery of coral reefs has been variable. In the Gulf of Mannar coast of India live coral cover has increased. In the Lakshadweep Islands there is little recovery in the shallow waters and the only appreciable live coral exists below the depth of 20m. There is no evidence of bleaching impact in Andaman and Nicobar Islands. In the Maldives there is better recovery and overall reef condition in the southern atolls with variable recovery in the rest of the country. Widespread bleaching was reported in the Maldives and Gulf of Mannar during April-May 2003; however, quick recovery has been observed with minimal mortality. High rates of recruitment indicate good potential for recovery in the central and southern atolls in the Maldives. In Sri Lanka most inshore coral habitats on the west coast have indicated poor recovery whilst there is good recovery with rapid recolonisation by branching *Acropora* species in the south coast. Recovery is patchy in the Bar Reef Marine Sanctuary in the Gulf of Mannar. Monitoring and management capacity have improved in the region. The Department of Environment and Forests has formed a Gulf of Mannar Trust. Legislation has been improved to protect corals and many other species under the Wildlife Act of India. In the Maldives a protected area system management protocol and an Atoll Ecosystem Management Project has been developed. Several legal instruments with respect to marine and coastal environment has been developed and reviewed. In Sri Lanka, two new Marine National Parks have been declared in 2003 and Special Area Management Programmes at three coral reef areas are being implemented. Status of coral reefs in the region since 2003 and their management are discussed.

Status of Coral Reefs in East Africa, 2004

*David O OBURA**

P.O.BOX 10135, Mombasa Republic of Kenya

dobura@cordio.info

This paper will summarize the findings of biophysical and socio-economic monitoring of coral reefs conducted during 2002-2004, and as reported in national GCRMN reports to be prepared in 2004. East African coral reefs that were severely impacted by the El Nino Southern Oscillation of 1997-98 have subsequently experienced a variety of recovery trajectories, varying from high recovery to further degradation. Surveys in the Songo Songo archipelago of Southern Tanzania in early 2003 revealed reefs that potentially experienced negligible bleaching in 1998, perhaps due to shading by consistently high turbidity levels from the Rufiji River. A moderate bleaching event was documented from central Tanzania to northern Kenya (and in the Seychelles) in early 2003 that resulted in negligible to low mortality. Socio-economic monitoring of coral reefs has been built up in 2002-2003 as a GCRMN activity, involving 4 sites in East Africa, resulting in the development of a manual and methodology to be applied more broadly in the region. New Marine Protected Areas (MPAs) incorporating coral reef areas designated or instituting management in 2002-2004 include: the Quirimbas National Park (Mozambique), Quilalea and xxx reserves (private, Mozambique), and Mnazi Bay-Ruvuma Estuary Marine Park (Tanzania). These and a number of fisheries and community-oriented initiatives, and management effectiveness and capacity building regional programmes are progressively increasing the area of coral reefs brought under management regimes, and increasing local to national capacities to manage coral reefs and threatening resource use patterns. Nonetheless, increasing regional coordination is desirable, as well as expansion of the scope of coral reef conservation and management through collaborative management schemes to attempt to approach the goal set by the World Parks Congress of 30% of marine areas effectively managed by 2010.

CORDIO a Regional Initiative for Monitoring and Research in Central and Western Indian Ocean

*Olof LINDEN**, David OBURA, David SOUTER, Rolph PAYET, Dan WILHELMSSON

PO Box 500, S-201 24 Malmö, Sweden

olof.linden@cordio.org

Elevated water temperatures associated with the 1997/98 El Niño caused widespread bleaching of coral reefs around the world. The reefs of the Central and Western Indian Ocean were severely affected. The CORDIO project was launched in January 1999 in order to assess the impacts of the acute phase of bleaching. CORDIO was initiated as a regional initiative supporting activities in 11 countries. Funding was provided by Sweden, Finland, the Netherlands and WWF. These activities yielded data from several monitoring stations in most of these 11 countries during 1999. In several cases, data from previous years monitoring were also available. Most of the research is carried out by local experts in each country. Follow-up research conducted during 1999 showed that the mortality of corals on reefs along East Africa, Seychelles, Sri Lanka and the Maldives ranged between of 50 to 90 %. CORDIO has since supported long-term studies in most countries of the region. These studies show a mixed picture. In several areas, significant recovery is now underway, while in other areas very little recovery has occurred. Research also shows that the diversity of many reefs has changed significantly since 1998, and that an evolution appears to be taking place. This evolution may result in a shift from reefs dominated by certain groups (such as Acropora) to reefs where other species dominate. Research under the CORDIO project will continue to carry out monitoring activities on reefs in the region where long-term data exist. In addition, CORDIO is becoming more involved in research on other stress factors affecting the survival of coral reefs, and on research related to management of reefs in the context of integrated coastal area management.

Coral Reef Monitoring- Which Methods?

*Jos HILL**

James Cook University, QLD 4811 Australia

jos.hill@jcu.edu.au

Coral reefs around the world are at risk from many threats. Monitoring the ecology of the reefs and socioeconomics of stakeholders is necessary to identify the nature of these threats and feasible solutions. Different management questions require different levels of monitoring intensity, data and detail. No single methodology will address all aspects deemed relevant and there is insufficient advice to help managers decide which methods they should use. Unfortunately lack of standardised protocols for addressing particular questions has led to a proliferation of survey methods, surveyed variables and variable definitions in different regions. This makes comparisons between areas difficult. We review the different methods, the extent of their use and their advantages and limitations and provide advice to managers on the best method to suit their needs.

Reefbase: A Global Information System on Coral Reefs

*Marco NOORDELOOS**, James K OLIVER, Nasir Bin NAYAN, Yusri Bin YUSUF, Moi Khim TAN, Calvin FOO, Dilla Binti Mohd Shukri SHAHRIYAH

PO BOX 500, Bayan Lepas, 11680 Penang Malaysia

m.noordeloos@cgiar.org

ReefBase (<http://www.reefbase.org>) is a global information system on coral reefs, and was developed by the WorldFish Center and the International Coral Reef Action Network (ICRAN). This online database provides quality information on the location, status, threats, and management of coral reefs in nearly 100 coral reef countries and territories. ReefBase serves as the central database for the Global Coral Reef Monitoring Network (GCRMN) and ICRAN, and continues to provide valuable information services to managers, policy makers, researchers, conservationists, educators, and students around the world. Through its central function within the GCRMN and continued collaboration with numerous coral reef organizations, ReefBase is focused on producing the key statistics and data summaries for coral reef status reports on national, regional, and global scales. In addition, ReefBase stores over 20,000 references (many of which can be downloaded), providing access to a wealth of management-relevant publications that are often difficult to access otherwise. ReefBase's online Geographic Information System (GIS), allows for display of a range of coral reef related datasets on interactive maps. With continued development of contents and functionality, ReefBase aims to facilitate informed management of coral reefs, and ultimately benefit poor people in developing countries who depend on these resources for food, income, and livelihoods.

Monitoring for Management Using Reef Check

*Gregor HODGSON**

1362 Hershey Hall, Institute of the Environment, Mailcode 95 1496 United States of America

gregorh@ucla.edu

Even in small countries, the number of individual sites that should be monitored to obtain a reliable estimate of coral reef status is on the order of 30 to 50. In large countries, this number would expand to hundreds of sites and in some cases over 1000. The reality is that few governments have been or will be willing to pay for this level of monitoring using highly detailed monitoring protocols and monitoring teams comprised of coral reef ecologists. This is why many governments around the world have turned to Reef Check, as the lowest cost method of monitoring reefs. The advantages of Reef Check are that the method is now a global standard, is extremely rapid, can be carried out by trained volunteers, and a new website will soon allow on-line, automated comparisons between reefs by time and location. By involving the community in monitoring, Reef Check builds support for government conservation initiatives. More importantly, Reef Check has been shown to be highly effective as a tool for judging conservation success at Marine Protected Areas in all tropical oceans. Of the 101 coral reef countries, the 30 or so that are not yet part of the Reef Check/GCRMN network are invited to appoint coordinators so that a complete picture of the health of the world's reefs can be tracked and appropriate management actions taken.

Status of Coral Reefs of the World: 2004, the Road to Recovery?*Clive R WILKINSON**

PO BOX 772, TOWNSVILLE 4810, AUSTRALIA

CLIVE.WILKINSON@IMPAC.ORG.AU

The status of coral reefs has declined since the first global assessments of the mid 1980s and early 1990s through three parallel destructive forces. Reefs are damaged by direct human impacts of over- and destructive fishing, sediment and nutrient pollution and damaging shoreline modifications; from outbreaks of coral and fish diseases and predators such as the crown-of-thorns starfish, all of which may be exacerbated by human activities; and the more recent global climate change impacts of coral bleaching mortality and the potential for damage from rising concentrations of carbon dioxide. The major El Nino/La Nina event of 1998 resulted in the near destruction of approximately 16% of the worlds reefs, however about half of these now show encouraging recovery, particularly those in well managed MPAs. However, assessments by the GCRMN, World Resources Institute, Reef Check, CORDIO, AGRRA and ReefBase show an increasing rate of direct human impacts with rising populations resulting in major damage to reefs in Eastern Africa, mainland South Asia, Southeast Asia and the wider Caribbean. There are, however, major national, and international activities by governments and NGOs to conserve coral reefs, which are showing encouraging results in reversing the decline over larger coral reef areas with greater recognition of the value of community involvement. This session summarises 80 national status reports documenting greater efforts that are resulting in the sustainable conservation of many coral reefs. All this could be jeopardised if the present rate of global climate change continues and results in more coral bleaching episodes like those of 1998. The predictions are cautiously optimistic. Cold water coral reefs are finally gaining recognition just as destructive deep sea trawling is causing havoc to these slow growing structures. These are now added to the ecosystems in need of urgent conservation.

Author	Session	Page
A		
AALBERSBERG, Bill	4-6	16
	4-7	65
ABAGE, Gloria	P 1-6	247
ABBOTT, Thorne	4-24	222
ABDUL RAHMAN, Ridzwan	P 4-1	401
ABDULKADIR, Sakdullah	P 4-18	351
ABDULLA, Ameer A	1-3	199
	4-15-D	206
ABE, Kohei	P 2-1	262
ABE, Mariko	P 1-1	301
ABE, Osamu	4-3	14
	P 2-8	267
	P 2-8	268
	P 2-8	270
	P 4-3	276
	P 2-3	313
	P 5-6	356
ABLAN, Menchie	1-6-B	99
ABRAR, Muhammad	P 1-8	248
ACEVEDO, Andrea	P 4-21	283
ACHITUV, Yair	1-9-C	72
ACOSTA, Alberto	P 1-8	248
	P 4-21	283
	P 4-2	331
	P 4-15	346
ACOSTA-DE-SANCHEZ, Alison R	P 1-1	304
ACOSTA-GONZALEZ, Gilberto	4-14	213
	P 2-1	255
ADDAMO, Anna M	4-12-A	36
ADDISON, Christine M	P 4-9	342
	P 1-2	366
ADJEROUD, Mehdi	1-2-A	188
	1-2-B	226
	P 2-1	255
	P 2-1	261
	P 3-6	390
	4-21-A	55
AEBY, Greta S	2-10-A	135
	1-4-B	168
	1-4-B	169
	P 1-4	378
AFZAL, Daniel C	P 4-1	398
AGATA, Seizen	P 2-8	267
AGUILAR, Sandra L	P 4-5	339
	P 4-14	395
AGUS, Budiyanto	P 4-2	335
AHAMADA, Said	P 4-1	417
	4-1	63
AHAMADA, Said M	P 2-1	255
AIRI, Valentina	P 1-2	367
AKAKURA, Yasuhiro	4-21-A	57
AKAMINE, Jun	4-13	200
	4-13	201
AKIMICHI, Tomoya	4-13	200
AKTANI, Unggul	P 4-11	343
AL CIBAHY, Ashraf	P 4-1	398
AL JABRI, Musallam M	P 4-21	283
AL MUZAINI, Mohamed	P 4-21	283
AL SHAIBA, Nasser	P 4-1	398
ALANO, Hiyas G	4-15-A	118
ALCALA, Angel C	P 4-1	407
ALCARIA, Joselito Francis A	P 4-1	398
ALCOLADO, Pedro M	P 4-2	330
ALDERSLADE, Phil	1-1-B	186
ALEXANDER, Soranno	P 2-1	259
ALFRED, J R B	P 4-1	417
	4-1	63
ALFRED, Jayakumar Balagurunathan	P 4-1	398

Author	Session	Page
ALFRED, Jayakumar Balagurunathan	P 4-1	404
	P 4-1	413
ALHAZEEM, Shaker H	P 4-2	330
ALHAZEEM, Shakier	P 4-1	408
AL-HORANI, Fuad A	P 3-2	325
ALI, Akbar Mohammad	5-6	51
ALI, Haji M	P 4-1	406
ALINO, Porfirio	5-3	144
	4-14	214
ALINO, Porfirio M	4-15-A	118
	2-3-B	164
	4-5	182
	P 2-3	312
	P 4-8	394
	P 4-1	407
	2-1-B	75
	2-1-B	76
	4-12-B	94
ALLEMAND, Denis	3-4	191
	P 2-12	323
	P 3-2	325
	P 3-2	326
	P 2-9	386
	P 3-6	390
	2-12	91
	2-5	113
ALLEN, Gerald R	4-9	157
ALLEN, Paula	1-8-B	85
ALMANY, Glenn R	1-8-B	84
ALMARRI, Mubarak A	P 5-6	357
ALMEIDA, Lisandro	P 3-2	325
AL-MOGHRABI, Salim M	3-3	50
ALON, Ezri	2-6	143
ALONSO SALVA, Mauricio	P 4-3	276
ALQASSIR, Jassim A	P 2-8	267
AL-ROUSAN, Saber	P 4-1	399
AL-SHAIKH, Khalid	P 4-1	399
AL-SUFYANI, Abdul Mohsen	P 4-1	403
AL-TAMIMI, Hani A	P 2-1	256
ALVARADO, Juan Jose	P 1-8	248
ALVAREZ-FILIP, Lorenzo	P 1-5	306
AL-ZIBDAH, Mohammad K	P 1-6	246
AMARAL, Fernanda	P 1-6	247
	P 1-1	304
	P 5-6	356
AMARAL, Joao	P 1-6	246
AMAT, Alexandra	2-9	176
	P 2-10	320
	P 2-9	386
	P 4-1	409
AMBLARD, Frederic	4-23	98
AMETISTOVA, Lioudmila	2-2	194
AMIR, Ran	3-3	50
AMOLO, Rizaller C	P 4-15	346
AMORES, Alfonso	4-15-E	237
AMORES, Mario	4-15-E	237
ANCOG, Isidore	P 4-15	347
ANDOH, Tadashi	1-2-C	228
ANDRAS, Jason	2-3-C	216
ANDRÉFOUËT Serge	3-5-B	108
	5-2	112
	4-15-B	119
	4-14	213
	P 5-1	291
	P 5-1	292
	P 1-3	373
	P 1-3	374
	4-12-B	95
ANDREW, Wayne	4-17	137

Author	Session	Page	Author	Session	Page
ANDREW, Wayne	4-7	65	ATKINSON, Margie	4-23	97
ANDREWS, Katherine	4-9	157	ATKINSON, Marlin J	3-5-A	105
ANEX, Rick	P 4-8	392		2-9	176
ANG JR, Put	P 4-2	330		3-6	230
	P 4-1	399		5-1	28
ANG, Put O	1-2-A	188		P 5-6	356
	3-4	192	ATKINSON, Scott	4-17	137
	4-14	212		4-15-D	208
	P 1-6	246	AUBANEL, Annie	P 4-1	415
	P 4-1	416		4-21-A	55
	4-1	62		4-1	61
ANGKAJI, Adrian A	P 1-8	250	AUMEND, James	4-15-D	206
ANLAUF, Holger	P 4-2	330	AUSTER, Peter J	1-3	199
ANTHONY, Ken R	4-2-A	126		P 4-12	280
ANTHONY, Kenneth	3-5-B	108		P 4-15	346
	2-11	221		P 5-5	355
	P 2-1	255	AVISHAI, Amir	1-2-A	188
	P 5-3	295	AWANG, Daud	P 4-1	399
ANTHONY, Shelley L	P 1-4	378	AYLING, Anthony	P 5-6	360
ANTICAMARA, Jonathan A	4-15-B	121	AYLING, Bridget F	P 2-8	267
ANTOSHKINA, Anna I	2-6	142	AYRE, David J	2-3-C	215
AOKI, Kanako	5-6	52	AYYASWAMY, Anandkumar	P 4-1	400
AOTA, Toru	4-21-A	57	AZAM, F	P 1-4	382
APPANA, Subhashni D	P 4-1	399	AZEEZ, Abdul	P 4-21	283
APPELDOORN, Richard S	4-25	203			
	4-12-B	94			
APPELGATE, Bruce	P 5-2	294			
APPRILL, Amy	5-1	28	B		
APPRILL, Amy M	1-9-C	73	BACO, Amy R	5-4	53
ARAI, Sachio W	4-18	79	BADAL, Mohammed Rezah	P 5-1	289
ARAKAKI, Takemitsu	P 2-12	322	BAGALIHOG, Solon D	P 4-1	398
ARAKAKI, Yuji	1-6-B	100	BAILLIE, Brett K	1-9-C	71
ARANGO, German	P 1-8	248	BAIRD, Andrew H	1-1-A	139
ARCEO, Hazel O	4-15-A	118		1-2-A	187
	P 4-1	407		P 3-1	272
	2-1-B	76		P 1-2	365
ARCHER, Jessica	1-9-B	70	BAK, Rolf P M	3-5-A	106
ARDIWIJAYA, Rizya	4-8	234		3-6	230
ARDIWIJAYA, Rizya L	P 4-12	281		2-1-A	25
ARENA, Paul T	4-9	157		P 1-3	376
ARGOLLO, Roberto M	2-8-B	89		2-1-B	74
ARIAS GONZALEZ, Jesus Ernesto	P 2-3	312	BAKER, Andrew C	1-9-A	20
ARIAS, Ernesto	2-3-C	217		P 2-3	313
ARIAS, M Cristina	1-1-B	185		1-9-B	68
ARIAS-GONZALEZ, J Ernesto	P 2-1	255	BAKUS, Gerald	2-3-B	164
	P 2-1	260	BALAO, Anapaola	4-11	160
	P 2-3	311	BALCIAUSKAS, Kovaldas	P 1-3	374
ARIAS-GONZALEZ, Jesus E	4-15-B	119	BALDELLI, Giuseppe	P 1-2	365
	4-14	213	BALLMENT, Beth	P 2-3	313
	P 1-2	370	BALMFORD, Andrew	P 4-11	343
	P 4-14	395	BALOTRO, Roland	3-5-A	106
ARMSTRONG, Roy A	P 2-12	324	BANCROFT, Kevin	P 4-7	340
ARNOLD, Suzanne N	1-2-B	227	BANDET, Marion	3-5-A	105
ARONSON, Richard B	3-5-B	109	BANDU, Amarasinghe	P 4-4	337
	4-20	127	BAN-HAIM, Yael	1-4-A	166
	2-1-A	22	BANKS, Kenneth	4-21-B	115
	P 4-3	277		P 2-7	266
	P 4-2	331	BANKS, Kenneth W	4-9	157
	2-8-B	89		2-7	31
ARVEDLUND, Michael	4-3	14	BANTANG, Johnrob	2-5	114
ARZAYUS, Felipe	5-2	110	BANTANG, Johnrob Y	P 4-14	395
ARZAYUS, L Felipe	5-2	110	BANZUELA, Socrates	P 4-15	347
ASAMI, Ryuji	2-8-B	87	BARBER, Kimberly	P 4-15	346
ASHOK KUMAR, Balaiyan	P 1-7	308	BARBER, Paul H	1-6-B	99
ASHWORTH, Jennifer S	4-12-A	36	BARILE, Peter J	4-3	13
ASSESSMENT TEAMS, The Agrra	2-1-A	22	BARNARD, Nicola J	4-24	224
ATCHISON, Amy D	2-3-C	216	BARNEAH, Orit	1-9-A	19
	P 2-3	309	BARNES, David J	2-8-A	35
ATEWEBERHAN, Mebrahtu	2-1-C	77	BARNHARDT, Walter A	2-7	32
			BARON, Nancy	4-5	181

