

Annual Report

Coral Reef Targeted Research &
Capacity Building for Management Program

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Acknowledgements

This report was developed and collated by Melanie King (Executive Officer) and Kristen Sampson (Project Officer) of the CRTR Project Executing Agency, with significant contributions from the following CRTR Program members:

Professor Ove Hoegh-Guldberg, Chair – Bleaching Working Group
Professor Peter Sale, Chair – Connectivity Working Group
Professor Drew Harvell, Chair – Disease Working Group
Professor Peter Mumby, Chair – Remote Sensing Working Group
Dr Alasdair Edwards, Chair – Restoration & Remediation Working Group
Professor Roger Bradbury, Chair – Modelling & Decision Support Working Group
Professor Ed Gomez, Chair – Southeast Asian Centre of Excellence
Dr Roberto Iglesias-Prieto, Chair – Mesoamerican Centre of Excellence
Dr Maggie Kyelawanga, Chair – East African Centre of Excellence
Dr Christopher Muhando – East African Centre of Excellence
Mr Andy Hooten, Synthesis Panel Executive Secretary & US Coordinator
Mr Mark Paterson, Communication Coordinator – Currie Communications
Ms Gabrielle Sheehan, Communication Officer – Currie Communications

Contributions have also been received from Working Group and Centre of Excellence members through their individual reports.

Further Information

Information used in this report has been collated from the individual Working Group and Centre of Excellence 2009 annual reports, and from communication activities during the reporting period. Additional information has been produced with the input of the Management Team.

For further information regarding this report and/or to request copies of the individual Working Group and Centre of Excellence reports, please contact the Executive Officer, Melanie King at m.king4@uq.edu.au.

Coral Reef Targeted Research & Capacity Building for Management Program, c/- Centre for Marine Studies,
Gerhmann Building, The University of Queensland, St Lucia, Queensland 4072, Australia
Tel: +61 7 3346 9942 Fax: +61 7 3346 9987 Email: info@gefcoral.org Internet: www.gefcoral.org

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Executive Summary

As the Coral Reef Targeted Research & Capacity Building for Management (CRTR) Program comes towards the end of Phase One in 2009, it sees the completion of almost five years of research from six Working Groups and four Centres of Excellence, comprising over 70 researchers. In addition to the research, the Program members have produced, or been involved in the production of, over 600 publications including peer-reviewed scientific literature, books, conference presentations, electronic products, grey literature articles and media articles, and participated in over 200 events. These activities have also led to the production of a number of communication and outreach outputs for research, management, policy and local community audiences.

In 2004 the CRTR Program commenced its research activities designed to address fundamental information gaps in our understanding of coral reef ecosystems, so that management options and policy interventions could be strengthened globally. The research undertaken over the past five years has encompassed coral bleaching and local ecological effects; coral disease; connectivity; restoration and remediation; remote sensing, and; modelling and decision support. The results and information produced from this research is now being accumulated into an impressive array of findings relevant to the scientific, management and policy communities at the global, regional and local levels.



Marine Protected Area, Apo Island, The Philippines. Photo: Gidi Levi

With increasing calls to further protect coral reef ecosystems and the life-forms they sustain, the research from the CRTR Program can assist in improving management and policy interventions, and future strategies. Key to this has been the work undertaken to understand the causes and stresses caused by mass coral bleaching events and coral disease. Research into the impacts of stress events on coral reefs has led to an improved understanding of how coral reefs respond or adapt to the impacts of different stress events. Observations have demonstrated that mild thermal stress events show different responses compared with extreme events – during extreme events, small colonies do better than larger colonies, while during mild events, colony size does not influence bleaching. Furthermore, separate studies from the Bleaching and Disease Working Groups have revealed that thermal stress plays a key role in increasing the incidence and susceptibility of corals to disease.

Additionally, the development of the “Lab in a Box” by the Disease Working Group will enable cutting-edge real-time advanced microscopy and molecular microbiology in coral disease research in remote field settings. This capability of working with fresh material and in tightly iterative mode has dramatically changed the depth and quality of data and observations that can be made in field-based coral microbiology. Given the limited resources that most remote island and reef managers have at their disposal, this toolkit could serve as a model for field coral microbiology.