Author	Session	Page	Author	Session	Page
BARR, Julie	4-11	159	BIJOUX, Jude	P 4-1	408
BARSHIS, Daniel J	P 1-3	372		P 4-1	417
BARTON, Andrew D	2-12	90		4-1	63
BASSI, Davide	2-6	143	BIRD, James C	2-11	220
	2-1-B	76	BIRKELAND, Charles	4-15-B	121
BASTIDAS, Carolina	P 2-3	310	BIRTLES, R Alastair	4-5	183
	P 1-3	377	BLACK, Kerry	2-3-A	131
	P 4-1	400	BLACK, Megan M D	P 1-9	251
	P 4-1	402	BLACKALL, Linda L	P 1-4	381
BATES, Nick R	2-9	176	BLACKBURN, Tanya H	4-24	224
BATTISTA, Tim A	P 4-4	337	BLAKEWAY, David	1-3	197
BAUMS, Iliana B	2-3-C	215		P 1-3	376
BAVESTRELLO, Giorgio	1-7	104	BLANCHOLT, Jean	3-6	232
BAYMAN, Paul	1-4-A	167	BLANCHON, Paul	P 2-1	258
BEAUREGARD, Allison Y	3-6	231	BLANCHOT, J	P 4-2	334
BEAVER, Carl R	4-9	157	BLANCHOT, Jean	3-4	191
BECHTEL, Jamie	2-1-C	78		3-4	192
BEER, Sven	P 2-12	322		P 3-4	389
BEGER, Maria	4-14	212	BLIDBERG, Eva M	P 3-3	274
	4-14	213	BLOHM, Dietmar	P 1-6	243
	P 2-1	261	BOAK, Ricahrd	4-2-B	152
BEGG, Gavin A	4-5	182	BODE, Lance	2-11	220
BEJARANO, Sonia	P 4-2	333	BODNAR, Andrea	P 1-9	254
	P 4-11	343	BOEING, Brian	1-9-B	70
	P 4-1	400	BOLAND, Gregory S	2-3-C	216
BEL MADANI, Ali	P 3-5	327		P 4-2	331
BELDIA II, Pacifico D	4-15-B	119	BOLDEN, Stephania	P 4-7	340
BELL, Lori J	1-6-B	101	BONALDO, Roberta M	P 5-6	356
BELLINI, Claudio	P 5-6	357		P 5-6	358
	P 5-6	360		P 5-6	360
BELLWOOD, David R	1-6-C	102	BONE, David	1-4-B	169
	2-3-B	162		P 1-4	380
	2-1-A	24		P 4-1	400
	2-1-A	26	BONITO, Victor	5-1	27
BELMAKER, Jonathan	P 1-3	372		2-1-C	77
BEN, Hoang X	P 4-7	340	BONITO, Victor E	4-2-B	151
	P 4-1	413	BOONYANATE, Potchana	P 5-3	296
BEN, John	4-8	234	BOORE, Jeffrey	P 1-1	303
BENA, Chiaki	P 2-1	256	BOOTH, David J	P 2-3	309
BENAYAHU, Yehuda	1-9-A	19		P 5-6	357
	P 1-6	245		1-8-A	81
	1-6-A	41	BORGES-SOUZA, Jose Manuel	P 2-1	257
	4-21-A	54	BORNEMAN, Eric	1-4-B	168
BENNETT, Gregory P	P 4-1	398		P 1-2	369
BENZONI, Francesca	4-12-A	36		P 1-4	378
	P 1-2	365		P 1-4	379
	P 4-1	408	BOTHNER, Michael	2-2	195
BERETTA, Giglia A	1-8-A	81		P 2-2	385
BERGER, Wolfgang H	2-7	31	BOTSFORD, Louis W	1-8-B	85
BERKELMANS, Ray	1-9-A	20	BOUCHET, Philippe	1-6-A	41
	2-11	220	BOUCHON, Claude	P 4-1	400
	P 2-12	322	BOUCHON-NAVARO, Yolande	P 4-1	400
	1-9-B	68	BOULOS, Areen	P 3-4	389
BERRIOS, Lisa	2-6	143	BOURMAUD, Chloe A F	1-6-A	42
BERUMEN, Michael L	2-10-A	135	BOURNE, David	1-4-A	166
BEUKERING, Pieter Van	4-14	211	BOURNE, David G	P 3-1	272
BEZY, M Bernadette	P 2-1	256	BOWDEN-KERBY, Austin	P 4-21	283
	4-21-A	56	BOWEN, Brian W	1-6-B	99
BHAGOOLI, Ranjeet	P 1-9	253	BOYETT, Holly	1-4-A	166
	1-9-B	70	BRADBURY, Roger H	4-5	181
BIANCHI, Carlo Nike	P 1-2	365	BRAGA, Juan Carlos	2-7	32
BIDIGARE, Robert R	5-1	28	BRAINARD, Russell	3-5-B	109
	1-9-C	73		2-12	90
BIEDENBACH, James	3-3	49	BRAINARD, Russell E	5-2	110
BIELAWSKI, Joseph P	P 1-3	372		2-10-A	135
BIGOT, L	P 4-2	334		4-3	15
BIGOT, Lionel	P 5-1	289		P 4-12	280
	P 4-1	417		2-1-C	77
	4-1	63	BRAINARD, Rusty	P 5-2	294

Author	Session	Page
BRAINARD, Rusty E	P 2-3	310
BRANDER, Robert W	P 3-5	327
BRANDO, Vittorio	5-2	111
BRANDT, Marilyn E	4-14	213
BRAZEAU, Daniel A	2-3-C	216
BREEMAN, Anneke M	2-1-C	77
BREIBART, M	P 1-9	251
BREITBART, Mya	3-1	46
BRENIER, Ambroise	1-8-A	83
BRICKNER, Itzik	1-9-A	19
	3-1	47
BRINGAS, Jose Ma Antonio	4-15-D	207
BRINKMAN, Richard	3-5-A	107
BRINKMAN, Richard M	2-11	220
BROAD, Kenneth	4-15-A	118
BROCK, John	P 2-1	256
	5-1	27
BROCK, John C	4-2-B	151
	2-9	178
BROCK, Richard	3-3	49
BRODIE, Jon E	4-18	79
BROGDON, Sara E	4-2-A	125
BROOKS, Andrew J	1-8-A	82
	1-8-A	83
BROWN, Eric	4-15-B	121
	P 4-3	277
BROWN, Eric K	2-2	195
	1-2-B	227
	P 1-2	365
BRUCKNER, Andrew W	1-4-C	218
	P 1-4	381
	4-21-A	55
BRUCKNER, Robin J	1-4-C	218
	4-21-A	55
BRUGGEMANN, Henrich J	2-1-C	77
BRUMBAUGH, Daniel	4-15-B	120
BRUMBAUGH, Daniel R	4-15-A	118
	2-1-A	22
	P 2-3	311
BRUNO, John	1-4-A	167
	P 3-3	275
BRUNS, Brigitte U	P 1-9	251
BRYLEWSKA, Helen	P 2-10	320
BRYLEWSKA, Nellie	P 2-9	386
BUARUANG, Jamrearn	P 4-5	338
BUCHER, Daniel J	3-3	49
BUCHERT, Martin P	P 4-15	347
BUCKLEY, Raymond	2-10-B	173
BUDD, Ann F	1-1-A	140
	1-1-B	184
	P 2-1	259
BUECHLER, Karin	2-1-A	26
BUHLE, Eric R	4-23	97
BUHL-MORTENSEN, Lene	P 5-4	297
BULINA, Maria	P 1-3	372
BUNCE, Leah	4-7	65
BUNCE, Leah L	4-8	233
BURCHETT, Sarah G	1-4-A	166
BURGESS, Samantha N	P 5-5	355
BURGESS, Scott	2-1-B	74
BURKE, Laurretta	5-2	112
	4-2-C	155
	P 4-14	395
BURR, George S	2-1-A	23
BUSCAIL, Roselyne	P 3-6	390
BYTHELL, John C	1-4-A	165
	P 1-4	379

Author	Session	Page
C		
C, Chellaram	P 1-4	379
CABAITAN, Patrick C	4-21-B	116
CABALLERO, Hansel	P 4-2	330
CABANBAN, A	P 4-1	417
	4-1	62
CABANBAN, Annadel S	4-2-C	155
	4-15-D	208
	P 4-1	401
CABIOCH, Guy	2-8-A	35
CABRERA, Brian	4-21-A	56
CABRERA, Brian T	4-12-A	37
CADIZ, Pablina L	P 4-21	288
CADWALLADER, Phil	4-15-D	206
CAHOON, Larry	P 3-3	275
CALCINAI, Barbara	1-7	104
CALDERON, Emiliano N	P 2-1	256
CALDERON, Magnolia O	2-10-A	134
CALDERON-AGUILERA, Luis E	4-2-B	153
CALDOW, Chris	4-14	211
CALDWELL, Roy L	4-21-A	54
CALEY, M Julian	2-1-A	26
CALLAGHAN, Elizabeth	P 4-24	396
CALLAHAN, Michael K	P 4-21	286
CALLENDER, Russell C	P 4-4	337
CAMACHO-LONDONO, Juan E	P 4-2	331
	P 4-15	346
CAMARENA, Tomas	4-11	160
CAMERON, Darren	4-15-D	207
CAMPOS, Wilfredo	4-14	214
CAMPOS, Wilfredo L	4-15-B	119
	P 4-1	407
CANTIN, Neal E	3-3	48
CAPARELLI, Alice C	P 1-2	365
CAPILI, Emmi B	4-2-B	151
CAPO, Thomas	4-21-B	115
CAPONE, Mark K	P 4-1	411
CAPPO, Mike	4-12-A	36
CARAS, Tamir	1-2-A	188
CARLON, David B	1-1-B	184
CARNAHAN, Elizabeth	P 4-2	332
CARO-ZAMBRANO, Carlos	P 4-1	410
CARR, R Scott	P 3-1	272
	3-3	49
CARRICART-GANIVET, Juan P	2-8-A	35
CARRINGTON, Emily	P 2-4	315
CARROLL, Andrew	1-2-A	188
CARTER, David W	P 4-5	339
CARTER, Dee	1-9-A	21
CARTER, Dee A	1-9-A	18
CARTER, Robert W	4-21-B	115
CARY, Jennie	P 2-1	258
CASARETO, Beatriz	P 3-6	390
CASARETO, Beatriz E	3-4	191
	3-4	192
	3-6	231
	3-6	232
CASELLE, Jennifer E	2-3-C	217
CASEY, Ken	P 5-2	294
CASEY, Kenneth S	5-2	110
	2-12	90
CASHMAN, Mary	4-5	181
CASTILLO, Arcadio	P 4-2	333
CASTILLO, Gem	4-14	214
CASTRO, Clovis B	P 2-1	256
	P 2-1	262
	P 4-1	403
CASTRO, Roberto	P 4-2	332
CASTRO-PEREZ, Jose M	4-14	213

Author	Session	Page	Author	Session	Page
CAUSEY, Billy D	4-15-D	207	CHIN, Heri	P 1-6	241
	P 1-4	382	CHINA, Katsunori	P 1-6	242
	4-18	79	CHINEAH, Vishwamitra	P 2-10	321
CAVA, Fabiana C	P 4-1	403	CHITTARO, Paul M	2-3-C	217
CELLIERS, L	4-2-B	153	CHIYONOBU, Shun	2-7	34
CELLIERS, Louis	2-1-B	75	CHOAT, Howard	P 1-6	243
CERRANO, Carlo	1-7	104	CHOAT, J Howard	4-5	182
CERVINO, James M	1-4-A	167	CHOI, Choyce L S	3-4	192
CESAR, Fabiana B	P 4-1	403	CHOI, L S	P 4-2	330
CESAR, Herman S J	2-5	114	CHOI, M M	P 4-2	330
	4-14	211	CHOJNACKI, Joe D	2-10-A	135
CH, Satyanarayana	P 4-1	400	CHOU, L M	P 4-1	412
CHABANET, P	P 4-2	334		P 4-1	417
CHABANET, Pascale	P 4-12	280		4-1	62
	P 2-3	312	CHOU, Loke Ming	1-1-B	184
	P 1-3	373		P 4-21	285
	P 1-3	374		P 1-1	304
	4-12-B	95		4-21-A	54
CHAD, Hewitt	P 4-2	334	CHOU, Loke-Ming	P 4-1	401
CHADWICK-FURMAN, Nanette	1-2-A	188	CHOU, Yalan	4-2-B	151
	1-2-B	226	CHOUKROUN, Severine	P 2-11	388
CHADWICK-FURMAN, Nanette E	P 2-12	322	CHOWDULA, Satyanarayana	P 4-8	392
CHALIAS, Vincent	4-23	98	CHRISTENSEN, John	4-14	211
CHAN, Alan L K	P 4-1	401	CHRISTENSEN, John D	4-9	156
CHAN, K	P 4-1	401		P 4-4	337
CHANCERELLE, Yannick	P 5-1	289	CHRISTIE, Patrick	4-6	16
	P 4-4	336	CHUANG, Christine	P 3-1	272
	4-21-A	55	CHURCH, Julie	4-11	160
CHANFI, Dhahabia	P 1-2	366		4-12-A	39
	P 4-1	408		P 4-1	407
CHANG, Chaoching George	1-1-A	140	CID, Gonzalo	4-7	65
CHANG, Chia-Ming	P 2-2	385	CINNER, Joshua	4-8	234
CHANG, Richard Y	P 2-3	309	CINNER, Joshua E	4-8	235
CHANKONG, Anchalee	P 1-3	372	CIPRIANI, Roberto	P 1-4	380
CHARPY, Loic	3-4	191	CLAGUE, David	P 2-8	270
	3-6	232	CLAGUE, David A	2-7	32
	P 3-4	389	CLARK, Randy	4-25	203
CHARUCHINDA, Mickmin	P 5-3	296	CLARK, Susan	1-2-B	226
CHASTON, Katherine	4-17	137	CLARK, Tracy H	4-8	234
CHAUVET, Claude	P 2-3	314	CLARO, Rodolfo	4-11	160
CHAUVET, Claude A	4-11	159	CLEARY, Daniel F R	2-5	113
CHAVANICH, Suchana	P 2-1	257		2-1-B	74
	P 4-21	288	CLIFTON, Julian	4-12-B	93
CHAVANNE, Cedric	P 4-15	347	CLIFTON, Kenneth	1-2-A	189
CHAVEZ, Ernesto A	P 2-1	257	CLUA, Eric	4-5	183
	4-12-B	93		P 1-3	373
CHAVEZ, Pat	2-2	195		P 1-3	374
CHEAL, Alistair J	2-1-A	24		4-12-B	95
CHELLARAM, C	P 4-21	287	CO, D Eric	4-24	223
CHEN, Allen C	P 1-1	301	CO, Eric	4-15-D	208
	P 1-1	305	COCHRAN-MARQUEZ, Susan	2-2	195
	1-6-B	99	COELHO, Vania	P 2-1	259
CHEN, Chang-Po	1-6-B	101	COELHO, Vania R	P 4-9	342
	1-6-B	99		P 1-3	375
CHEN, Chaolun A	1-1-A	141	COFFROTH, Mary A	1-9-C	71
	P 4-1	401	COFFROTH, Mary Alice	P 2-3	313
CHEN, Chaolun Allen	1-6-B	101		1-9-C	71
	1-1-A	140	COFFROTH, Mary-Alice	1-9-A	20
	1-9-B	69		P 1-9	252
CHEN, Chien-Hsun	P 4-1	401	COLANTONI, Paolo	P 1-2	365
CHEN, Li-Shu	P 5-6	357	COLEMAN, Greg	P 4-1	402
CHEN, Ming-Hui	P 1-4	379		2-1-B	74
CHEVANNES CREARY, Marcia M	4-2-B	153	COLEMAN, Max L	3-3	50
	P 4-4	336	COLES, Steve L	1-6-C	103
CHEVILLON, Christophe	3-5-B	108		1-4-B	168
CHIKAMORI, Masashi	5-2	111	COLIN, P L	1-9-B	68
	4-16	179	COLIN, Pat L	4-11	161
	4-16	180	COLIN, Patrick L	P 3-5	329
	P 4-16	350	COLLEY, Susan B	1-2-A	189

Author	Session	Page	Author	Session	Page
COMIN, Francisco A	P 4-2	333	DAI, Chang-Feng	1-6-A	41
COMLEY, James	P 4-1	404		P 4-1	416
CONKLIN, Eric	4-24	223		4-1	62
CONNELL, Joseph H	2-1-B	75	DALE, Amy	1-4-A	166
CONNELLY, Sandra J	1-9-A	20	DALZELL, Paul	4-12-A	40
CONNOLLY, Sean	P 2-1	255	DAMIANO, Cristiana	P 5-6	357
CONNOLLY, Sean R	1-6-C	102	D'AMICO, Tamara M	P 4-1	403
	2-1-A	24	DANG, Phong X	P 2-8	267
CONRUYT, Noel	P 4-12	280	DANIEL, Mike W	P 1-9	251
COOSHNA, Dorothy	P 4-12	280	DANIELS, Camille	P 4-2	332
COPPER, Paul	2-6	142	DANIELS, Carol	P 4-1	406
CORBETT, James	4-15-D	206	DAOLU, Wang	P 4-15	347
CORNELL, Howard V	2-1-A	23	DARWINTO, Harto	P 4-24	396
CORNISH, Andrew S	4-12-A	36		P 4-1	407
	P 4-1	402		P 4-1	414
CORNISH, Andy	4-11	159	DASCHBACH, Nancy	P 4-8	392
CORRADO, Piccinetti	4-2-C	155	DAVEY, Andrew M	3-1	47
CORREA, Jackeline	P 4-11	343	DAVIES, Andrew N	P 4-1	414
CORREGE, Thierry	2-8-A	35	DAVIES, Jamie G	4-8	234
CORTES, Jorge	P 2-1	256	DAVIS, Allicia	2-6	143
	P 2-1	257	DAVY, Joanne E	1-4-A	166
	P 4-1	415		P 1-4	381
	4-1	61	DAVY, Simon K	1-4-A	166
COSTA, Cristiane	P 1-6	246	DAWSON, Michael N	1-6-B	101
COTTALORDA, Jean Michel	P 2-12	323		1-6-B	99
COURA, Marcia	P 5-6	356	DAY, Jon	4-15-D	206
COWEN, Robert	4-15-A	118		4-15-D	207
COWEN, Robert K	1-8-B	86	D'CROZ, Luis	2-10-A	134
COX, Evelyn F	P 1-2	366	DE BEER, Dirk	5-1	28
CRABBE, Michael J C	2-2	194		P 3-2	325
CROQUER, Aldo	1-4-B	169	DE GOEIJ, Jasper M	3-6	231
	P 1-5	306	DE LA GUARDIA, Elena	P 4-2	330
	P 1-3	377	DE NYS, Rocky	P 3-1	272
	P 1-4	380	DE PUTRON, Samantha	P 2-9	386
	P 4-1	400	DE PUTRON, Samantha J	1-2-A	190
	P 4-1	402		P 2-10	320
	P 4-1	415		P 4-1	409
	4-1	61	DE VOOGD, Nicole J	1-7	104
CRUZ, Igor C	P 4-1	406	DE'ATH, Glenn	4-2-A	126
CRUZ-PÍÑON, Gabriela	P 1-6	241		2-1-A	24
CUET, Pascale	3-4	191	DEBROT, Dolfi A	P 1-3	376
CUMARANATHUNGA, Ruchira	4-12-A	38	DEENMAHOMED, Umar	P 5-1	289
CUNANAN, Chona	4-15-D	207	DEFELICE, Ralph C	1-8-B	86
CURPEN, Sarvanen	P 5-1	289	DEIS, Donald R	4-20	127
CURRAN, H Allen	2-6	143	DEIYE, Margo	P 4-1	402
	2-2	196	DEKKER, Arnold	5-2	111
	P 4-24	396	DELEAN, Steve	1-8-B	84
	2-8-B	88	DELEAN, Steven	2-1-A	24
CURRY, Richard	4-21-B	115	DELESALLE, Bruno	3-4	191
CURRY, Richard C	4-2-B	153		3-4	192
CURRY, Richard W	P 4-21	284	DELGADILLO, Oscar M	P 4-11	343
	P 1-4	382	DELMAS, Charles	3-4	191
			DEMARTINI, Edward E	P 2-3	309
				2-1-C	77
				2-3-C	217
D			DEREK, Hogan	4-15-A	118
DA SILVEIRA, Fabio Lang	P 1-6	242	DESALLE, Rob	P 2-3	311
	P 1-6	244	DESLARZES, Ken	4-2-C	154
	P 1-1	303	DESLARZES, Ken J P	4-2-C	154
DAF, Spem	P 4-1	408		P 4-2	331
DAHLGREN, Craig P	4-15-A	118	DEVANTIER, Lyndon	4-15-E	236
	4-15-B	120		P 1-6	241
	2-1-A	22	DEVINCK, Francois	P 4-1	414
DAI, Chang-Feng	4-17	138	DEVLIN, Michelle	4-18	79
	1-1-A	140	DIAZ-PULIDO, Guillermo	2-10-B	172
	1-1-A	141	DINSDALE, Elizabeth A	1-4-B	170
	1-1-B	186		4-8	233
	4-14	212	DIPPER, Frances	P 4-1	414
	P 2-12	324	DIPPER, Frances A	P 1-8	250
	P 4-1	401			

Author	Session	Page
DIRESTA, Dan	4-21-B	115
DIXON, Brian	2-3-A	130
DIZON, Romeo M	1-3	197
DJOHANI, Rili	4-14	211
DOBSON, Eric	5-1	30
DOCKER, Margaret F	2-3-B	163
DODGE, Richard	2-7	31
DODGE, Richard E	4-21-B	115
	4-20	128
	4-9	157
	2-10-B	174
	P 2-7	266
	P 2-8	268
	P 4-21	285
	5-1	29
	P 5-1	291
	P 5-4	297
	4-21-A	57
	2-8-B	88
	2-8-B	89
DOLLAR, Steven	2-2	195
DOMEIER, Michael L	4-11	161
DOMINGUEZ, Miriam	4-3	14
DOMINICI-AROSEMENA, Arturo	P 1-6	243
DONALDSON, Terry J	1-6-A	42
DONE, Terry	2-1-A	22
	2-11	220
DONE, Terry J	4-2-A	126
	P 2-3	312
DONNER, Simon	2-11	220
DOOLITTLE, Daniel	5-3	144
DORNELAS, Maria	1-6-C	102
DOUGLAS, Angela E	2-10-B	174
	1-9-B	70
DOUGLAS, Nancy L	1-4-A	167
DOUILLET, Pascal	3-5-B	108
	3-6	232
	P 3-5	327
	P 3-5	328
DOVBYSHEVA, Tatjana	P 1-5	306
DOVE, Sophie	2-10-B	172
	2-12	92
DOVE, Sophie G	4-2-A	125
DOWNING, Nigel	2-10-B	173
DOWNS, Craig A	4-2-A	125
	4-9	156
	3-3	50
DOYLE, Joana I	4-24	224
DUBINSKY, Zvy	2-9	176
	1-2-A	188
	1-2-B	226
	1-9-C	72
DUDGEON, Christine	P 1-6	243
DUKE, Norman C	4-25	204
DULVY, Nicholas K	4-5	181
	4-12-A	37
DUNBAR, Robert B	3-6	231
DUNLAP, Matthew J	2-10-A	135
	P 1-2	366
DUNN, Simon R	1-9-C	71
DUNSMORE, Linda	5-1	27
DUNSTAN, Andrew J	P 4-11	343
DURANT, Daisy	P 1-3	373
DURIVAUULT, Jerome	3-1	46
DURVILLE, P	P 4-2	334
DUSTAN, Phillip	5-1	30
DUTRA, Guilherme F	4-3	15
	P 4-7	340
DUTRA, Leo X C	P 2-10	321

Author	Session	Page
DUTRA, Leo X C	P 4-2	331
	P 2-2	385
	P 4-1	406
	2-8-B	89
DYGICO, Marivel	P 2-1	262
DYGICO, Marivel P	2-10-A	136
	P 4-8	392
E		
EAKIN, C Mark	4-24	222
	P 2-8	268
	2-8-B	89
EDEN, Noa	1-9-C	72
EDINGER, Evan	2-6	142
EDINGER, Evan N	2-1-A	23
EDWARD, Ahser	P 4-3	276
EDWARDS, Alasdair J	1-2-B	226
EDWARDS, Peter E	P 4-1	406
	P 4-1	416
	4-1	62
EDWARDS, Peter E T	4-21-A	56
EFENDI, Yempita	P 1-8	248
EGHTESADI ARAGHI, Peyman	P 3-3	274
EGHTESADI, P	P 4-1	416
EGHTESADI-ARAGHI, Peyman	P 4-1	403
EHLER, Charles	4-7	65
ELDERFIELD, Harry	P 2-7	264
ELEDUI, Adalbert	4-17	137
EMAUROIS, Carol	P 4-1	404
EMMANUEL, Tessier	P 5-3	295
ENGELS, Mary S	2-2	196
ENGLE, David	P 1-1	303
ENRIQUEZ, Susana	1-9-B	69
ENRIQUEZ, Susanna	2-10-B	172
EPP, Laura S	1-6-A	43
ERDMANN, Mark E	4-9	158
ERDMANN, Mark V	2-5	114
EREZ, Jonatan	2-9	177
	P 4-3	278
EREZ, Jonathan	2-9	176
	1-9-C	72
ERICKSON, Amy Anne	P 1-8	249
ERIKSON, Christine	P 5-6	362
ESBELIN, Clementine	3-4	191
ESTEVES, Eduardo	P 1-6	247
ESTRADA, Melissa Anne F	2-5	114
ETHEREDGE, Susan	P 4-24	396
EVANO, Noel P	4-15-B	119
EVANS, David J	4-2-C	154
	P 4-2	331
EVERSON, Alan R	4-12-A	40
F		
FABRICIUS, Katharina	2-1-A	24
	5-1	28
	1-9-B	68
FABRICIUS, Katharina E	4-2-A	126
	1-1-B	185
FABURADA, Arturo O	P 4-8	392
FAHY, Daniel P	4-21-A	57
FAHY, Elizabeth G	4-20	128
FALLON, Stewart J	2-7	32
FALTER, James L	3-5-A	105
FALTER, Jim	3-6	230
FAN, Tung-Yung	1-1-B	186
	1-2-A	187

Author	Session	Page	Author	Session	Page
FAN, Tung-Yung	P 2-1	263	FISHER, Gary	4-20	127
	P 2-12	324	FISHER, Louis E	4-9	157
	P 4-22	353	FISHER, Rebecca	2-3-B	162
	P 1-2	368		2-3-B	163
	P 4-1	401		P 2-3	310
FANG, Lee-Shing	1-2-A	187	FISK, Dave	P 4-1	415
	P 2-1	263		4-1	61
	P 4-22	353	FISK, David A	P 4-15	346
	P 1-2	368	FITT, William K	1-9-A	18
FARAJ, Muna N	P 4-1	403		1-9-A	19
FAURE, Gerard	P 4-12	280		1-9-A	21
FAURE, Vincent	3-6	232		P 1-9	251
FAUTH, John E	4-2-A	125		P 2-4	318
FEINGOLD, Joshua S	2-10-A	134	FITZPATRICK, Ben M	4-15-B	120
FEITOZA, Bertran	P 1-6	247	FLAMENT, Pierre	P 4-15	347
FEITOZA, Caroline	P 4-1	403	FLETCHER, Charles H	2-2	196
FELDMAN, Gene	5-2	112		2-7	32
	4-15-C	147	FLEURY, Beatriz G	P 4-4	336
FELIS, Thomas	P 2-8	267	FLOETER, Sergio	5-6	51
	2-8-B	87	FLOETER, Sergio R	1-3	198
FENNER, Douglas	2-5	114	FLORES, Daisy	4-7	65
FERDELMAN, Tim	P 3-2	325	FLOT, Jean-Francois	1-1-B	184
FERGUSON, Katherine M	1-9-A	18		P 1-1	301
FERGUSON, Nadia-Deen	P 3-1	273	FLYNN, Adrian J	4-11	160
FERGUSON, Scott	P 5-2	294		P 2-1	257
FERNANDES, Leanne	4-15-D	206	FOALE, Simon	4-8	234
	4-15-D	207	FOALE, Simon J	P 4-8	393
FERRARIS, Jocelyne	4-5	183	FOGARTY, Nicole D	2-3-A	131
	P 1-3	373		P 1-2	366
	P 1-3	374	FOLEY, David	5-2	110
	1-8-A	83	FOLEY, Janet	1-4-C	218
	4-12-B	95	FOLEY, Patrick	1-4-C	218
FERREIRA, Beatrice	5-6	51	FONG, Peggy	2-10-A	134
FERREIRA, Beatrice P	4-12-A	38		P 2-10	320
	P 4-1	403	FONSECA, Mark S	4-20	127
FERREIRA, Beatrice Padovani	P 4-1	409		P 4-9	342
	4-7	66	FOO, Calvin	P 4-1	418
FERREIRA, Carlos E L	1-3	198		4-1	64
FERREIRA, Carlos Eduardo L	P 4-4	336	FOREMAN, William F	P 3-1	272
FERREIRA, Carlos Eduardo Leite	5-6	51	FORRESTER, Graham	1-8-B	85
FERRIER-PAGES, Christine	3-4	191	FORRESTER, Graham E	P 1-4	381
	3-4	192	FORSMAN, Zac H	1-1-A	140
	P 2-9	386	FORTES, Miguel D	4-25	203
	P 3-6	390	FOSSAA, Jan H	5-4	53
	3-1	46	FOSSHAGEN, Haralds	5-4	53
FERRO, Fleur M	4-9	157	FOSTER, Sarah J	4-5	181
FICHEZ, Renaud	3-5-B	108	FOUKE, Bruce W	3-1	46
FIELD, Don	P 1-2	366		3-1	47
FIELD, Michael	2-2	195	FOX, George E	1-1-A	140
	P 2-2	385	FOX, Helen E	P 4-15	347
FIELD, Michael E	2-2	195		4-21-A	54
	2-2	196	FRADE, Pedro	P 1-3	376
	1-2-B	227	FRANCINI-FILHO, Ronaldo B	4-2-C	155
	2-7	32		2-1-C	77
FIELD, Mike	3-3	49	FRANCO, Georgia M O	P 1-6	242
FIELD, Steven F	P 1-3	372	FRANZ, Bryan	4-15-C	147
FIGUEIRA, Will F	4-15-B	119	FRAUNIE, Philippe	P 3-5	328
FINE, Maoz	1-5	133	FRAZER, Thomas	4-15-B	120
	2-10-B	173	FRETWELL, Carol	P 4-24	396
	P 1-4	381	FRETWELL, Carol R	4-24	222
FINKBEINER, Mark A	5-1	30	FREY, Melissa	1-6-A	44
FINLEY, Rachel	1-8-B	85	FREY, Melissa A	2-1-A	23
FINLEY, Rachel J	P 1-4	381	FRIAS-LOPEZ, Jorge	3-1	46
FIRING, Eric	P 2-3	310		3-1	47
FIRING, June B	P 2-3	310	FRIED, Stephanie	P 4-8	392
FISCHER, Andrew M	5-2	111		P 4-8	393
FISHER, Elizabeth M	4-2-A	125	FRIEDLANDER, Alan	4-15-B	121
	P 2-12	322	FRIEDLANDER, Alan M	P 2-3	309
FISHER, Esther	3-3	49		P 4-4	337

Author	Session	Page
FRIEDMAN, Kim	4-12-B	95
FRIEDMAN, Kim J	4-5	182
FRIEDMANN, Kim	4-5	183
FROUIN, Patrick	5-6	52
FROULA, Jeff	1-9-C	71
FRYER, Brian J	2-3-A	130
	2-3-C	217
FUJII, Satoshi	2-3-B	162
FUJIMURA, Hiroyuki	2-9	178
	P 2-12	322
	P 2-9	387
FUJIOKA, Yoshimi	P 2-1	258
	P 2-1	260
	P 2-3	313
FUJITA, Kazuhiko	P 2-7	264
	P 2-7	265
	P 2-4	317
FUJITA, Yoshihisa	P 1-6	242
FUJIWARA, Shuichi	4-15-B	119
	4-20	128
FUKAMI, Hironobu	1-6-B	101
	1-1-A	139
	1-1-B	184
	P 1-1	301
FUKAMI, Kimio	3-6	231
FUKASAWA, Toshifumi	5-3	145
FUKUDA, Hideki	P 3-6	390
FUKUDA, Isao	P 1-6	242
	P 1-9	253
FUKUOKA, Kouki	P 4-21	285
FULTON, Christopher J	2-1-A	26
FUNAKOSHI, Yoshitaka	P 1-8	250
FURLA, Paola	P 2-12	323
	2-12	91
FURNAS, Miles J	4-18	80
FURUKAWA, Tetsuro	P 1-4	384
FURUSHIMA, Yasuo	4-20	128
	P 3-5	327
FURUYA, Atsumi	4-12-B	95

G

G, Mathews	P 3-3	274
GADEMANN, Rolf	2-12	91
GAGAN, Michael K	2-9	177
	P 2-9	386
GAHARA, Hiroaki	P 4-21	286
GALLI, Paolo	4-12-A	36
GALLOWAY, Sylvia B	P 1-4	381
GALLUP, Christina	2-7	32
GALVIS, Nohora	4-7	67
GALZIN, Rene	2-3-B	164
	P 5-1	289
	P 1-3	373
	P 1-3	374
	1-8-A	83
	4-12-B	95
GARCIA, Adriana E	P 2-3	310
GARCIA, Camilo B	P 4-11	343
GARCIA, Elia	P 4-3	277
GARCIA, Elia M	P 1-5	306
GARCIA, Gerardo	4-14	213
GARCIA, Miguel A	P 4-21	284
	P 4-2	332
GARCIA-MOLINER, Graciela E	4-12-A	39
GARCIA-SAIS, Jorge R	P 4-2	332
GARCIA-URUENA, Rocio Del Pilar	5-3	145
GARCIA-URUENA, Rocio P	P 4-2	332
GARNIER, Remi	3-4	191

Author	Session	Page
GARREN, Melissa	P 1-9	251
GARRETT, Suzanne L	P 4-15	347
GARRIGUE, Claire	P 4-1	414
GARRISON, Virginia H	P 3-1	272
	P 4-21	284
GARZA-PEREZ, Joaquin R	4-15-B	119
GARZA-PEREZ, Rodrigo	P 2-1	255
GARZA-PEREZ, Rodrigo J	4-14	213
GARZON-FERREIRA, Jaime	P 4-2	333
	P 1-3	375
	P 4-1	400
	P 4-1	410
	P 4-1	415
	4-1	61
GASPARINI, Joao Luiz	5-6	51
GATES, Ruth D	1-9-C	73
GATTUSO, Jean-Pierre	P 2-9	386
GAYANILO JR, Felimon C	4-14	214
GAYANILO, Felimon C	4-14	211
GAYLE, Peter	P 1-8	248
	2-1-C	78
GEBELEIN, Jennifer	5-2	112
GEBELEIN, Jennifer L	5-2	112
GEHRING, Peter M	4-2-C	154
GEISTER, Joern	P 1-1	302
GEKTIDIS, Marcos	P 4-1	403
GELLER, Jonathan B	1-6-A	44
GENOVESE, Salvatore J	3-5-B	109
GERALD, Lila	2-8-B	88
GERONIMO, Rollan C	2-5	114
	P 4-14	395
GERUNG, Grevo	4-15-E	236
GEYNET, Yannick	P 4-12	280
GHILAGABER, Mehari Y	2-1-B	74
GIBB, Olivia	2-8-B	87
GIL-AGUDELO, Diego L	1-4-A	166
	P 1-4	381
GILBES, Fernando	P 5-1	292
GILES, Brian	4-12-A	37
GILL, Andrew B	4-12-B	93
GILLIAM, David S	4-21-B	115
	4-9	157
	4-21-A	57
GILMOUR, James	3-5-A	107
	2-10-B	172
GILMOUR, James P	2-1-B	76
GINSBURG, Robert	P 4-2	333
GINSBURG, Robert N	2-1-A	22
	P 2-1	258
	P 4-2	330
GINTERT, Brooke	5-3	144
GIRVETZ, Evan	1-4-C	218
GISCHLER, Eberhard	2-1-A	25
	P 2-8	268
GITTENBERGER, Adriaan	1-6-B	100
GITTENBERGER, Edmund	1-6-B	100
GITTINGS, Steven R	4-20	127
Giyanto	P 4-2	335
	P 5-6	362
GJERDE, Kristina	4-15-D	206
GLASSOM, David	2-1-B	75
GLEASON, Arthur	5-3	144
GLUMAC, Bosiljka	2-6	143
GLYNN FAHY, Elizabeth	4-21-A	57
GLYNN, Peter W	2-10-A	134
	1-2-A	189
	1-6-A	43
	1-8-A	83
GOCHFELD, Deborah J	1-4-B	169

Author	Session	Page	Author	Session	Page
HARDING, Simon P	P 4-1	404	HELMLE, Kevin P	P 2-8	268
HARDMAN, Emily	P 2-1	262		2-8-B	88
HARDY, Thomas A	2-11	220		2-8-B	89
HARE, Jonathan A	2-3-C	217	HELMUTH, Brian	P 2-4	315
HARII, Saki	3-5-B	108	HENDEE, James C	2-12	90
	2-10-A	136	HENDRY, Helen J	P 4-11	343
	1-2-B	225	HENMI, Sachi	P 2-8	271
	P 1-6	247	HEPBURN, Leanne J	P 2-1	258
	P 5-6	359	HERDIANA, Yudi	P 4-12	281
HARPER, Doug	P 4-14	395	HERMANSEN, Tyge D	4-3	14
HARRINGTON, Lindsay	1-2-B	227	HERNANDEZ, Erdwin A	P 4-2	330
HARRINGTON, Lindsay M	2-1-A	24	HERNANDEZ, Malva	P 1-1	304
HARRIS, Melanie	5-1	27	HERNANDEZ, Miguel	P 4-2	330
HARRIS, Melanie S	4-2-B	151	HERNANDEZ, Stephanie	P 4-1	408
HARRISON, Peter	1-2-A	188	HERNANDEZ, Xavier	1-4-A	166
HARRISON, Peter L	1-2-A	187	HERNANDEZ-LANDA, Roberto C	P 4-14	395
	1-2-B	225	HERNANDEZ-PECH, Xavier	P 1-9	252
HARROD, Chris	P 1-8	249	HERON, Mal L	3-5-A	107
HART, Deirdre	P 3-5	327	HERON, Scott F	3-5-A	107
HARVELL, C D	1-4-A	165		2-11	220
HARVELL, C Drew	1-4-A	167	HERRERA, Jorge A	P 4-2	333
	P 1-4	382	HERRERO-PEREZRUL, Maria Dinorah	4-12-A	37
HARVELL, Drew	2-3-C	216	HERZLIEB, Steven E	4-2-C	154
HASEGAWA, Hitoshi	P 4-18	351	HEUNG-SIK, Park	P 2-4	315
	P 4-1	405	HEVER, Brendan	1-1-A	139
HASEGAWA, Shiro	P 2-1	262	HEYWARD, Adnrew J	2-10-A	135
HASHIMOTO, Kazumasa	P 2-1	258	HEYWARD, Andrew	2-10-B	172
	P 4-3	276	HIBBERT, Marlon H	4-21-A	56
	P 2-3	313	HIBINO, Kohei	P 2-8	270
HASSAN, Moshira	P 4-1	404	HICKERSON, Emma L	4-2-B	152
	P 4-1	416		4-9	156
	4-1	62		P 4-2	331
HASTINGS, Alan	4-15-A	118	HICKEY, Donald	5-1	27
HATA, Akiko	P 2-8	270	HICKEY, T Donald	4-2-B	151
HATA, Hiroki	5-6	52	HIDAKA, Michio	1-1-A	140
HATA, Hiroshi	P 4-22	353		1-4-B	168
HATCHER, Bruce G	2-3-A	130		1-2-C	228
	2-1-B	74		P 1-9	253
	2-1-C	78		P 1-2	367
HATTA, Masayuki	P 1-1	302		1-9-B	70
	4-21-A	57	HIGA, Yoshimi	P 4-1	405
HATTORI, Akihisa	P 2-3	310	HIGUCHI, Tomihiko	P 2-12	322
HAWKINS, Christopher	4-8	235	HILL, Andrew	P 4-7	340
HAYAKAWA, Hideki	1-2-C	228	HILL, Jos	P 4-1	418
HAYASHI, Isao	P 4-21	288		4-1	64
HAYASHI, Naoki	1-2-B	227	HILL, Ronald L	4-25	203
HAYASHI, Tohru	P 4-22	353		4-12-B	94
HAYASHIBARA, Takeshi	5-3	144	HILL, Ross	2-12	91
	P 4-21	285	HILLARY, Annie I	4-6	17
	P 4-21	288	HIRATSUKA, Yuji	1-6-B	100
	P 3-6	390		P 5-6	357
	P 3-6	391		5-6	52
HAYES, Marshall	3-1	46	HIXON, Mark A	1-8-A	82
HAYES, Raymond	1-4-A	167	HIYAGON, Hajime	5-4	53
	3-1	46	HO, Mengfei	3-1	46
HAZRA, Amit L	P 2-1	258	HOANG, Phan K	P 4-7	340
HEARN, Clifford J	3-5-A	105		P 4-1	413
	P 3-5	327	HOARE, Ana M	P 4-2	332
	P 3-5	329	HOCHBERG, Eric J	5-1	28
HEATH, Dan	2-3-A	130	HODEL, Erin C	4-3	13
HEATH, Daniel D	2-3-B	163	HODGE, Jonathan	5-2	111
HEBERT, Pascal	P 2-3	314	HODGE, Sebastien	1-1-A	139
HECKMAN, Mark B	4-24	222	HODGSON, Gregor	P 4-1	418
HEIMANN, Kirsten	P 5-6	360		4-1	64
HEINONEN, Kari	P 5-5	355		4-23	96
HEISS, Georg A	P 4-1	404	HOEG, Jens T	P 1-6	242
	P 4-1	416	HOEGH-GULBERG, Ove	1-9-B	69
	4-1	62	HOEGH-GULDBERG, Hans	2-11	221
HELLBERG, Michael E	2-3-C	215	HOEGH-GULDBERG, Ove	4-2-A	125