Research from across the scientific working groups has also led to valuable information for the improved establishment of Marine Protected Areas (MPAs), and their value in protecting coral reef systems from environmental and anthropological impacts. For example, work undertaken into the resilience to disease through the establishment of MPAs has found lower disease prevalence within MPAs than the adjacent fished areas, which was strongly correlated with fish functional diversity.

Equally important in determining zoning such as MPAs, or understanding which reefs are replenished from what sources is the understanding of the connectivity of larvae both from coral and fish species. Research under the CRTR Program into the development of immunogenetic tags to identify coral planulae to species, and the development of a novel 'magnetic particle' technique for measuring movement of water and particles away from spawning sites of corals, has led to an extension in knowledge of coral genetics in the Mesoamerican region, and advanced knowledge of coral larval biology and behavior that could be important in developing new models of coral dispersal. The work undertaken by the Connectivity Working Group has now resulted in connectivity issues being more firmly based in management decisions.



Habitat survey, Lingayan Gulf.

A new technique developed by members of the Remote Sensing Working Group has also led to the ability to identify areas of the coastal zone that have particularly benign physical conditions in terms of coral bleaching. The method also includes important new advances to the design of marine reserves such that connectivity and different reserve design criteria can be incorporated explicitly into the algorithm. The methods have now been showcased for the Bahamas and Belize.

Practical on-ground information for managers has also been developed. With the increasing emphasis on aquaculture as a source of food and income for many communities throughout areas such as Asia, members of the CRTR Program made some breakthrough discoveries in determining that potentially pathogenic microorganisms such as *Roseobacter* spp. and *Disulfovibrio* spp., are likely moving from fish pens onto the reef. This discovery necessitates that "Best Practices Guidelines" be established for aquaculture adjacent to reefs in order to preserve the ecosystem for fisheries and the other life-forms it sustains.

Research into coral restoration techniques has demonstrated a number of successes with various cost-effective methods of coral restoration being explored. Much of this work is being undertaken in Bolinao, Philippines, whereby the research team has been exploring methods including coral fragment transplantation techniques and larvae rearing before being transplanted out onto the reef. Recent work has included collaborations with local communities on the transplantation of corals and the work has shown good results and much promise with the potential for scaling up. Using principally a locally available resilient species, *Porites cylindrica*, local volunteers transplanted more than a thousand second generation transplants and locally available 'corals of opportunity' successfully, with a high degree of survival. The activity used no scuba and no adhesives, strictly volunteer time, and generated much interest for future expansion.



Remote sensing tools developed over the five years will also assist in management and policy decision-

Community volunteers transplant coral using low cost methods, with goggles as their only equipment.

making at the regional and local scales. The creation of the Reef Observer software tool uses a state-of-the-art model of radiative transfer, together with a large spectral library of coral reef substrata, to quantify the feasibility of any coral reef remote sensing project. Reef Observer also has a capacity to identify whether particular changes in coral reef state can be detected using remote sensing. The user can specify the type of change (% substrata), the depth, the clarity of the water, and type of sensor. The radiative transfer software used to power Reef Observer is now complete and is being disseminated free of charge.

The online Reef Remote Sensing Toolkit was extended to help practitioners match their remote sensing objectives to the appropriate technologies (this toolkit covers a wide range of mapping problems and essentially stops short of making prescriptive predictions for more detailed remote sensing problems – for which Reef Observer is used). The upgraded Toolkit is due for release on the website in December 2009.

These findings, amongst others, play an important role in assisting to develop mitigation and adaptation strategies and provide the basis for identifying the least/most vulnerable reefs and predicting the spatial distribution of future coral reefs and developing management priorities that are most appropriate for their future.

In addition to the research element, the Program has continued to make strong in-roads into building the capacity of scientists and managers in developing countries through student scholarships, training workshops and courses and the release of new information. Following the success of the Future Leaders Forum in 2007 and a follow-up meeting at the International Coral Reef Symposium in 2008, the scholars' network of Masters, PhDs and Post-doctoral researchers now extends to approximately 60 students from 17 countries around the world. Cementing the success of this group, the network will release an anthology of their work under the CRTR Program in early 2010.

Importantly in the final stages of Phase One, the CRTR Communication Team have continued to work with the Working Groups and Centres of Excellence in producing relevant products adapting their research outputs for target audiences. Information produced and packaged during the year has included products ranging from advisory briefs and guides, to reports and case-study analyses.

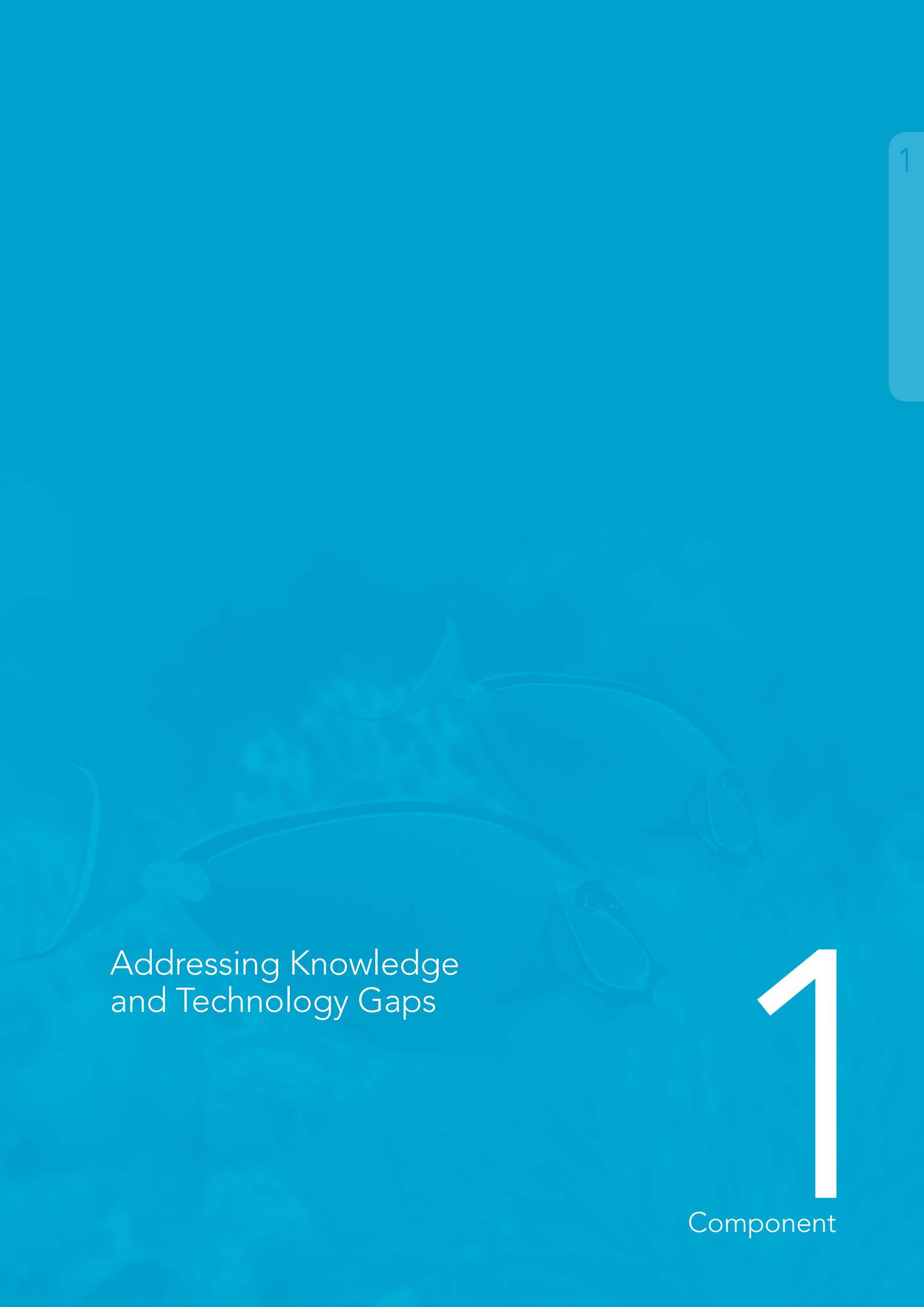
Products developed from the research outputs will continue into early 2010 with the release of connectivity and remote sensing handbooks, a coral reef restoration manual, a report on the role of indigenous knowledge in the management of fish stocks and coral reefs in Tanzania, and an anthology of the CRTR scholars' work from Phase One.