Author	Session	Page	Author	Session	Page
HOEGH-GULDBERG, Ove	1-5	133	HUGHES, Terence P	2-1-A	23
	2-10-B	172		2-1-A	24
	3-4	192	HUI, Huang	P 4-15	347
	1-9-A	20		P 4-1	416
	1-9-A	21		4-1	62
	2-11	221	HUNTER, Cynthia L	4-24	223
	P 1-4	381	HUTCHINGS, Patricia A	1-5	132
	2-12	92	HUZAIMI TAJUDDIN, Badrul	P 4-1	401
	3-5-B	109	HWANG, Shen	1-6-B	99
	2-12	90	HWANG, Sung-Jin	4-21-B	116
5-2	110		1-2-A	187	
HOEKE, Ron	P 2-3	310	I		
HOEKE, Ron K	2-1-C	77	IBARRA, Roberto	P 4-21	284
HOEKE, Ronald	1-6-B	100		P 4-2	332
HOEKSEMA, Bert W	2-5	113	IBRAHIM, Rahmat	4-20	128
	P 1-1	303	IDIP JR, David	P 5-6	359
	2-1-B	74		P 4-1	404
	2-3-A	130	IDIP, D	1-9-B	68
	2-3-A	130	IDIP, David	P 1-2	369
HOEY, Andrew S	4-24	223	IGARASHI, Takeshi	P 4-1	405
HOFFMANN, Tegan C	2-3-B	162	IGLESIAS-PRIETO, Roberto	1-4-A	166
HOGAN, J Derek	P 1-6	247		2-10-B	172
HOHENEGGER, Johann	1-8-A	81		2-9	176
HOLBROOK, Sally J	1-8-A	82		P 1-9	252
	1-8-A	83		1-9-B	69
HOLDERIED, Kristine	5-2	111	IIDAI, Taku	4-13	200
HOLLINGSWORTH, Lea L	1-2-A	189	IJIMA, Hiroko	P 2-8	268
	1-2-C	228	IIZUKA, Hiroyasu	3-5-B	108
HOLMES, Andrew J	1-9-A	18	IKEDA, Atsushi	P 4-21	286
	4-15-A	118	IKEDA, Emiko	P 2-4	315
HOLMES, Katherine E	4-15-B	120	IKEDA, Yutaka	3-6	231
	2-1-A	22		P 4-22	353
	P 2-3	311	IKEMA, Takeharu	P 5-1	289
HOLMSTROM, Carola	P 3-1	272		5-1	29
HOLT, Ashley	4-15-C	147	IMAGAWA, Shuzo	1-2-C	228
HOLZWARTH, Stehani R	4-3	15		P 1-9	253
HOLZWARTH, Stephani R	4-2-B	152	IMAHARA, Yukimitsu	P 1-1	302
HONDOU, Yasushi	P 2-3	311	IMENIS, Juliana	P 1-6	246
HONEBRINK, Randy	4-24	223	INABA, Makoto	P 2-10	320
HONGO, Chuki	P 2-4	315		P 1-2	367
HOOGENBOOM, Mia	P 2-1	255		P 4-1	405
HOON, Vineeta	4-5	183	INAGAKI, Miyuki	2-7	33
HOOPER, John N A	1-6-A	43	INAGAKI, Shizue	2-7	31
HOOTEN, Anthony J	P 4-19	352	INNES, James	4-15-D	206
HOOTEN, Russell	3-3	49		4-15-D	207
HORI, Nobuyuki	2-7	31	INOUE, Mayuri	P 4-3	276
	P 2-4	317		3-3	49
HORIKOSHI, Kazuo	P 2-10	320	INVOLTI, Marco	1-2-A	187
	P 1-2	367	IRIKAWA, Akiyuki	1-4-B	168
HORINOUCI, Masahiro	2-3-B	163		P 4-1	405
HOSHINO, Naoko	P 2-1	262	IRIYAMA, Keiko	P 5-6	361
HOSSAIN, Mirza M M	2-9	177	IRYU, Yasufumi	P 2-7	264
HOULBREQUE, Fanny	3-4	191		P 2-7	265
	3-4	192		P 2-7	266
HOURIGAN, Thomas F	4-12-B	93		P 2-8	269
HOWARD, Edward G	P 5-1	289		2-7	31
HOWITT, Libby	P 2-3	312		P 2-4	315
HSIEH, Hernyi	P 4-1	401		P 2-4	316
HSIEH, Hwey-Lian	1-6-B	101		2-7	34
HUBBARD, Dennis K	2-6	143		2-8-B	87
HUDSON, J Harold	2-1-A	25	ISA TANZIL, Jani T	P 4-21	285
HUDSON, James H	4-21-A	54	ISA, Yeishin	P 1-6	242
HUDSON, Marco	P 1-6	247		P 1-6	245
	P 5-6	356	ISDALE, Peter J	P 2-8	269
HUFFARD, Christine L	1-6-B	101	ISHIGAMI, Kenji	3-5-B	108
HUGHES, Alec T	P 4-1	398	ISHIHARA, Yasufumi	P 3-5	328
HUGHES, Julian	2-3-A	131	ISHIKAWA, Kyoko	5-6	52
HUGHES, Terence P	1-6-C	102			
	4-5	181			
	1-2-C	229			

Author	Session	Page
ISHIKAWA, Y	3-4	192
ISHIKAWA, Yoshio	P 3-6	390
ISOMURA, Naoko	P 1-1	302
IWAHARA, Lisa	P 1-8	249
IWAI, Kenji	1-9-A	19
IWAO, Kenji	4-3	13
	4-3	14
	1-2-B	225
	P 1-9	253
	P 3-3	274
	P 4-21	285
	P 4-21	288
	P 5-3	296
	P 1-1	302
	P 4-1	405
	4-21-A	57
IWASAKI, Akira	P 5-1	291
IWASAKI, Seiji	P 3-3	274
IWASE, Akihiro	2-10-A	135
	P 2-4	316
IWASE, Fumihito	P 4-22	353
	P 4-1	405
IWASHITA, Tsutomu	P 4-21	286
J		
J R B, Alfred	P 4-1	400
JAAP, Walter C	4-9	157
JACINTO, Rita	P 1-3	376
JACKSON, Jeremy B C	4-5	181
JACQUET, Severine	3-4	191
JACUKIEWICZ, Jennifer A	P 4-7	340
JAGO, Belinda	4-15-D	206
	4-15-D	207
JAMAL, Yousef	P 1-5	306
JAMESON, Stephen C	4-2-A	125
	4-9	156
JARA, Javier	P 1-1	304
JARAYABHAND, Padermsak	1-6-B	101
	1-9-B	69
	1-6-B	99
JARECKI, Lianna	1-8-B	85
JATULAN, William	4-6	16
JAUBERT, Jean	P 2-9	386
JAYAKUMAR, Kannan	P 5-3	295
JAYEWARDENE, Danielle	4-15-B	121
JE, Jong-Geel	P 4-1	405
	P 4-1	416
	4-1	62
JEFFREY, Chris	4-14	211
JEFFREY, Christopher F G	4-9	156
JEFFS, Andrew	2-3-B	163
JENG, Ming-Shiou	1-6-A	41
JENKINS, Aaron P	4-15-D	208
JENNINGS, Kylie	4-24	224
JENNINGS, Simon	4-5	181
JENNIONS, Michael	2-1-A	23
JEYABASKARAN, R	1-4-B	171
	4-16	179
JIDDAWI, Narriman	4-11	160
JIM, Kloulechad	P 1-2	369
JIMBO, Mitsuru	1-9-A	19
JIMENEZ, Carlos	P 2-1	256
	P 2-1	257
JIMENEZ, Juan M	1-5	132
	2-10-B	173
JOHNSON, Kenneth G	2-6	143
JOHNSSON, Rodrigo	P 1-6	242
	P 1-6	244

Author	Session	Page
JOHNSTONE, Ron	P 1-3	373
JOKIEL, Paul	2-2	195
JOKIEL, Paul L	2-2	195
	4-21-A	55
JOMPA, Jamaluddin	4-20	128
JONES, Geoffrey	2-3-B	164
JONES, Geoffrey P	2-3-A	130
	4-14	213
	2-3-C	217
	1-8-B	85
JONES, Ian S F	2-2	194
JONES, Loureene A	P 4-1	416
	4-1	62
JONES, Roger	2-11	220
JONES, Ross J	3-4	192
	P 1-4	381
	3-3	48
JONES, Willam B	P 5-1	292
JONES, William B	P 5-1	292
JORDAN, E	P 1-4	382
JORDAN, Lance K B	4-9	157
	4-12-B	94
JOUON, Aymeric	3-5-B	108
	P 3-5	327
	P 3-5	328
JOYCE, Karen	5-1	28
JOYCE, Karen E	P 5-1	290
	P 5-1	291
JOYEUX, Jean	5-6	51
JUERGENS, Lars	P 1-6	242
JUINIO-MENEZ, Ma Antonette R	P 4-8	394
JUINIO-MENEZ, Marie Antonette	4-14	214
	P 4-5	338
JUNCKER, Matthieu	P 2-1	259
	2-1-B	75
JUNTARUK, Napalai	P 2-1	259
JUPITER, Stacy D	4-25	204
JUPP, David L B	P 5-1	290
K		
KAANDORP, Jaap A	3-5-A	106
KACZMARSKY, Longin T	1-4-B	170
KADEKARU, Eiko	4-13	201
KAERIYAMA, Masami	1-9-A	19
KAHNG, Samuel E	5-6	51
KAJIWARA, Kenji	P 4-8	393
	P 4-1	405
KAKUMA, Shinichiro	2-3-B	162
	4-13	200
	P 5-6	359
KAKUTA, Satomi	P 5-1	293
KALOMBO, Hassan J W	4-12-A	39
KAMBER, Balz S	4-25	204
KAMEI, Yoshiaki	4-24	223
KAMEL, Haidy N	P 1-6	245
KAMIKI, Takayuki	P 3-2	325
KAMIMURA, Masahito	5-6	52
KAMIYA, Hisao	1-9-A	19
KAMIZATO, Mamoru	P 4-21	286
KAMU, Irene	4-15-D	207
KAMUKURU, Albogast	4-11	160
KAN, Hironobu	P 2-8	269
	2-7	32
KAN-ATIREKLAP, Supawat	P 5-3	296
KANDEL, Frederique	1-6-C	103
KANENO, Hirokazu	P 3-1	272
KANG, Rae S	P 1-6	244
KANNO, Susumu	P 3-5	327

Author	Session	Page	Author	Session	Page
KAPPEL, Carrie	4-15-A	118	KIKUCHI, Ruy K P	2-8-B	89
KAPPEL, Carrie V	4-15-B	120	KIKUCHI, Yuji	4-13	201
	4-5	181	KIM, Kiho	1-4-A	167
	2-1-A	22		P 1-4	381
KARLSON, Ronald H	2-1-A	23	KIMURA, Tadashi	3-5-B	108
KARUNARATHNE, Chaminda	P 4-1	410		P 4-1	405
KASFIKI, Sofia E	P 4-2	332		P 4-1	416
KASSEM, Ken	4-15-D	207		4-1	62
KASSEM, Kenneth R	P 5-2	294	KIMURA, Tetsuya	P 3-3	274
KATO, Ken	5-3	144	KINANE, Sean W	3-5-A	107
	P 4-16	350	KING, William	P 4-9	342
KATO, Tohru	P 4-16	350	KINGSFORD, Michael J	2-3-A	131
KATOH, Masaya	2-3-C	215	KINGSTON, Bruce	4-15-D	206
KATSUMATA, Masaharu	P 5-6	361		4-15-D	207
KAUFMAN, Les	2-1-C	78	KINLAN, Brian P	4-15-C	146
KAUNDA-ARARA, Boaz	4-11	160	KINOSHITA, Shigenobu	P 5-1	293
KAWABATA, Maki	4-13	200	KINTZING, Elizabeth	1-8-B	85
KAWAHATA, Hodaka	P 1-9	253	KINZIE, Robert A	1-9-C	73
	P 2-8	270	KIRATA, Taratau	P 4-1	405
	P 4-3	276		P 4-1	415
	P 3-2	325		4-1	61
	3-3	49	KISO, Katsuhiko	2-3-C	215
	2-8-B	87	KITA, Masaki	P 5-6	358
KAWANA, Toshio	P 2-8	269	KITADA, Yukio	2-9	178
	2-7	32		P 3-2	325
KAWASAKI, Hiroyuki	2-3-B	163		P 2-9	387
	P 2-10	321	KITAGAWA, Hiroyuki	P 2-8	267
KAWASAKI, Tadayuki	5-3	145		P 2-8	270
KAYANNE, Hajime	5-2	111	KITALONG, Ann	4-3	14
	2-10-A	136		P 4-5	338
	2-9	178	KITAMURA, Kyoko	2-6	142
	4-16	179	KITAMURA, Makoto	P 5-6	358
	4-16	180	KITAMURA, Yasushi	3-5-B	108
	4-25	205		3-5-B	109
	1-2-B	225		P 3-5	328
	P 2-8	268	KIYASHKO, Serguei I	P 1-8	250
	P 2-8	270	KLANTEN, Selma O	1-6-B	100
	P 2-4	315	KLAUS, James S	P 2-1	259
	P 4-16	350		3-1	47
	P 4-22	353	KLAUS, Jim	3-1	46
	P 5-6	356	KLAUS, Rebecca	4-2-B	152
KAZCMARSKY, Longin	1-4-B	170		P 2-1	262
KEELY, Brendan J	1-9-B	70	KLEIN, Eduardo	P 4-1	402
KELLER, Brian D	4-9	157	KLEYPAS, Joan	2-1-A	23
	4-18	79	KLIN, D	P 1-9	251
KELLOGG, Christina A	P 3-1	272	KLIN, Davey	3-1	46
KELMANSON, Ilya V	P 1-3	372	KLIN, David I	3-3	48
KELTY, Ruth	4-9	156	KLOULCHAD, Valentino	4-11	159
KENCH, Paul S	P 3-5	327	KLUETER, Anke	2-12	92
	2-7	33	KNOWLTON, Nancy	1-6-B	101
KENCHINGTON, Ellen L	P 5-4	298		1-1-A	139
KENDALL, Matt	4-14	211		1-1-B	184
KENDALL, Matt S	P 4-4	337		P 1-9	251
KENWORTHY, W Judson	4-20	127		P 1-1	301
KENYON, Jean	P 1-2	366		P 1-1	304
	2-1-C	77		3-1	46
	2-12	90		3-3	48
KENYON, Jean C	2-10-A	135	KOBAYASHI, Masato	P 1-2	367
KERR, Alex M	2-1-B	75	KOBAYASHI, Miyako	P 2-3	310
KERR, Alexander M	1-1-A	139	KOBAYASHI, Noriko	P 1-2	367
KERSWELL, Ailsa P	1-6-C	102	KOBAYASHI, Takashi	5-6	52
KHALAF, Ibtisam A	P 4-3	276	KOCHZIUS, Marc	P 1-6	243
KHALAF, Maroof A	P 4-2	333		P 4-2	333
KIENE, William	4-8	234	KOETTER, Iris	1-7	104
KIKUCHI, Ruy K P	P 4-21	287	KOHLER, Kevin	2-10-B	174
	P 2-10	321	KOHLER, Kevin E	P 2-8	268
	P 4-2	331		P 4-21	285
	P 2-2	385		P 4-9	342
	P 4-1	406	KOHN, Alan J	1-6-A	43

Author	Session	Page
KOIKE, Isao	P 3-6	390
	P 3-6	391
KOIKE, Kazuhiko	1-9-A	19
KOJA, Keiko	4-13	201
KOJIMA, Syoutirou	2-3-B	162
KOJIS, Barbara	P 4-11	344
KOJIS, Barbara L	1-2-B	227
	P 3-1	273
	P 2-2	385
	P 4-1	409
KOLINSKI, Steven P	4-21-A	55
KOMEMUSHI, Sadawo	P 3-1	272
KONGJANDTRE, Narinratana	P 1-3	373
KONOW, Nicolai	1-6-C	102
KOO, Bon Joo	P 4-1	405
KOOL, Johnathan T	4-14	211
KOONJUL, Meera	P 4-1	417
	4-1	63
KOOP, Klaus	P 1-3	373
KOSMININ, Vladimir	P 4-2	330
KOSMYNIN, Vladimir N	4-20	127
	P 4-21	286
KOSNIK, Matthew A	1-6-A	41
KOSUGA, Keiyuu	P 5-6	358
KOTB, Mohammed M A	P 4-1	416
	4-1	62
KOUCHI, Naoko	4-25	205
KOUCHI, Shigeru	5-6	51
KOULECHAD, Jim	P 4-1	404
KOURAFALOU, Villy	3-5-A	106
KOYAMA, Tomoyuki	P 5-6	358
KOZIUMI, Noriko	P 3-1	272
KRAJEWSKI, Joao P	P 5-6	356
	P 5-6	358
	P 5-6	360
KRAMARSKY-WINTER, Esti	3-1	47
	3-3	50
KRAMER, Phillip	4-15-A	118
KRAMER, Phillip A	5-3	144
	2-1-A	22
	P 2-1	258
KRAMER, Phillip A	P 4-2	330
KRANENBURG, Christine	5-2	112
KRITZER, Jacob P	2-3-B	163
KRITZER, Jake	2-3-A	130
KRONEN, Mecki	4-5	182
	4-5	183
	P 4-5	339
	P 1-3	373
	P 1-3	374
	4-12-B	95
KRUGER, A	4-2-B	153
KRUPP, David A	1-2-A	189
	1-2-C	228
KRUPP, Friedhelm	P 4-1	399
	1-8-B	84
KUARTEI, Jason	4-11	159
	P 4-1	415
	4-1	61
KUBOTA, Shin	1-6-A	42
KUCHINOMACHI, Makoto	4-21-A	57
KUEHL, Jennifer	P 1-1	303
KUFFNER, Ilsa	P 2-1	256
	5-1	27
KUFFNER, Ilsa B	4-2-B	151
KUGURU, Baraka L	P 2-12	322
KUHL, Michael	2-12	91
KUHLMANN, Kai-J	4-15-E	236
KUHNERT, Henning	P 2-8	267