The East African COE produced a handbook to document the traditional fish stock management techniques of Zanzibar fishers. Photo: Assaf Zvuloni

Phase One has seen a culmination of high-level, synthesised research information, information outputs and capacity building activities being undertaken with the networks generated now spanning 70 senior scientists and 60 scholars from 23 countries. The success from the first five years has been seen in the numerous research findings, many of which have been published in over 600 research publications, and in the large number of training workshops, information exchanges, conferences, media events and meetings that have been participated in or organised by Program members. Additionally, there have been management and policy successes with local practices under review or changes already being made.

Whilst the planning for Phase Two is underway, it will be important to maintain the momentum gained under the first Phase and to use the information still forthcoming from the science projects, to guide the future management of and policy decision-making for coral reefs.

A faint, light blue background image of a fish, possibly a salmon, is visible across the entire page. The fish is oriented horizontally, facing right, and its scales and fins are subtly detailed.

Addressing Knowledge and Technology Gaps

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Component

Addressing Knowledge and Technology Gaps

Despite an increasing awareness of the importance of coral reef ecosystems to human populations around the world in terms of ecosystem goods and services including food security, livelihoods, tourism, and coastal defence, there are still many gaps in the scientific knowledge regarding the forms and functions of these ecosystems. To address these knowledge gaps, the CRTR Program is organised around six key scientific themes under Component One, which address the scientific gaps pertaining to:

- Coral bleaching and local ecological responses
- Connectivity and large-scale ecological processes
- Coral disease
- Remote sensing
- Coral restoration and remediation
- Modelling and decision support

Highlights of progress over the reporting period are outlined below, with detailed progress available from the Working Group Annual Reports.



Coral Bleaching and Local Ecological Responses

Working Group Members:

Prof Ove Hoegh-Guldberg, Chair – Centre for Marine Studies, The University of Queensland, Australia
Prof Yossi Loya, Co-Chair – Department of Zoology, Tel Aviv University, Israel
Prof Robert van Woesik – Department of Biological Sciences, Florida Institute of Technology, USA
Dr Tim McClanahan – The Wildlife Conservation Society, Kenya
Dr Roberto Iglesias-Prieto – Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México
Dr Ruth Gates – Hawaii Institute of Marine Biology, University of Hawaii, USA
Dr Michael Lesser – Department of Zoology, University of New Hampshire, USA
Dr John Bythell – Department of Marine Sciences & Coastal Management, University of Newcastle, UK
Dr Christian Wild – University of Munich, Germany

The Bleaching Working Group (BWG) has focused on key gaps in our understanding of mass coral bleaching and related ecological phenomena, and has pursued research projects that range from establishing a better understanding of why corals bleach and get diseased, to the impacts of coral mortality on fish populations and human dependents. The associated research has been conducted across the four Centres of Excellence: Heron Island (Australia), Zanzibar (Tanzania), Bolinao (Philippines) and Puerto Morelos (Mexico). In addition to producing over 230 peer-reviewed papers, the BWG has trained 17 postgraduate students and has supported many more through its regional workshops and research projects.



Fishermen in Mtwara, Tanzania. Photo: Tim McClanahan

Whilst focusing on the key gaps in understanding mass coral bleaching, the BWG has made significant progress through increasing the understanding of the geographical and functional diversity of *Symbiodinium* (single-celled algae which live in a symbiotic relationship with coral reefs), and played a significant role in the establishment of a worldwide database of *Symbiodinium* genetics. The results indicate there are marked regional differences in the diversity and ecological dominance of symbiotic algae, with the patterns probably influenced by long-standing environmental conditions and/or from historical changes in climate during transitions between geological periods. Coral-algal symbioses are highly responsive to change through partner recombination but these processes may require time scales of centuries or more in duration.

Furthermore, recent genetic studies have identified large differences between *Symbiodinium* occupying different host species, indicating potentially hundreds of different species. At the outset of this project the understanding of the differences between species of *Symbiodinium* was confined to a number of non-coding sequences such as 18S, 28S and ITS ribosomal sequences. This project made a major contribution to filling this particular gap in understanding *Symbiodinium* by expanding the number of sequenced genes from a little over 10 to over 1450.

The results of these projects have established an important platform for exploring the major responses of *Symbiodinium* to stresses such as those arising from climate change, and for



Bleached versus normal *Acropora* near Great Keppel Island Southern Great Barrier Reef in January 2006. Photo: Ove Hoegh-Guldberg

exploring the underlying differences between reef-building corals in their response to environmental stress. They will also be instrumental in improving management strategies to adapt to changes in the environment of coral reefs.