Author	Session	Page
KULBICKI, Michel	4-11	160
	4-5	183
	P 1-3	373
	P 1-3	374
	4-12-B	95
KULHANEK, Emmanuelle	P 2-12	323
KUMAGAI, Wataru	3-5-B	108
	2-10-A	136
	4-25	205
KUMARA (FRANSISCU BDUGE), Terney Pradeep	4-12-A	38
KUMARAGURU, Arumugam Kuppusamy	P 5-3	295
KUNIYOSHI, Midori	4-13	201
KUNTZ, Neilan	3-3	48
KUNZMANN, Andreas	P 4-11	343
KUO, Fu-Wen	1-2-A	187
KURAHASHI, Shunsuke	P 4-21	286
KURING, Norman	5-2	112
	4-15-C	147
KURITA, Naoyuki	P 5-6	356
KUROSAWA, K	3-4	192
KURTEN, Martina	P 4-1	402
KUSAKABE, Minoru	5-4	53
KUSEN, Janny D	4-13	202
KUSHMARO, Ariel	3-1	47
KUTSER, Tiit	5-3	144
	P 5-1	290
L		
LABORDE, Ivette	P 1-3	373
LABROSSE, Pierre	4-5	183
	P 1-3	373
	P 1-3	374
	4-12-B	95
LADLE, Ricahrd J	P 1-1	304
LADLE, Richard J	1-1-B	184
LAGES, Bruno G	P 4-4	336
LAJEUNESSE, Todd	1-9-B	69
LAJEUNESSE, Todd C	1-9-A	18
	1-9-A	19
	1-9-A	21
	P 1-9	251
LAM, Kahterine K	1-9-B	69
LAM, Katherine K	1-6-B	101
LAMMERS, Marc	2-1-C	77
LANG, Judith C	2-1-A	22
	4-24	222
	P 2-1	258
	P 4-3	276
	P 4-2	330
	P 4-2	333
	2-9	176
LANGDON, Chris	2-9	178
LANGDON, Christopher	P 3-4	389
LANGLADE, Marie-Jose	4-3	13
LAPOINTE, Brian E	P 1-3	373
LARKUM, Anthony	2-12	91
LARKUM, Anthony W	2-12	91
LARKUM, Tony	4-5	182
LASKER, Howard R	P 2-10	320
LATERVEER, Michael	P 4-21	287
	P 4-22	354
LATHUILIERE, Bernard	P 1-1	302
LATUMBO, Maria Zoe C	P 4-8	392
LAUGHLIN, Joe L	4-2-B	152
LAUGHLIN, Joseph L	P 4-1	411
LAVIDES, Margarita N	4-15-D	207
	P 4-15	347

Author	Session	Page	Author	Session	Page
LAWRENCE, Loretta A	P 4-3	276	LIN, Ting Pong	1-2-A	188
LAWSON, Gregory	2-6	143	LINDEMAN, Ken	4-11	160
LAWTON, Angela	3-4	192	LINDEN, Olof	4-12-A	38
LAZAR, Boaz	2-9	177		P 4-1	412
	P 4-3	278		P 4-1	418
LE RENARD, Jacques	P 4-12	280		4-1	63
LEAL, Flavia	P 1-6	246	LINS DE BARROS, Monica M	P 1-2	368
LEAO, Zelinda	P 4-1	415	LINTON, Dulcie M	P 4-1	406
	4-1	61		P 4-1	416
LEAO, Zelinda M	P 4-1	406		4-1	62
LEAO, Zelinda M A N	P 4-21	287	LIPSCHULTZ, Fred	3-5-A	105
	P 2-10	321	LIPSCHULTZ, Fredric	3-5-A	106
	P 4-2	331	LITAKER, R W	P 1-9	251
	P 2-2	385	LITTLE, Angela	1-9-A	21
	2-8-B	89	LITTLEWOOD, D Timothy	1-6-A	44
LEBERER, Trina	P 4-12	280	LIU, Chunying	5-2	110
LECCHINI, David	2-3-B	164		2-11	219
LECLERCQ, Nicolas	P 2-9	386	LIU, Gang	5-2	110
LECLERE, Lucas	1-6-A	42		2-11	219
LECOMTE-FINIGER, Raymonde	P 2-3	312		2-12	90
LECORNEC, Florence	2-8-A	35	LIU, Li-Lian	4-2-B	151
LEDESMA, Micaela	P 2-1	262	LIU, Pi-Jen	P 1-2	368
LEDESMA, Micaela C	2-10-A	136	LIU, Shang-Yin Vanson	1-1-B	186
LEDREW, Ellsworth F	5-1	29	LIVIKO, Ian	4-8	234
	P 5-1	290	LLEWELLYN, Ghislaine	4-15-D	207
LEE, Hung-Jen	P 2-2	385		P 5-2	294
LEE, Tom	3-5-A	106	LLOYD, John	P 4-7	340
LEGGAT, Bill P	P 2-12	323	LOBEL, Phillip S	4-17	137
LEICHTER, James J	3-5-B	109	LOCH, Karen	2-10-B	173
LEIS, Jeffrey M	2-3-B	163	LOCH, Wolfgang	2-10-B	173
LENIHAN, Hunter S	3-5-A	106	LOCKE, Jean	P 1-1	304
LEON, Alberto	P 2-1	256	LOGAN, Joshua B	2-2	195
LEONG, Jo-Ann C	1-4-B	168	LOH, Tse Lynn	P 4-21	285
	1-2-C	228	LOH, Tse-Lynn	5-1	27
LEQUEUX, Didier	P 4-4	336		4-21-A	54
LESCINSKY, Hal	2-1-A	23	LOH, William	1-9-B	68
LESSIOS, Harilaos A	1-6-A	45	LOH, William K W	1-9-A	21
LESTER, Sarah E	1-3	198	LONG, Nguyen V	P 4-7	340
LEVITAN, Don R	1-1-B	184		P 4-1	413
LEVY, Oren	2-9	176	LONGENECKER, Kenneth	1-6-C	103
	1-9-C	72	LONGO, Leila L	1-1-B	185
LEWIN-KOH, Nicholas J I	1-1-B	184		P 1-6	244
	P 1-1	304	LONGSTAFF, Ben	5-2	111
LEWIS, Adam	4-15-D	207	LOPEZ-PEREZ, R Andres	1-6-A	43
LEWIS, Sara M	1-2-C	229	LOPEZ-RIVERA, Maria Del Mar	P 4-15	348
LEWIS, Teresa D	1-4-B	168	LOTT, Christian	5-1	28
	1-2-C	228	LOTTO, Severine	P 3-2	325
LEWMANOMONT, Kanjanapaj	P 5-6	359	LOUGH, Janice	2-1-A	23
LI, Vincent	P 4-4	337	LOUGH, Janice M	2-9	177
LIANGMIN, Huang	P 4-15	347		2-8-A	35
LIAO, Pei-Jun	1-6-B	99		P 2-9	386
LICUANAN, Wilfredo R Y	4-14	214	LOUIS, Max	P 4-1	400
LICUANAN, Wilfredo Y	4-2-B	151	LOURIE, Sara A	2-5	113
	P 4-1	407	LOWE, Dave	4-15-D	207
LIDDLE, Larry B	P 1-3	374	LOWRY, Kem	4-6	16
LIDZ, Barbara H	P 4-2	332	LOYA, Yossi	2-10-B	173
LIEN, Yi Ting	1-6-B	101		3-1	47
LIEN, Yi-Ting	1-9-B	69		3-3	50
LIM, Alan H	P 5-1	290		2-8-B	87
LIM, May T	2-5	114	LO-YAT, Alain	2-3-C	217
	P 4-14	395	LOZOUET, Pierre	1-6-A	41
LIN, Ho-E	1-6-B	101	LUCKHURST, Brian	P 4-1	409
	1-9-B	69	LUCKHURST, Brian E	4-11	161
LIN, Ho-I	1-1-A	141	LUGO, Miguel A	4-9	157
	P 1-1	301		P 1-4	382
	P 1-1	305		P 4-24	396
	1-6-B	99	LUNDQVIST, Mats L	P 1-4	382
LIN, Ke-Han	1-2-A	187	LUNKAPIS, Gaim	4-2-C	155
	P 1-2	368	LUO, Hongli	P 4-14	395

Author	Session	Page
LYNCH, Tara	P 4-1	417
	4-1	63
LYONS, Sarah C	4-15-D	206
M		
M, Venkatesh	P 3-3	274
MABROUK, Ayman	4-12-A	36
MACDONALD, Angus H H	P 1-1	302
MACDONALD, Iain A	P 1-5	306
	3-3	49
MACHADO, Altair J	2-8-B	89
MACHIYAMA, Hideaki	P 2-6	319
MACINTYRE, Ian G	3-5-B	109
	2-1-A	22
MADRID, Renata Rivera	P 2-3	312
MAEDA, Yasunobu	P 2-4	316
MAEDA, Yasuo	2-7	33
MAEHARA, Hiromi	4-21-A	57
MAEKAWA, Satoshi	P 4-18	351
MAEMOKU, Hideaki	P 2-4	316
MAENOSONO, Takefumi	P 5-6	361
MAGHSOUDLOO, A	P 4-1	403
MAGHSOUDLOU, A	P 4-1	416
MAGHSOUDLOU, Abdolwahab	P 3-3	274
MAGNO, Marites M	P 4-15	348
MAGRON, Franck	4-5	183
	4-12-B	95
MAGSINO, Richard M	2-3-C	215
MAGUER, Jean-Francois	P 3-6	390
MAHARAVO, Jean	P 4-1	417
	4-1	63
MAIDA, Mauro	4-12-A	38
	P 4-1	403
MAIDENS, Jon	5-2	112
	P 4-14	395
MAIER, Conny	3-6	230
MAINA, Joseph	4-8	234
MAJEWSKI, Michael S	P 3-1	272
MAKAIAU, Jarad	4-12-A	40
MAKAIAU, Jarad L	4-12-B	93
MAKOLOWEKA, Solomon J	4-12-A	39
MALAVAR, Nora	P 1-4	380
MALAY, Maria Celia D	P 1-6	243
MALDONADO, Adrian	P 4-2	333
MALLELA, Jennie	1-5	132
	P 1-8	249
MALVADKAR, Urmila	4-15-A	118
MAMAUAG, Samuel S	4-5	182
MAMONTO, Dennie	4-13	202
MANELE, Bruno K	P 4-8	393
MANFRINO, Carrie	P 2-1	259
	P 4-9	342
MANGI, Stephen	4-8	234
MANGION, Perrine	1-6-A	42
MANGUBHAI, Sangeeta	1-2-A	188
MANICA, Andrea	P 4-11	343
	4-7	66
MANOHAR, Chitra	1-9-C	71
MANRIQUE, Nelson A	P 4-2	333
	P 4-1	400
MANTHACHITRA, Vipoosit	P 1-3	372
	P 1-3	373
MANZELLO, Derek	2-12	90
MAPSTONE, Bruce D	4-5	182
MARAGOS, James E	4-17	137
	2-9	177
	P 1-6	243
	P 5-6	361

Author	Session	Page
MARCHIORO, Gabriel B	4-3	15
MARCOS, Ma Sheila Angeli C	5-3	144
MARIBOJOC, Wilson	4-15-E	237
MARIE, Dominique	1-7	104
MARIN, Sylvia	4-15-B	120
MARION, Guy	4-25	204
MARION, Guy S	3-6	231
MARKS, Alan	5-2	111
MARNANE, Michael J	4-8	234
	P 4-12	281
MARQUES, Luciana	P 1-6	246
MARQUIS, Christopher P	P 3-1	272
MARSH, K Erica	1-4-B	169
MARSH, Loiset M	4-2-A	126
MARSHALL, Justin	4-24	224
MARSHALL, Nadine A	4-5	183
MARSHALL, Paul	4-15-C	146
	2-11	219
MARTIN, Laura E	1-6-B	101
	1-6-B	99
MARTINEZ, Robert	1-4-A	167
MARTINEZ, Silvia	P 1-8	248
MARTIN-GARIN, Bertrand	P 1-1	302
MARUYAMA, Tadashi	1-9-A	19
	P 1-9	253
MARX, Danilo	P 4-1	403
MASON, Benjamin M	P 4-3	278
MASON, Lou B	2-11	220
MASUIKE, Aya	P 4-2	334
MASUMOTO, Takashi	P 4-21	286
MASUNAGA, Naoto	P 2-4	317
MATE, Juan L	2-10-A	134
	P 4-2	333
MATHEWS, G	P 4-21	284
MATSUDA, Hiroki	P 2-1	262
	P 2-7	266
MATSUDA, Hiroyuki	P 5-3	296
MATSUDA, Shinya	P 1-6	243
MATSUDA, Tomonari	P 3-3	274
MATSUI, Saburo	P 3-3	274
MATSUI, Yohei	P 2-8	268
MATSUMOTO, Eiji	P 2-8	269
MATSUMOTO, Hisashi	P 4-8	393
MATSUMOTO, Sadayoshi	P 3-1	272
MATSUMOTO, Takashi	P 4-1	405
MATSUNAGA, Tadashi	P 1-4	384
MATSUNAGA, Tsuneo	5-1	29
	P 5-1	291
MATSUOKA, Takeshi	2-3-B	162
MATSUZAKI, Hiroyuki	P 2-8	268
MATTHEWS, Kathryn	1-3	197
MATTHEWS, Kathryn A	P 2-8	269
MATZ, Mikhail V	P 1-3	372
MAY, Anita S	1-2-A	189
MAYPA, Aileen P	P 4-21	288
	P 4-4	337
MAZEL, Charles H	1-2-B	225
	P 5-3	295
MAZZOLI, Claudio	P 2-8	269
MBIJE, Nsajigwe	P 4-1	407
MCCABE, Jennifer	P 1-9	251
MCCAFFREY, Mark S	4-24	222
MCCARTNEY, Michael M	P 1-1	303
MCCLANAHAN, Tim	2-10-B	175
	4-8	234
MCCLANAHAN, Tim R	4-8	234
MCCOOK, Laurence	4-15-C	146
	4-7	65
MCCOOK, Laurence J	2-10-B	172

Author	Session	Page	Author	Session	Page
MCCORMICK, Mark I	2-3-A	130	MIEOG, Jos C	1-9-B	68
	1-2-C	229	MIKI, Wataru	P 3-1	272
	1-8-B	85	MILL, Aileen C	4-5	181
MCCORRY, Denise	4-12-A	37	MILLER, Cheryl L	P 4-21	286
	P 4-1	402	MILLER, Dean K	4-5	183
	4-21-A	56	MILLER, Ian	P 5-1	290
MCCORRY, Denise M	P 4-4	337		P 4-1	402
MCCULLOCH, Malcolm	P 2-8	269	MILLER, Jeff	4-2-C	154
MCCULLOCH, Malcolm T	P 2-8	267		1-4-C	218
	P 5-5	355	MILLER, Joyce	P 5-2	294
MCDONALD, Abbi	2-10-B	172	MILLER, Joyce E	2-1-C	77
MCDONOUGH, William F	P 2-8	269	MILLER, Karen J	2-3-C	215
MCFADDEN, Catherine S	1-1-B	186	MILLER, Margaret W	2-3-A	131
MCFIELD, Melanie	4-15-D	207		1-4-B	169
MCFIELD, Melanie D	4-15-B	120		2-3-C	215
	4-2-B	151		P 4-2	335
MCGARRITY, Cheryl	4-2-C	154		P 1-2	370
MCGARRITY, Cheryl J	4-2-C	154		P 1-4	382
MCGINNITY, Peter	4-15-D	206	MILLS, Deetta K	1-4-A	165
MCGLONE, Doug H	2-5	114		1-4-A	167
MCILWAIN, Jennifer L	4-11	159		P 1-4	383
MCKENNA, Sheila A	4-15-C	146	MILOH, Tuvia	4-21-A	54
MCLAUGHLIN, Sandra	4-15-A	118	MINAGAWA, Megumi	P 4-21	285
MCLAUGHLIN, Shawn	P 1-4	382	MINAMI, Yosuke	4-16	179
MCLAUGHLIN, Shawn M	P 1-4	382	MITCHELL, Alan	4-18	80
MCLEAN, Roger F	2-7	32	MITCHELL, James G	P 3-1	272
MCMANUS, John	4-15-A	118	MITCHELL, Rebecca E	4-12-A	37
	P 4-12	281	MITSUBUCHI, Takehiro	P 2-8	267
MCMANUS, John W	4-14	211		P 2-8	269
	4-14	214	MITSUHASHI, Masako	P 1-6	244
MCNEILL, Donald F	P 2-1	259	MITSUMI, Jun	3-5-B	108
MCNUTT, Chad A	2-3-C	216		2-10-A	136
MCTEE, Sarah A	P 2-1	260		4-25	205
MEADOWS, Melissa G	2-3-B	162	MIWA, Takashi	P 2-8	269
MEDINA, Monica	P 1-1	303	MIYAJIMA, Toshihiro	P 3-6	390
	1-9-C	71		P 3-6	391
MEDINA-HERNANDEZ, Alicia C	P 2-1	260	MIYAMOTO, Yasuaki	P 4-1	406
MEEKAN, Mark	4-12-A	36	MIYASATO, Seiyuu	P 4-21	286
MEEKAN, Mark G	2-3-B	163	MIYAZATO, Hitoshi	P 4-9	342
	2-3-C	217	MIYAZAWA, Yasumasa	2-3-B	162
MELIANE, Imen	P 4-2	334		P 5-6	359
MEMBRILLO-VENEGAS, Nestor	4-15-B	119	MIZOGUCHI, Tadahiro	4-21-A	57
	4-14	213	MOFFITT, Russell	2-12	90
	P 2-1	255	MOFFITT, Russell A	5-2	110
MENDEZ, Eugenio R	1-9-B	69	MOHAMED, Fairouz	P 4-4	337
MENDONCA, Vanda M	P 4-21	283	MOHAMMED, Eiman K	P 4-1	403
MENESES, Anna B	P 4-15	349	MOHAMMED, Mohammed S	P 4-1	406
MENEZ, Marie Antonnette J	2-3-C	215	MONACO, Mark	4-14	211
MENG, Pei-Jie	P 2-2	385		P 5-2	294
MERLE, Pierre-Laurent	P 2-12	323	MONACO, Mark E	4-9	156
	2-12	91	MONACO, Mark M	P 4-4	337
MERRIFIELD, Mark	3-5-B	109	MONDON, Thomas	5-6	52
MERRIFIELD, Mark A	3-5-A	105	MONGER, Bruce C	5-2	111
MESSING, Charles G	P 5-4	297	MONK, Lisa A	P 4-3	276
MEUNIER, Sabrina	P 4-1	417	MONSATO, Dewey	4-15-E	237
	4-1	63	MONTAGGIONI, Lucien F	2-8-A	35
MEUSEL, Michael	P 1-1	302	MONTAGNA, Paolo	P 2-8	269
MEYER, Christopher P	1-6-A	44	MONTEL, Yves	3-4	192
	2-8-B	87	MONTGOMERY, Anthony D	4-12-A	37
MEZAKI, Shigekazu	P 5-6	359	MONTY, Jamie A	4-21-B	115
MEZAKI, Takuma	P 1-6	246	MOORE, Abigail M	P 4-24	396
MFILINGE, Prosper L	4-18	80		P 4-1	407
MICHELI, Fiorenza	4-15-A	118		P 4-1	414
	4-15-B	120	MOORE, Jon	P 5-5	355
	4-5	181	MOOTHIEEN PILLAY, Kamla R	P 2-10	321
	2-1-A	22	MOOTS, Kate A	P 5-6	362
	1-8-B	85		P 4-1	411
MICLAT, Evangeline	4-15-D	207	MORA, Camilo	1-6-C	103
MICLAT, Evangeline B	4-15-D	208		2-3-B	162

Author	Session	Page
MORA, Camilo	2-3-C	217
MORADI, M	P 5-1	292
	P 4-1	411
MORANCY, Richard	4-21-A	55
MORELOCK, Jack	P 3-3	275
MORETZSOHN, Fabio	1-6-C	102
MORGAN, Michael B	4-2-A	125
	3-3	48
MORGAN, Sian K	4-25	205
	P 4-6	279
MORI, Mutsumi	2-9	178
MORIMOTO, Maki	P 2-8	268
	P 2-8	270
	P 5-6	356
MORIMOTO, N	P 2-1	260
MORRI, Carla	P 1-2	365
MORRISON, Douglas	P 1-4	382
MORSE, Aileen A	P 1-2	365
MORSE, Aileen N C	4-21-A	56
MORTENSEN, Paal	P 5-4	297
MORTENSEN, Paal B	5-4	53
MOSES, Chris	2-8-B	88
MOSHIDI, Mohd Zakaria	P 4-1	399
MOTOKAWA, Tatsuo	1-2-A	190
	P 4-21	286
MOU THAM, Gerard	P 1-3	374
MOULDING, Alison L	4-21-A	55
MOURA, Barbara	4-3	13
MOURA, Rodrigo L	4-3	15
	4-2-C	155
	P 4-7	340
	2-1-C	77
MOUS, Peter J	4-14	211
	4-21-A	54
MOUTHAM, Gerard	4-5	183
	P 1-3	373
	P 1-3	374
	4-12-B	95
MOW, June Marie	P 4-15	348
MOYER, Ryan P	P 5-1	291
	P 5-4	297
MOYNE-PICARD, Marylene	P 4-1	417
	4-1	63
MUCCIARONE, David A	3-6	231
MUDA, Abd Aziz	P 4-1	399
MUEHLIG-HOFMANN, Annette	4-8	233
MUHANDO, Christopher A	1-2-B	226
	P 4-1	406
MUKAE, Nao	4-3	13
MUKAI, Hiroshi	4-25	204
MUKMININ, Ahmad	P 4-12	281
MUKO, Soyoka	2-10-A	135
MULCAHY, Robert D	P 4-21	284
MULEY, E V	P 4-21	287
MULIPOLA, Antonio	P 4-1	411
MULJADI, Andreas H	4-21-A	54
MULLER, Anne	2-9	177
	P 2-9	386
MULLER, Berry	P 2-1	261
MULLER, Erinn M	1-4-B	168
MULLER-KARGER, Frank	P 5-1	292
MULLER-KARGER, Frank E	5-2	112
MULRENNAN, Monica E	4-7	65
MULYANA, Yaya	4-9	158
MUMBY, Peter J	4-15-A	118
	4-15-B	120
	2-3-A	129
	2-1-A	22
Munasik	P 1-2	371

Author	Session	Page
MUNDAY, Philip L	1-8-A	82
MUNKSGAARD, Niels C	2-3-C	217
MURAKAMI, Akio	P 1-9	253
MURAKAMI, Kazuo	P 2-7	265
MURAMOTO, Koji	1-9-A	19
MURAOKA, Atsuko	P 2-7	264
MURDOCH, Thaddeus	P 4-2	331
	P 4-1	409
MURDOCH, Thaddeus J T	2-1-A	23
	P 4-3	277
MUSHIAKE, Keiichi	P 2-3	311
MUSTAPA, Irwanshah B	4-5	181
MUTHIGA, Nyawira	4-7	66
MUZIK, Katherine M	P 5-4	297
MYERS, Carey	P 1-4	381
MYOUNG, Jung G	P 1-6	244
N		
NADAOKA, Kazuo	3-5-B	108
	2-10-A	136
	2-3-B	162
	2-9	178
	4-25	205
	1-2-B	225
	P 1-6	247
	5-1	29
	P 3-5	329
	P 5-6	359
	P 2-7	265
NAGAI, Kouchi	4-12-B	95
NAGANO, Akira	P 2-1	260
NAGAO, Masayuki	4-18	79
NAGATA, Junji	4-25	203
NAGELKERKEN, Ivan	4-25	204
	4-13	200
NAITOH, Naoki	4-16	179
NAJIMA, Yayoi	P 3-5	328
NAKADA, Satoshi	P 2-7	266
NAKAGAWA, Hiroshi	5-4	53
NAKAI, Shunichi	P 2-4	316
NAKAI, Tatsuo	P 4-1	405
NAKAIZUMI, Masamitsu	P 4-21	286
NAKAMICHI, Kazunori	P 5-6	361
NAKAMORI, Toru	2-6	142
	P 2-7	265
	P 2-4	316
NAKAMURA, Eriko	1-9-C	73
NAKAMURA, Takashi	3-5-A	107
	P 2-1	263
	P 2-4	316
	P 3-2	325
	P 3-5	328
NAKAMURA, Yohei	2-3-B	163
NAKANO, Yoshikatsu	1-2-C	228
	P 4-21	286
	P 5-6	358
	P 1-2	368
	P 1-4	383
	P 2-9	387
	1-9-B	69
NAKAOKA, Masahiro	4-25	205
NAKATANI, Yukihiko	P 5-1	289
NAKAYA, Seiji	4-8	235
NAKAZA, Eizo	3-5-B	108
	3-5-B	109
	P 3-5	328
NAKAZONO, Akinobu	P 2-3	311
NANAMI, Atsushi	P 2-3	311

Author	Session	Page	Author	Session	Page
NANOLA JR, Cleto L	4-2-B	151	NOJIMA, Satoshi	P 4-1	405
NANOLA, Cleto L	4-5	182	NOMURA, Keiichi	P 4-1	405
	P 4-1	407	NONAKA, Masanori	4-24	223
	2-1-B	76		P 5-4	297
	4-12-B	94		P 4-1	405
NARUSHIMA, Izumi	4-25	204	NOORDELOOS, Marco	5-2	112
NASCIMENTO, Helisangela A	2-8-B	89		P 4-1	407
NASEER, Abdulla	2-1-C	78		P 4-1	418
NASHIRO, Kazue	4-13	201		4-1	64
NATAKA, Shinpei	2-6	142	NOREEN, Annika	1-9-B	68
NAUGHTON, John	4-12-A	38	NORMAL, Eriko	P 1-9	253
	4-21-A	55	NOTHDURFT, Luke D	2-8-A	35
NAWATA, Hiroshi	P 4-5	338	NOWLIS, Joshua Sladek	4-12-B	94
NAWOJCHIK, Robert	4-2-C	154	NOZAKI, Ken	5-3	144
	P 4-2	331		P 4-16	350
NAYAN, Nasir Bin	5-2	112		P 4-22	353
	P 4-1	418	NOZAWA, Yoko	P 2-1	260
	4-1	64	NUCLEAR, Paulwatt	P 1-7	308
NDOBE, Samliok	P 4-24	396	NUGUES, Maggy M	2-1-B	74
	P 4-1	407	NUNDLALL, Ushveen	P 5-1	289
	P 4-1	414	NUNES, Marcelo A	4-3	15
NEBELSICK, James H	2-6	143	NUNES, Vasco	3-5-A	105
	2-1-B	76	NUNEZ-LARA, Enrique	P 4-14	395
NEGAHDARIPOUR, Shariar	5-3	144	NUR, Mohammed	P 4-1	407
NEGISHI, Akira	5-3	144			
	P 4-16	350	O		
NEGRAO, Fabio	P 2-1	256	OBURA, David	P 4-2	334
NEGRI, Andrew	2-1-A	24		P 4-1	407
	3-3	48		P 4-1	412
NEIGEL, Joe	1-1-A	139		P 4-1	418
NELSON, Dave	1-9-C	71		4-1	63
NELSON, David	1-9-C	71	OBURA, David O	2-10-B	174
NEMETH, Richard S	4-2-C	154		4-12-A	39
	4-11	160		P 4-1	417
NERI, Patrizia	P 4-2	332		4-1	63
NERO, Vanessa L	P 1-8	249	OCHAVILLO, Domingo G	2-3-B	164
	2-1-A	25		4-23	96
	P 3-3	275	ODAWARA, Kei	P 2-7	264
	P 5-2	294		P 2-7	265
NESSA, Natsir	4-20	128	OFWEGEN, Leen Van	P 1-6	245
NETO, Augusto M	2-8-B	89	OGATA, Takehiko	1-9-A	19
NEVES, Elizabeth G	P 1-6	242	OGAWA, Hiroshi	P 3-6	390
	P 1-6	244	OGAWA, Kazunari	P 1-1	302
	P 1-1	303	OGDEN, John C	4-5	181
NEWMAN, Candace M	5-1	29		P 4-3	277
	P 5-1	290		4-12-B	95
NEWMAN, Stephen S	P 4-11	345	OGSTON, Andrea	2-2	195
NGOWO, Redfred	P 4-1	407		P 2-2	385
NGUYEN, Tac An	2-5	114	OHBA, Hideo	P 2-1	258
NIA, Antoine	P 4-1	415		P 2-1	260
	4-1	61		P 2-3	313
NIEUWLAND, Gerard	2-1-A	25		P 2-4	315
NINOMIYA, Sayuko	P 4-21	286		P 3-6	391
NIPPER, Marion	3-3	49	OHDE, Shigeru	2-9	177
NISHIDA, Mutsumi	1-1-A	140		P 2-7	264
NISHIDA, Yasuhiro	P 3-1	272	OHKAWA, Naoto	5-1	29
NISHIHARA, Moritaka	P 1-6	244	OHMIYA, Kunio	P 3-3	274
NISHIKAWA, Akira	2-3-A	129	OHNISHI, Akira	P 5-6	361
	2-10-A	135	OHNO, Mitsunori	4-3	13
	P 1-2	369	OHTA, Hidekazu	3-3	49
NISHIMORI, Masahiro	P 5-1	293	OKAJI, Ken	P 5-6	359
NISHIMURA, Kiyokazu	5-3	144		P 4-1	404
NOBCHINWONG, Parnhathai	P 1-2	369	OKAMOTO, Mineo	4-20	128
NOHARA, Masato	P 4-3	276	OKANO, Takahiro	4-6	17
NOJIMA, Hajime	P 4-12	281		P 4-24	396
NOJIMA, Satoshi	4-20	128	OKI, Katsuki	P 4-1	405
	P 2-1	260	OKI, Kazuo	5-1	29
	P 2-8	270	OKITSU, Akiko	4-13	202
	P 2-4	317			

Author	Session	Page
OKUBO, Nami	1-2-A	190
	P 4-21	286
OKUNO, Atsuro	2-3-C	215
OLIVEIRA, Marilia D M	P 4-21	287
	P 2-10	321
	P 4-1	406
	2-8-B	89
OLIVEIRA, Paulino P	2-8-B	89
OLIVER, James K	5-2	112
	P 4-1	407
	P 4-1	418
	4-1	64
OLIVER, Jamie	4-15-C	147
	2-11	219
OLIVER, Peter G	P 1-6	247
OLKERIIL, Ilebrang U	4-17	137
OLSON, Donald B	4-15-A	118
OLSON, Julie B	1-4-B	169
OMATA, Tamano	P 1-9	253
	P 2-8	270
OMIJA, Tatsuo	P 4-3	277
OMORI, Makoto	1-2-A	190
	P 4-21	286
	P 1-4	384
	4-21-A	57
OMORI, Shinji	P 4-12	281
OMOTO, Kunio	2-7	33
OMURA, Akio	P 2-7	265
	P 2-7	266
	2-7	33
	P 3-5	329
ONAKA, Osamu	P 4-7	341
ONAKA, Susumu	P 2-4	317
ONDA, Mariko	4-21-A	57
ONO, Masahiro	1-2-B	227
OOKA, Shuya	2-9	178
OOMORI, Tamotsu	P 2-12	322
	P 3-2	325
	P 2-9	387
	P 3-6	390
	2-11	220
	4-15-E	236
OPPENHEIMER, Michael	P 4-2	332
ORAM, Risa G	2-2	194
ORLANDI, Antonio	2-10-B	172
ORTIZ, Juan Carlos	4-6	17
OSADA, Kei	P 4-1	402
OSBORNE, Kate	1-8-B	84
	1-8-B	84
OSENBERG, Craig W	P 1-2	367
OSHIRO, Wakako	4-15-A	117
OSORIO, Rose-Liza E	P 4-7	341
OSUGA, Yutaka	5-3	144
OTANI, Kenji	P 4-16	350
	5-3	145
OTERO, Ernesto	5-2	111
OUBELKHEIR, Kadija	3-5-B	108
OUILLO, Sylvain	P 3-5	327
	P 3-5	328
	P 4-15	349
OVENDEN, Ming	P 1-9	254
OWEN, Richard	4-23	97
OWENS, Randall	P 1-1	301

P

PADDACK, Michelle J	1-3	198
	1-2-B	227
	1-8-B	86

Author	Session	Page
PAETZOLD, Juergen	3-6	230
	P 2-8	267
PAGE, Cathie	1-4-A	166
PAGE, Cathie A	1-4-B	170
PAJARO, Marivic	P 4-15	347
PAJARO, Marivic G	4-7	65
PALAKI, 'Asipeli	4-8	235
PALARDY, James E	1-3	197
	P 2-8	269
PALUMBI, Stephen R	4-15-A	117
	4-15-A	118
	1-1-A	141
PANDOLFI, John M	P 2-3	311
	4-5	181
PANES, Hazel M	2-1-A	23
	P 4-6	279
PANGGA, Imelda C	P 4-15	348
PANTOS, Olga	1-4-A	165
	P 1-4	379
PAOLO, Usseglio	2-3-C	217
PAPHAVASIT, Nittharatana	P 4-11	345
PAPINA, M	P 1-9	251
PARDEDE, Shinta	4-8	234
PARDEDE, Shinta T	P 4-12	281
PARINGIT, Enrico C	3-5-B	108
	4-25	205
PARK, Heung S	5-1	29
	P 3-5	329
PARK, Heung-Sik	P 1-6	244
PARKER, Justin H	P 4-5	339
PARKS, John E	P 1-3	375
PARRISH, Frank A	4-15-A	117
PARRISH, James D	5-4	53
PARRISH, David L	1-8-B	86
PARRY, David L	2-3-C	217
PASCAL, Chabanet	P 5-3	295
PASISI, Brendon	P 4-1	415
	4-1	61
PASOS-PINTO, Silvia E	P 2-3	311
PASTOR, Davelyn S	P 4-5	338
PATERSON, Arthur	4-7	65
PATINO, Susana A	P 4-21	284
	P 4-2	332
PATISAYNA, Kampee	P 4-11	344
PATTEN, Nicole L	P 3-1	272
PATTENGILL-SEMMENS, Christy V	4-23	97
PATTERSON, Edward J K	P 3-3	274
	P 4-21	284
PATTERSON, Heather	P 4-21	287
	P 1-4	379
PATTERSON, Jamila	2-3-A	131
PAUL, Valerie J	4-13	201
	P 4-5	339
PAULAY, Gustav	P 4-11	344
	P 1-4	379
PAULY, Daniel	P 1-4	379
	4-9	158
PAVIA, Richard Thomas Jr B	1-6-B	100
PAWLAK, Geno	P 1-6	245
	P 1-8	249
PAWLOWSKI, Jan	P 2-1	261
	P 2-8	269
PAYET, Rolph	1-6-A	44
	2-8-B	87
PAVIA, Richard Thomas Jr B	4-12-A	40
	P 4-22	353
PAWLAK, Geno	3-5-A	105
	1-9-A	18
PAWLOWSKI, Jan	P 1-9	252
	P 4-1	412

Author	Session	Page	Author	Session	Page
PAYET, Rolph	P 4-1	418	PLATHOG, Sakanan	1-6-B	101
	4-1	63		1-9-B	69
PAYET, Rolph A	P 4-1	408		1-6-B	99
PAYRI, Claude	P 4-1	408	PLATHONG, Sakanan	4-15-E	236
PEARS, Rachel	P 1-6	243	POCHON, Xavier	1-9-A	18
PEARS, Rachel J	4-5	182		P 1-9	252
PECKOL, Paulette	P 4-24	396	POGGE, Amy	P 1-1	303
PENIN, Lucie	P 2-1	261	POLLNAC, Richard	4-6	16
PENLAND, Lolita	P 4-1	404	POLSENBERG, Johanna	P 4-12	281
PENLAND, Lolita K	P 1-2	369	POLSON, Sara C	P 1-4	382
PENN, Tony	4-20	127	POLSON, Sarah	1-4-A	167
PENNOBER, Gwenaelle	1-6-A	42	POLSON, Shawn	1-4-A	167
PEPLOW, Lesa	1-1-B	185	POLSON, Shawn W	P 1-4	382
PEREIRA, Paulo G P	4-3	15	POLUNIN, Nicholas	P 1-3	374
PEREIRA, Renato C	P 4-4	336	POLUNIN, Nicholas V C	4-5	181
PERERA, Nishan	P 4-1	410		4-8	233
PEREVOLOTFKY, Avi	3-3	50		4-12-A	37
PEREZ, Carlos D	4-3	13	POMEROY, Robert	4-6	16
PERKOL-FINKEL, Shimrit	1-6-A	41	POMEROY, Robert S	4-15-A	117
	4-21-A	54	PONCE-TAYLOR, Daniel J	P 5-6	362
PERRY, Christopher	P 2-1	258	PONTON, Dominique	2-1-B	75
PERRY, Christopher T	1-5	132	PORCHER, Michel	4-21-A	55
PET, Jos S	4-21-A	54	PORTER, James W	1-9-C	72
PETELO, Peter	P 4-1	415	PORTILLO, Pedro	P 4-1	400
	4-1	61	POSSINGHAM, Hugh P	4-5	181
PETERSEN, Dirk	P 4-21	287		4-14	213
	P 4-22	354	POTHIN, Karine	P 2-3	312
PETERSON, Eric	4-14	212	POTTER, Ian I	P 4-11	345
PETTERSON, Jim	4-2-C	154	POTTER, John R	5-1	27
PETTONGMA, Rattika	P 4-21	287	POTTS, Donald	P 2-8	270
PEYROT-CLAUSADE, Mireille	1-5	132		2-7	32
PHANTEWEE, Wasana	P 2-10	321	POTTS, Donald C	2-5	113
PHILIBOTTE, Jason	4-17	137		2-9	177
PHILREEFS, Sour K	P 4-1	417		4-25	204
	4-1	62		P 5-6	361
PHINN, Stuart	5-1	28	POTTS, Kennard W	4-2-A	125
PHINN, Stuart R	4-25	204	POUJADE, Sebastien	P 4-4	336
	P 5-1	290	POWER, Mary	P 4-1	415
	P 5-1	291		4-1	61
PHOEL, William C	4-20	128	PRATCHETT, Morgan S	2-10-A	135
PHONGSRI, Wichanan	P 2-10	321		1-8-A	82
PHONGSUWAN, Niphon	P 1-3	374	PRATES, Ana P	P 4-1	403
PICCINETTI, Corrado	P 4-2	332	PRATES, Ana Paula L	P 4-1	409
PICHON, Michel	P 4-12	280		4-7	66
	P 1-1	303	PRATHEP, Anchana	P 5-6	359
	P 1-2	365	PRECHT, William F	4-20	127
	P 4-1	408		2-1-A	22
PILLER, Werner	2-7	31		P 4-2	331
PINAZO, Christel	3-6	232		2-8-B	89
PINCA, Silvia	1-7	104	PRESTO, Kathy	P 2-2	385
	4-16	180	PRICE, Kathy L	P 1-4	382
	4-14	212	PUOTINEN, Marji L	2-2	194
PINCA, Silvia A	P 2-1	261	PURKIS, Samuel	2-10-B	174
PINIAC, Gregory A	4-20	127	PURKIS, Samuel J	5-1	29
	P 4-3	277		P 5-1	291
	P 4-9	342	PUTRA, Saptia	P 4-12	281
	P 1-2	366	PUVEREL, Sandrine	P 3-2	325
PIRES, Debora O	P 5-5	355			
	P 1-2	365			
	P 1-2	368			
	P 4-1	403			
PITT, Joanna M	4-25	203			
	P 4-1	409			
PIZARRO, Valeria	P 2-1	261			
	P 4-15	348			
PLANES, Serge	2-3-A	130			
	2-3-B	164			
	2-3-C	217			
PLANTIVAUX, Amandine	2-12	91			

Q

QIU, Wanfei	P 5-6	359
QUAN VAN, Nguyen	P 2-3	312
QUIBILAN, Miledel C	4-15-A	118
	P 4-1	407
QUIBILAN, Miledel Christine C	2-1-B	75
QUINN, Norman	P 5-6	360
	P 2-2	385
	1-2-B	227
QUINN, Norman J	P 3-1	273

Author	Session	Page
QUINN, Norman J	P 4-1	409
QUINN, T Patrick	4-20	128
QUINN, Terrence M	2-8-B	87
	2-8-B	89
QUINN, Thomas P	4-21-A	57
QUOD, Jean P	P 4-2	334
QUOD, Jean Pascal	P 4-1	417
	4-1	63
QUOD, Jean-Pascal	3-4	191
	P 2-3	312

R

RADETIC, Josipa	P 1-2	367
RADFORD, Ben T	4-2-A	126
	P 2-3	312
RADFORD, Ben T M	P 1-3	376
RADIKEDIKE, Ratu Pio	4-8	235
RAE SEON, Kang	P 2-4	315
RAGHUKUMAR, S	1-4-B	171
RAGHURAM, Kosalai Pargunam	P 4-1	409
RAGOONATH, Davecia	P 1-4	383
RAHAMAN, Shak M B	3-5-B	108
	3-5-B	109
	P 3-5	328
RAHMAN, Azizur M	P 1-6	245
RAHMAN, M Aminur	1-6-B	100
	P 5-6	357
	5-6	52
RAHMAN, M Saifur	1-6-B	100
	P 5-6	357
	5-6	52
RAHMAN, Ridzwan A	4-15-D	208
RAINES, Peter S	4-24	224
	P 5-6	362
	P 4-1	404
RAJASURIYA, Arjan	P 4-1	410
	P 4-1	417
	4-1	63
RALPH, Peter J	1-9-B	68
	2-12	91
RAMAN, B Muthu	P 1-9	252
	P 3-2	326
RAMIREZ, Wilson	2-6	143
RAMIREZ, Wilson R	P 3-3	275
RAMOHIA, Peter	P 4-1	398
RAMOS, Marcelo	P 1-6	246
	P 1-6	247
RAMOS, Ruth	P 4-3	277
RAMSDEN, Clive A	P 4-15	349
RANSOM, Bruce H	5-3	145
RASSER, Michael	2-6	143
RAVELO, A Christina	P 2-8	270
RAVELO, Christina A	2-9	177
RAVILLIOUS, Corinna	4-15-C	147
RAYMUNDO, L	P 1-4	382
RAYMUNDO, Laurie J	1-4-B	170
	P 4-21	288
RAYMUNDO, Laurie Jeanne H	P 4-22	353
RAZAK, Tries	4-23	96
RAZAK, Tries B	P 1-1	303
REATH, Pakki	1-6-C	103
REBOTON, Clarissa T	1-4-B	170
RECKSIEK, Conrad W	4-25	203
REED, Ashley	P 1-3	375
REES, Max	2-10-B	172
REEVES, Emma	P 2-1	261
REID, David G	1-6-A	44
REID, Pamela	5-3	144

Author	Session	Page
REINICKE, Goetz B	P 1-6	242
	P 4-2	330
REITNER, Joachim	P 1-7	308
REMILY, Elizabeth	1-4-A	165
	P 1-4	383
RENDON-AGUILAR, Luis G	P 5-6	362
RENEMA, Willem	2-5	114
RENLIN, Zou	P 4-15	347
RENNEBERG, Reinhard	P 4-4	337
REYES, Michelle Z	4-21-B	116
REYES-BONILLA, Hector	4-2-B	153
	P 1-8	248
	1-6-A	43
REYES-NIVIA, Maria C	P 4-1	410
REYNAUD, Stephanie	P 2-9	386
REYNOLDS, Wendy S	1-9-C	71
REZAEI-MARNANI, Hamid	1-5	133
REZENDE, Sergio M	P 4-1	403
RICHARD, Cecile	3-4	191
RICHARDS KRAMER, Patricia	2-1-A	22
RICHARDS, Vincent P	2-3-C	216
RICHARDSON, Laurie	P 1-4	383
RICHARDSON, Laurie L	1-4-A	165
	1-4-A	167
	P 1-4	383
RICHIER, Sophie	P 2-12	323
	2-12	91
	2-7	32
RICHMOND, Bruce M	P 4-1	412
RICHMOND, Matthew	2-1-C	77
RICHMOND, Robert	1-2-B	225
RICHMOND, Robert H	4-18	79
RICHTER, Claudio	1-7	104
	3-6	232
	4-23	98
RIDDLE, Dana	4-23	98
RIDEP-MORRIS, Alma	4-9	158
RIDGWELL, Andy J	2-7	31
RIEDMILLER, Sibylle	P 4-12	282
RIEGL, Bernhard	P 2-7	266
	5-1	27
	P 5-1	291
RIEGL, Bernhard M	2-10-B	174
	5-1	29
RIKER-COLEMAN, Kristin	2-7	32
RINGOR, Cherry L	2-7	33
RINKEVICH, B	4-21-B	115
RIPLEY, Herbert T	P 5-1	292
RITSON-WILLIAMS, Raphael	P 1-8	249
RITSON-WILLIAMS, Raphael D	1-6-B	100
	P 1-6	245
RIVERA-MADRID, Renata	P 2-3	311
ROA-QUIAOIT, Hilly Ann	4-23	98
ROBBART, Martha L	P 4-2	331
ROBBINS, William D	4-12-A	36
ROBERSON, Keith A	4-24	222
ROBERTS, Caroline A	P 1-8	249
ROBERTSON, D Ross	P 1-3	376
	1-6-B	99
ROBERTSON, David R	1-6-A	45
ROBERTSON, Ross	1-6-C	103
	2-3-A	129
ROBINSON, Judy L	4-20	128
ROBINSON, Julie	5-2	112
	4-15-C	147
ROBINSON, Julie A	5-2	112
ROBISON, Jennifer	1-9-B	69
ROCHA, Luiz A	1-6-B	99
RODRIGUES, Lisa J	2-10-A	134

Author	Session	Page	Author	Session	Page
SAN-NAMI, Toshiro	P 4-7	341	SCHREIBER, Ulrich	2-12	91
SANO, Mitsuhiko	2-3-B	163	SCHRIMM, Muriel	P 3-6	390
SANO, Motohiko	P 4-21	285		4-21-A	55
SANO, Yae	4-17	138	SCHROEDER, Robert	3-5-B	109
SANO, Yuji	5-4	53	SCHROEDER, Robert E	4-2-B	152
SANTALLY, Mohammad	P 4-12	280		P 4-1	411
SANTAVY, Deborah L	1-4-B	169		2-1-C	77
SANTILLAN, August S	4-15-B	119	SCHUELI, Luca	P 4-1	404
SANTODOMINGO-AGUILAR, Nadiezhda	P 1-3	375	SCHUHMACHER, Helmut	2-10-B	173
SANTOS RODRIGUEZ, Lyn Ohala	P 2-3	312		P 4-22	354
SANTOS, Andre M M	4-3	13	SCHULTZ, Stewart T	2-1-A	22
SANTOS, Francisco A R	2-8-B	89	SCHUPP, Peter J	P 1-7	308
SANTOS, Michelle	P 1-6	246	SCHUTTENBERG, Heidi	2-11	219
	P 1-1	304	SCHUTTENBERG, Heidi Z	4-15-C	146
SANTOS, Scott R	1-9-A	18	SCHUYLER, Qamar A	5-1	30
	1-9-A	20	SCHWARZ, Jodi	1-9-C	71
SARAN, Nakul	5-3	145	SCHWARZ, Jodi A	1-9-C	71
SARRAMEGNA, Sebastien	4-11	160	SCOLA GAGLIARDI, Maria	P 4-2	332
SASAKI, Keiichi	P 2-7	265	SCOTT, Anna	1-2-A	187
SASAKI, Miho	P 1-6	247	SCOTT, David B	P 5-4	298
	P 5-6	359	SEBENS, Kenneth	3-5-A	105
SATO, Akinori	4-13	202		P 2-4	315
SATO, Daisaku	4-16	179	SEBENS, Kenneth P	3-5-A	106
SATO, Norio	5-6	51	SEDIGHI, Omid	P 5-1	292
SATO, Tetsu	P 4-18	351		P 4-1	411
	5-6	52	SEE, Wolf R	2-10-B	173
SATO, Tokiyuki	P 2-7	264	SEEKINGS, Paul	5-1	27
	P 2-7	266	SEETO, Pamela	4-15-D	208
	2-7	34		4-7	65
SATOH, Takanori	P 1-9	253	SEGAL, Barbara	P 2-1	256
SATOU, Kenji	2-3-B	162		P 2-1	262
SAUAFEA, Fatima	4-8	235		P 1-2	365
SAUNI, Lilian Fay	P 4-5	339	SEGUIN, Fany	P 4-1	408
SAUNI, Samasoni	4-5	183	SEGURA, Alvaro	P 2-1	256
	P 4-5	339	SEINO, Satoquo	P 3-5	329
	P 1-3	374	SEKI, Izumi	4-12-B	95
SAUNI, Samisoni	4-12-B	95	SEKIGUCHI, Yoshihiro	P 5-1	289
SAWABE, Akiyoshi	P 3-1	272	SELKOE, Kimberly A	2-3-B	164
SAZIMA, Cristina	P 5-6	358	SEMMENS, Brice X	1-3	199
	P 5-6	360		P 4-15	346
SAZIMA, Ivan	P 5-6	358		4-23	97
	P 5-6	360	SEMON, Kathleen L	P 1-8	249
SCARTH, Peter F	P 5-1	290		2-1-A	25
	P 5-1	291		P 3-3	275
SCHAFFELKE, Britta	4-24	223		P 5-2	294
	P 5-6	360	SENTENI, Alain	P 4-12	280
SCHITTONI, Joseph A	4-20	127	SERIZAWA, Masumi	P 3-5	329
SCHLENZ, Erika	1-1-B	185		P 4-7	341
SCHLEYER, Michael	P 1-1	302	SEYMOUR, Justin R	P 3-1	272
	2-1-B	75	SHAFIR, S	4-21-B	115
SCHLEYER, Michael H	4-2-B	153	SHAHRIYAH, Dilla Binti Mohd Shukri	P 4-1	418
SCHLOEDER, Carmen M	P 1-2	370		4-1	64
SCHMAHL, George P	4-2-B	152		3-3	50
	4-9	156	SHALMON, Benny	P 4-1	412
	P 4-2	331	SHANDHOUR, Saif	P 2-1	263
SCHMIDT, Christiane	4-23	98	SHAO, Kwang-Tsao	P 5-6	357
SCHMIDT, Gregory W	1-9-A	18		1-6-B	99
	1-9-A	19	SHARMA, Charu	2-1-A	23
	1-9-A	21	SHASHAR, Nadav	P 1-3	372
	P 1-9	251	SHAUL, Richard	P 5-4	297
SCHMIED, Loys	3-5-B	108	SHEARER, Tonya L	1-9-A	20
	P 3-5	327		P 2-3	313
SCHMITT, Russell J	1-8-A	81	SHEAVLY, Seba B	P 4-3	276
	1-8-A	82	SHEEHY, Michael	2-3-C	217
	1-8-A	83	SHEMESH, Aldo	2-8-B	87
SCHNEIDER, Kenneth	1-9-C	72	SHENG, Jinyu	2-3-A	130
SCHNEIDER, Kenneth Haim	2-9	176	SHENKAR, Noa	2-10-B	173
SCHNITZLER, Christine E	1-1-B	185	SHEPHERD, Ross	P 3-2	326
SCHOENBERG, Christine H L	1-5	132	SHEPPARD, Charles	P 4-1	412

Author	Session	Page	Author	Session	Page
SHIBATA, Sanae	4-21-A	57	SMITH, Garriet W	1-4-A	165
SHIBATA, Yasuyuki	P 2-8	267		1-4-A	166
	P 2-8	270		P 3-1	272
SHIBATA, Yozo	5-3	145		P 1-4	381
SHIBUNO, Takuro	2-3-B	163		2-1-B	74
	P 2-1	258	SMITH, Jennifer	1-3	197
	P 2-1	260	SMITH, Jennifer E	4-24	223
	P 4-3	276	SMITH, Jennifer M	2-8-B	89
	P 2-3	313	SMITH, Lance W	P 2-12	323
SHIMA, Jeffrey S	1-8-A	81	SMITH, Luke	3-5-A	107
	1-8-B	84	SMITH, Luke D	2-10-B	172
SHIMAZAKI, Hiroto	5-2	111	SMITH, Stuan R	P 4-3	277
SHIMIZU, Hirofumi	5-3	144	SMITH, Tyler B	3-4	193
	P 4-21	285		P 2-10	320
	P 4-21	288	SNELL, Terry W	4-2-A	125
SHIMOIKE, Kazuyuki	4-3	13		3-3	48
	P 5-3	296	SO, Erica K Y	P 1-6	246
	P 4-1	405	SOEDHARMA, Dedi	P 2-4	317
SHIMOMURA, Yuko	4-21-A	57	SOFONIA, Jeremy J	3-5-B	108
SHINN, Eugene A	P 3-1	272		P 5-3	295
SHIRAI, Kotaro	5-4	53		2-6	142
SHIROMA, Kazuyo	P 2-12	322	SOJA, Constance M	1-4-C	218
SHISLER, Joanna	3-1	46	SOKOLOW, Susanne	4-24	224
SHIVJI, Mahmood S	2-3-C	216	SOLANDT, Jean-Luc	P 4-1	404
SHJEGSTAD, Sonia	1-6-B	100	SOLOFA, Anama	P 4-1	411
SHOKRI, Mohammad Reza	1-5	133	SOLOMON, Mark	P 4-8	394
SHOKRI, Nahid	1-5	133	SOMEYA, Shinichi	5-6	51
SHUMAN, Craig	4-23	96	SOMKLEEB, Nipat	P 4-11	345
SHUTLER, Sharon K	4-20	127	SONG, Jun-Im	4-21-B	116
SHYU, Mei-Ling	P 4-14	395		1-2-A	187
SIBERT, John	5-2	110	SOONG, Keryea	P 1-2	368
SICILIANO, Daria	2-9	177		P 1-4	379
	P 5-6	361		P 4-1	401
SILENZI, Sergio	P 2-8	269	SOON-KIL, Yi	P 2-4	315
SILVA, Bruno G T	4-3	13	SORIANO, Maricor	5-3	144
SILVEIRA, Susan	P 1-6	246	SOUR, Kim	P 4-1	412
	P 1-6	247	SOUTER, David	4-12-A	38
SILVEMAN, Jacob	2-9	177		P 4-1	412
SILVER, Eli	2-7	32		P 4-1	418
SILVERMAN, Jacob	P 4-3	278		4-1	63
SIMONDS, Kitty M	4-12-B	93	SOUTER, Petra	P 2-3	313
SIMPSON, Chris	P 2-1	258	SOUTH, G Robin	4-15-E	236
	P 4-7	340	SPALDING, Heather	1-3	197
SIMPSON, Stephen D	2-3-B	163	SPANNO, Saulo	P 4-1	406
SKELTON, Posa A	4-15-E	236	SPEIGHT, Martin R	4-7	66
	P 1-6	241	SPIELER, Richard E	4-20	128
SKEWES, Tim	4-5	182		4-9	157
SKIRVING, William	5-2	110		4-21-A	57
	2-11	220		4-12-B	94
	P 5-1	289	SPONAUGLE, Su	1-8-B	86
	2-12	90	SPRAGGINS, Alan	5-2	112
SKIRVING, William J	3-5-A	107	SPURGEON, James P G	4-6	16
	2-11	219	SRINIVASAN, Maya	1-8-B	85
	2-11	220	ST MARY, Colette M	1-8-B	84
SKIRVING, William S	2-11	219	STAKE, Joel	1-1-A	139
SKUZA, Michele	4-18	80	STAMBLER, Noga	1-9-C	72
SLATER, Deb	4-15-D	206	STANHOPE, Michael J	2-3-C	216
SLATTERY, Marc	1-4-B	169	STANLEY JR, George D	2-6	142
	P 1-6	245	STANTON, Frank G	P 4-24	397
SLEEMAN, Jai C	P 1-3	376	STARGER, Craig J	P 2-3	313
SLINGSBY, Shauna N	1-2-C	228	STARMER, John	P 1-6	245
	P 3-3	275	STAT, Michael	1-9-A	21
SMITH, Carolyn R	4-2-A	125	STEAD, Selina	4-8	233
SMITH, Celia	1-3	197	STEFFEN, Jan H	4-23	97
SMITH, Celia M	4-24	223	STEIG, Tracey W	5-3	145
SMITH, David J	2-2	194	STEINBERG, Craig	3-5-A	107
SMITH, G	P 1-4	382	STEINBERG, Craig R	2-11	220
SMITH, G W	1-4-A	165		P 2-11	388
SMITH, Garriet	1-4-A	167	STEINBERG, Peter D	P 1-7	308

Author	Session	Page
STEINER, Andrea	P 1-6	247
	P 5-6	356
STENECK, Robert S	1-2-B	227
	2-1-A	23
STEPHENSON, Jennifer Ibi	P 3-1	273
STEVEN, Andrew D L	5-2	111
	3-6	230
STJOHN, Jill	4-12-A	38
STOBART, Ben	2-10-B	173
STOCKWELL, Brian L	P 4-11	345
STOFFLE, Richard W	4-15-A	118
STORLAZZI, Curt	2-2	195
	P 2-2	385
STORLAZZI, Curt D	2-2	195
	1-2-B	227
STOUT, David	4-21-B	115
STRONG, Alan	2-11	220
	2-12	90
STRONG, Alan E	5-2	110
	2-11	219
STRYCHAR, Kevin B	P 5-4	298
STUKEN, Anke	1-5	132
STUMPF, Richard	4-15-C	147
STUMPF, Richard P	5-2	111
	5-2	112
SUGIHARA, Kaoru	P 2-7	265
	P 2-4	315
	P 2-4	317
	P 4-1	405
Suharsono	P 4-2	335
SUHARSONO, Suharsono	P 4-1	412
SUHARSONO, Vo S T	P 4-1	417
	4-1	62
SUKARNO, Johan O	4-23	96
SULIANSI, Muhammad S	4-5	181
SULISTIONO, Sulistiono	P 2-4	317
SULLIVAN SEALEY, Kathleen M	P 1-8	249
	2-1-A	25
	P 3-3	275
	P 5-2	294
SULU, Reuben	P 4-1	402
	P 4-1	405
	P 4-1	415
	4-1	61
SUMIYA, Yasuji	P 3-1	272
SURESHKUMAR, Chellasamy	P 4-1	413
SUSSMAN, Meir	1-4-A	166
SUTHERLAND, Kathryn P	1-4-A	166
SUTTHACHEEP, Makamas	5-1	30
SUWA, Ryota	P 1-9	253
SUZUKI, Atsushi	P 1-9	253
	P 2-1	258
	P 2-1	260
	P 2-8	270
	P 4-3	276
	P 3-2	325
	3-3	49
	2-8-B	87
	P 1-9	253
	P 4-21	288
SUZUKI, Go	P 4-21	288
SUZUKI, Rintaro	P 1-5	307
SUZUKI, Y	3-4	192
SUZUKI, Yasuhiro	5-1	29
SUZUKI, Yoichi	4-25	205
SUZUKI, Yoshimi	P 5-6	359
	3-4	191
	3-6	231
	3-6	232
	P 3-6	390

Author	Session	Page
SUZUKI, Yoshiyuki	P 4-24	396
	3-5-B	108
	2-10-A	136
SUZUKI, Youichi	2-3-B	162
	2-7	31
SUZUKI, Yuka	2-7	31
SWART, Peter	2-8-B	88
SWART, Peter K	2-2	196
	P 2-8	268
SYAHAILATUA, Augy	1-9-C	72
	P 5-6	361
SYMONS, Lisa C	4-20	127
SZMANT, Alina	2-8-B	89
	1-2-B	225
SWEARER, Stephen E	1-9-C	71
	1-9-C	72
SWEATMAN, Hugh	2-3-A	131
	2-1-A	24
SZMANT, Alina M	P 4-1	402
	1-8-B	84
	P 4-3	278
SZYMCHAK, Ron	P 1-1	303
	P 1-2	370
	2-12	91

T

TABARANZA, Don Geoff	4-15-D	207
TABATA, Masahiro	4-20	128
TABETA, Shigeru	2-2	194
TADDEI, Dorothee	5-6	52
TAIRA, Hatsuo	P 2-12	322
TAKADA, Yoshitake	P 2-1	258
	P 2-1	260
TAKAHASHI, Keisuke	P 4-3	276
	P 2-3	313
TAKAHASHI, Yoshihiro	4-6	17
TAKAHASHI, Yoshihiro	1-2-B	227
TAKAHASSHI, Soyo	4-13	200
TAKAOKA, Tori	P 1-1	303
TAKASHI, Nishida	P 2-3	311
TAKATSU, Naoyuki	5-3	145
TAKEDA, Masatsune	P 1-6	244
TAKEKAWA, Daisuke	4-13	200
TAKEMURA, Akihiro	4-3	14
TAKEUCHI, Tsutau	P 2-7	265
TAKEYAMA, Haruko	P 1-4	384
TAKISHITA, Kiyotaka	P 1-9	253
TALAUE MCMANUS, Liana	4-15-A	118
TALAUE-MCMANUS, Liana	P 4-8	394
TALGE, Helen K	P 2-12	322
TAM, Man Cheong	P 4-11	345
TAM, T W	P 4-2	330
TAM, Tze-Wai	4-14	212
TAMAKI, Motoya	5-3	144
	P 4-21	285
	P 4-21	288
	3-5-B	108
TAMASHIRO, Kouji	3-5-B	109
TAMBUTTE, Eric	P 3-5	328
	3-4	191
	P 2-12	323
TAMBUTTE, Sylvie	P 3-2	325
	P 2-12	323
TAMELANDER, Jerker	P 3-2	325
TAMELANDER, Jerker	P 3-2	323
TAMELANDER, Jerker	P 5-6	361
TAMURA, Akira	P 5-6	361
TAMURA, Hitoshi	3-5-B	108

Author	Session	Page	Author	Session	Page
TAMURA, Hitoshi	2-10-A	136	THORROLD, Simon	2-3-B	164
	2-3-B	162	THORROLD, Simon R	2-3-A	130
	2-9	178		2-3-C	217
	4-25	205	THOSTESON, Eric D	5-3	145
	P 3-5	329	TIAN, Wen-Miin	5-1	27
TAMURA, Keiichi	P 4-21	286	TIBBETTS, Brent R	P 4-1	411
TAMURA, Masayuki	5-2	111	TIGHE, Stacey A	4-9	158
	P 4-16	350	TILLIER, Simon	1-1-B	184
TAN, Moi Khim	P 4-1	418	TIMKO, Mark A	5-3	145
	4-1	64	TIMMERS, Molly A	4-3	15
TANAKA, Jiro	1-9-C	73	TING, Chau-Ti	P 1-1	305
TANAKA, Jun	P 4-21	286	TIQUIO, Ma Gregoria Joanne P	4-25	205
TANAKA, Junichi	P 1-6	246	TITLYANOV, Eduard A	2-10-A	135
TANAKA, Keiko	P 2-1	262		P 1-8	250
TANAKA, Y	4-25	204	TITLYANOVA, Tamara V	2-10-A	135
TANAKA, Yasuaki	P 3-6	390		P 1-8	250
	P 3-6	391	TODD, Brian D	P 2-4	318
TANANGONAN, Jb	P 4-2	334	TODD, Peter A	1-1-B	184
TANG, Liqun	2-3-A	130		P 1-1	304
TANGJAITRONG, Supichai	5-1	30	TOGUCHI, Ken	P 5-6	359
TANIGUCHI, Hiroki	4-3	13	TOKESHI, Mutsunori	P 2-1	260
	P 4-21	286	TOKESHI, Ryoko	P 2-9	387
	P 4-21	288	TOKESHI, Ryuko	2-9	178
	P 5-3	296	TOKORO, Tatsuki	2-9	178
	P 1-4	384	TOLEDO-HERNANDEZ, Carlos	1-4-A	167
	4-21-A	57	TOLER, Strawn K	P 2-12	322
	4-7	67	TOONEN, Robert J	P 1-3	372
TANIGUCHI, Kouhei	P 2-9	387	TORRES, Juan L	P 2-12	324
TANZER, John	4-15-D	206	TORRES-PULLIZA, Damaris	5-2	112
	4-15-D	207		P 5-1	292
TATEDA, Yutaka	4-3	13	TORRETON, Jean P	3-4	191
	3-6	231	TORRETON, Jean-Pascal	3-6	232
	P 5-3	296	TOSCANO, Marguerite A	P 5-2	294
TATSUKAWA, Kenichi	P 5-3	296	TOTTORI, Kaiho	P 2-1	258
TAUSA, Nofoaiga	P 4-1	411		P 2-1	260
TAWAKE, Alifereti	4-8	235	TOTTORI, Saori	3-6	231
	4-7	66	TOUCHARD, Marc	3-4	191
TAYLOR, Jacqueline F	P 5-6	362	TOUGAS, Jennifer I	1-9-C	72
TAYLOR, Jaqueline F	4-24	224	TOYOSHIMA, Junko	1-9-C	73
	P 5-6	362	TRAPIDO-ROSENTHAL, Henry	P 1-9	254
TAYLOR, Michelle	4-23	96		1-9-B	70
TAYLOR, Mike W	P 1-7	308	TRAVERS, Michael J	P 4-11	345
TEDENGREN, Michael	P 3-3	274	TREML, Eric A	4-14	212
TELEKI, Kristian	2-10-B	173	TRIANNI, Michael S	P 5-6	362
TENORIO, Michael C	P 5-6	362		P 4-1	411
TENTORI, Ernestina	P 3-2	326	TRIBOLLET, Aline D	2-9	178
TERASHIMA, Hiroaki	P 2-10	321	TRICART, Sandrine	P 4-12	280
TERRY, Astrid	1-9-C	71	TSAI, Min-Li	P 2-2	385
TERUYA, Toshiaki	P 5-6	358	TSAI, Wan-Hsu	4-14	212
TESCH, Sheryll	P 4-15	349	TSENG, Ching	P 1-1	301
TESFAYE, Melaku	P 2-7	265	TSUCHIDA, Satoshi	P 5-1	291
THACKER, Robert W	P 1-6	245	TSUCHIYA, M	P 1-9	251
THAMAN, Batiri	4-6	16	TSUCHIYA, Makoto	4-3	14
THOMAS, Chris	4-15-D	206		P 1-1	301
THOMAS, Florence I M	3-5-A	107		P 4-18	351
THOMAS, James D	2-3-C	216		P 5-6	361
THOMAS, Nickie	P 1-3	374		4-18	80
THOMASSIN, Bernard	P 4-1	408	TSUDA, Masaya	P 4-22	353
THOMPSON, Andrew R	1-8-B	84	TSUKAYAMA, Seikoh	3-5-B	108
THOMPSON, Angus	2-1-A	24		3-5-B	109
	2-1-B	74		P 3-5	328
	1-8-B	84	TSUSHIMA, Miyuki	P 3-1	272
THOMPSON, Leanne	4-15-D	206	TUAN, Vo S	P 4-7	340
THOMPSON, Peter	P 4-14	395		P 4-1	413
THOMPSON, Philip	5-1	27	TUDHOPE, Alexander W	2-1-A	23
THORNHILL, Dan J	1-9-A	19	TUMI, Chris	P 4-8	394
THORNHILL, Daniel J	1-9-A	18	TUN, K P P	P 4-1	412
	1-9-A	21	TUN, Karenne P P	P 4-1	417
	P 1-9	251		4-1	62

Author	Session	Page
TUNG, Ching-Pin	4-14	212
TUNG, Ya-Hsuan	P 2-12	324
TUPPER, Mark H	4-12-B	95
TURAK, Emre	4-15-E	236
	P 1-6	241
TURNBULL, Jane	4-8	233
TURNER, John	4-2-B	152
	P 2-1	262
TURQUET, Jean	3-4	191
TYLER, Elizabeth H	4-7	66

U

UCHIDA, Senzo	4-24	223
	P 5-4	297
UCHIDA, Tetsuo	P 2-8	267
	P 2-8	269
UCHINO, Kanako	P 5-3	296
UDA, Takaaki	P 3-5	329
	P 4-7	341
UDUI, Masao	P 4-1	404
UEDA, Fujio	4-13	200
UEHARA, Tsuyoshi	1-6-B	100
	P 5-6	357
	5-6	52
UEMURA, Daisuke	P 5-6	358
UENO, Mitsuhiro	3-5-B	108
	P 4-1	405
UENO, Shinpei	P 1-8	250
	P 4-1	405
UEZU, Eiko	4-13	201
UEZU, Kayoko	4-13	201
UGALDE, Juan A	P 1-3	372
ULSTRUP, Karin E	1-9-B	68
UMEZAWA, Yu	P 3-6	390
	P 3-6	391
URABE, Shinichi	1-2-B	227
	4-21-A	57
USTIN, Susan L	5-1	28
UWATE, Roger	P 4-11	344
UYCHIAOCO, Andre J	P 4-1	407
UYCHIAOCO, Andre Jon	2-5	114
	P 4-14	395
UYCHIAOCO, Andre T	4-15-A	118

V

V, Naganathan	P 4-12	282
VAITAUTOLU, Selaina	4-8	235
VALAVI, Hamzeh	P 5-1	292
	P 4-1	411
VALENTINE, Peter S	4-5	183
VALERO, Sofia	P 1-4	380
VAN DER VELDE, Gerard	4-25	203
	4-25	204
VAN DUYL, Fleur C	3-6	231
VAN HERWERDEN, Lynne	P 1-6	243
VAN LAVIEREN, Hanneke	P 5-6	361
VAN NEIL, Kimberly	4-2-A	126
	P 2-3	312
VAN OPPEN, Madeleine	4-2-A	125
	P 1-6	243
	P 2-3	313
VAN OPPEN, Madeleine J	1-9-B	68
VAN OPPEN, Madeleine J H	1-1-B	185
	1-9-A	20
	1-9-A	21
	P 2-3	311

Author	Session	Page
VAN OPPEN, Madeleine J H	1-9-B	68
VAN OPPEN, Madeliene J H	P 1-1	301
VAN SOEST, Rob W M	1-7	104
VAN WOESIK, Robert	5-3	145
	1-2-A	189
	P 1-1	301
	P 2-4	316
VANAI, Paino	P 4-1	408
VARASTEHE, M R	P 5-1	292
	P 4-1	411
VARGAS-ANGEL, Bernardo	4-3	13
VASCONCELOS, Selma	P 1-6	246
	P 1-6	247
VASQUEZ, Oswaldo E	4-21-A	56
VASTA, Gerardo	1-4-A	167
VAUSE, Belinda	P 5-6	362
VECSEI, Adam	2-7	31
VELARDI, Angela	P 4-2	332
VENKATARAMAN, K	P 4-1	417
	4-1	63
VENKATARAMAN, Krishnamoorthy	P 1-6	247
	P 1-7	308
	P 4-1	398
	P 4-1	404
	P 4-1	409
	P 4-1	413
VENKATESH, M	P 4-21	284
VENN, Alexander	1-9-B	70
VENN, Alexander A	1-9-B	70
VERHEIJ, Eric	4-12-A	39
VERMEIJ, Mark J A	3-5-A	106
	2-3-A	131
	1-3	198
	P 1-2	370
	P 1-3	376
VERON, J E N	2-1-B	76
VICENTE, Vance	P 1-3	373
VICTOR, Steven	P 4-1	404
	4-18	79
VIDELER, John J	1-8-A	81
VIEHMAN, Shay	4-21-B	115
	P 1-4	383
VIERROS, Marjo K	4-15-D	206
VIEUX, Caroline	P 4-1	415
	4-1	61
VIGLIOLA, Laurent	4-5	183
	P 1-3	373
	P 1-3	374
	4-12-B	95
VILA-NOVA, Daniele A	4-3	13
VILELA, Camila	P 1-6	246
VILLANOY, Cesar L	P 4-15	348
VINCENT, Amanda C J	4-15-B	121
	4-5	181
	4-25	205
	P 4-4	337
	4-12-A	37
	4-7	65
	4-23	97
VIRLY, Sabrina	P 4-1	414
VISRAM, Shakil M	2-10-B	174
VISVALINGHAM, Sarala	P 5-6	362
VIYAKARN, Voranop	P 2-1	257
	P 4-21	288
VOLLMER, Steven V	1-1-A	141
VOSS, Joshua D	1-4-A	165
	1-4-A	167
VROOM, Peter	2-1-C	77
VUKI, Veikila C	P 4-1	399

Author	Session	Page
WOESIK, Rob Van	1-4-B	168
WOLANSKI, Eric	4-18	79
WOLFF, Matthias	P 4-11	343
WOLSTENHOLME, Jackie	1-1-A	141
WOLSTENHOLME, Jacqueline K	1-1-A	141
WON, Ki-Sik	P 4-5	339
WONG, Steven H	P 4-5	339
	P 4-14	395
WOOD, Elizabeth M	4-5	181
	P 1-8	250
	P 4-1	414
WOOD, Richard	4-15-C	147
WOODLEY, Cheryl M	4-2-A	125
	4-9	156
	P 1-4	381
	P 1-4	382
WOODMAN, George H	P 4-4	337
WOOLDRIDGE, Scott	2-1-A	22
	2-11	220
WORHEIDE, Gert	P 1-7	308
	1-6-A	43
WORK, Thierry M	1-4-B	168
WRIGHT, Margaret	4-18	80
WRIGHT, Wayne	5-1	27
WU, Bing-Je	P 2-1	263
WU, Tai-Ying	P 2-12	324
WULFF, Janie L	1-7	104
	4-24	222
WUNSCH, Mark	1-7	104

X

XIAOPING, Huang	P 4-15	347
XIUBAO, Li	P 4-15	347

Y

YAGI, Hiroe	2-7	33
YAHYA, Yunaldi	4-23	97
YAKOVLEVA, Irina	P 1-9	253
	1-9-B	70
YAKOVLEVA, Irina M	2-10-A	135
YAMADA, Hideaki	2-3-C	215
YAMADA, Shigeaki	P 2-7	266
YAMADA, Tsutomu	P 2-7	264
	P 2-7	265
	P 2-8	269
	P 2-8	271
	2-7	31
	P 2-4	315
	P 2-4	316
	2-8-B	87
YAMAGUCHI, Kunihisa	P 2-10	320
YAMAGUCHI, Toru	5-2	111
	4-16	179
	4-16	180
	P 4-16	350
YAMAMOTO, Hidekazu	P 4-21	286
	4-21-A	57
YAMAMOTO, Hiromi	4-24	223
YAMAMOTO, Hiroyuki	P 3-5	327
YAMAMOTO, Kazuyuki	P 2-7	266
	2-7	34
YAMAMOTO, Masanobu	1-2-B	225
YAMAMOTO, Satoshi	P 2-7	265
YAMAMOTO, Shoji	4-16	180
YAMAMOTO, Takamichi	P 2-10	320
YAMAMURO, Masumi	5-3	144

Author	Session	Page
YAMAMURO, Masumi	4-25	204
YAMANO, Hiroya	5-2	111
	4-3	14
	4-16	179
	4-16	180
	5-1	27
	5-1	29
	P 5-1	291
	P 4-16	350
	P 4-1	405
YAMASAKI, Hideo	3-5-A	107
	P 2-1	263
	P 3-2	325
	P 3-2	326
	P 3-5	328
YAMASHIRO, Hideyuki	1-4-B	168
	P 1-4	383
	P 4-16	350
YAMAZAKI, Hiroto	P 2-1	263
YAMAZAKI, Seitaro S	P 2-1	263
YAMUNA, Ruby	4-8	234
YAN, Hong Y	2-3-B	163
YANAKA, Shigeru	4-13	200
YANG AMRI, Affendi	P 4-1	401
YANG, Jay M	1-6-B	99
YANG, Ming Jay	1-6-B	101
YANG, Yi-Chen	4-14	212
YANUARITA, Dewi	4-20	128
YAP, Helen T	1-3	197
YASUDA, Naoko	P 1-4	383
YASUDA, Nina	3-5-B	108
	P 1-6	247
	P 5-6	359
	P 4-18	351
YASUMURA, Shigeki	2-9	178
YATES, Kimberley K	P 2-1	256
YATES, Kimberly	P 4-1	417
YEEMIN, T	4-1	62
	4-8	234
YEEMIN, Thamasak	P 2-1	259
	P 3-3	275
	P 4-21	287
	5-1	30
	P 1-7	308
	P 2-10	321
	P 4-5	338
	P 1-2	369
	P 4-1	414
YELLOWLEES, David	P 2-12	323
YEN, Ching-Ya	P 2-2	385
YI, Soon K	P 1-6	244
YI, Soon Kil	P 4-5	339
YIM, Wyss W -S	P 4-3	276
YNIGUEZ, Aletta	4-14	213
YOGI, Tsutomu	P 4-9	342
YOKOCHI, Hiroyuki	P 4-1	405
YOKOHAMA, Yasutsugu	1-9-C	73
YOKOI, Kensuke	P 5-6	359
YOKOKI, Hiromune	5-2	111
	4-16	179
	4-16	180
	P 4-16	350
YOKOUCHI, Hiroko	P 1-4	384
YONEYAMA, Sumio	P 2-10	320
YORINOBU, Minoru	P 1-9	253
YOSHIDA, Katsumi	3-6	231
YOSHIDA, Mari	5-1	27
YOSHIDA, Masahito	4-25	205
YOSHIDA, Minoru	P 4-1	405
YOSHIDA, Naohiro	4-3	14

Author	Session	Page
YOSHIDA, Naohiro	P 2-8	268
YOSHIHARA, Miki	P 4-16	350
YOSHII, Satoshi	P 4-16	350
YOTOLEMBAH, Sofyan A	P 4-24	396
	P 4-1	407
	P 4-1	414
YOTSU-YAMASHITA, Mari	P 1-6	245
YU, Hon-Tsen	1-1-B	186
YUSUF, Yusri	P 4-1	401
YUSUF, Yusri Bin	P 4-1	418
	4-1	64

Author	Session	Page
--------	---------	------

Z

ZACCANTI, Francesco	4-2-C	155
	P 4-2	332
	P 1-2	367
ZAHIR, Hussein	P 4-1	417
	4-1	63
ZAKAI, David	1-2-A	188
	1-2-B	226
	3-3	50
	1-9-C	72
ZANINETTI, Louisette	P 1-9	252
ZAPATA, Fernando A	1-5	132
	P 1-3	376
ZASK, Alon	3-3	50
ZAWADA, David	1-2-B	225
	P 5-3	295
ZEA, Sven	P 2-1	261
ZEKERIA, Zekeria A	1-8-A	81
ZELLER, Dirk	4-12-A	40
ZERN, Ya-Ching	P 1-1	305
ZGLICZYNSKI, Brian J	4-2-B	152
	P 4-1	411
ZHANG, Cheng-Cai	P 3-4	389
ZHIJUN, Dong	P 4-15	347
ZIBDAH, Mohammad	4-23	98
ZICUS, Sandra	4-24	224
ZIELKE, Sandra	P 1-9	254
	1-9-B	70
ZILMAN, Gregory	4-21-A	54
ZIMMERMANN, Matthew	4-24	223
ZIV, Yaron	P 1-3	372
ZLATARSKI, Vassil N	1-1-B	185
ZOCCOLA, Didier	P 2-12	323
	P 3-2	325
ZUBILLAGA, Ainhoa L	P 1-3	377
ZULUAGA-MONTERO, Anabella	P 1-8	250
ZUSCHIN, Martin	P 1-6	247