Understanding of the interactions of reef-building corals and *Symbiodinium*, with the broader range of symbiotic organisms associated with them, is critical to understanding not only the basic biology of corals, but also their response to stress and disease. Research undertaken by BWG members set out to describe host symbiont mutualism between corals, dinoflagellates and bacteria, and resulted in a large number of new observations and discoveries. The research identified the critical role of the mucus layer on corals as a barrier to microbial invasion, and concluded after extensive studies that bacteria are rare within the tissues of corals.



Amphiprion-Maldives. Photo: Tim McClanahan

Members of the group also explored the potential role of bacteria in causing bleaching, discovering that *Vibrio* and other bacterial infections are most likely secondary rather than primary causes of bleaching and disease. It became clear that thermal stress increases the incidence and susceptibility of corals to disease, which echoes results discovered within the Disease Working Group of the CRTR Program.

Research undertaken on the effects of bleaching on coral and fish communities in the Western Indian Ocean compiled approximately 2000 site-time combinations of coral cover for the whole Western Indian Ocean (WIO) for the period 1958-2005 and analysed regional patterns and identified the 1998 climatic oscillation as the most significant factor in affecting regional variation in coral cover. Further analysis of change in coral cover and community structure, and their relationship with environmental properties, indicated that the impact of the disturbance was variable in space in association with region-specific environmental properties; primarily the background temperature, light condition and water current. This has been mapped and provides the basis for identifying least and/or most vulnerable reefs and predicting the spatial distribution of future coral reefs and developing management priorities that are most appropriate for their future.

Full details of the research findings and achievements of the Bleaching Working Group can be found in the report "*Bleaching and Related Ecological Factors: CRTR Working Group Findings 2004-2009*" (www.gefcoral.org).



Photo: D. Thornhill

Connectivity and Large-scale Ecological Processes

Working Group Members:

Prof Peter Sale, Chair – Biological Sciences, University of Windsor, Canada
Dr Carmen Ablan – Molecular Genetics Laboratory, The WorldFish Center, Malaysia
Dr J Ernesto Arias – Lab. Ecologica de Ecosistemas de Arrecifes Coralinos, CINVESTAV-U, Mexico
Prof Mark Butler IV – Department of Biological Sciences, Old Dominion University, USA
Prof Robert Cowen – Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA
Dr Bret S. Danilowicz – Paulson College of Science & Technology, Georgia Southern University, USA
Dr Geoff Jones – School of Marine Biology & Aquaculture, James Cook University, Australia
Dr Serge Planes – Centre National pour la Recherche Scientifique, Universite de Perpignan, France
Prof Barry Ruddick – Department of Oceanography, Dalhousie University, Canada
Dr Yvonne Sadovy – Society for the Conservation of Reef Fish Aggregations, The University of Hong Kong
Prof Robert Steneck – School of Marine Sciences/Darling Marine Center, University of Maine, USA
Prof Alina M. Szmant – Coral Reef Research Group, Center for Marine Science, University of North Carolina at Wilmington, USA
Dr Simon Thorrold – Biology Department, Woods Hole Oceanographic Institution, USA
Dr Mary Alice Coffreth – Department of Biological Sciences, State University of New York, USA
Dr Ken Lindeman – Environmental Defense, Miami, USA
Dr Enric Sala – Center for Marine Biodiversity and Conservation, Scripps Institute of Oceanography, USA

Coral reefs are patchily distributed ecosystems potentially connected by ocean currents. 'Connectivity' is the flux of items between locations. The complexity of water movement in and around coral reef systems makes the building of detailed information on connectivity patterns challenging and requires large teams and simultaneous field observations and/ or collections over relatively large regions. Much of the work undertaken by the Connectivity Working Group (CWG) has focused on demographic connectivity. The research undertaken by the CWG over the past five years has resulted in connectivity issues now being more firmly based in management decisions. This is also being reflected in the tone of the Connectivity Handbook, which will be available in early 2010.

The final year of Phase One, has seen the CWG focusing its efforts on (i) the final analysis and publication of research results for the sub-projects, (ii) further developing thinking on the application of the science of connectivity into MPA design, and (iii) effectively transferring knowledge of connectivity science to the management community. Priority questions for the CWG centred on developing ways to measure connectivity in reef species including fish, corals and lobster.

Whilst the CWG's five-year workplan was very ambitious there has been some major outputs including a number of important technical achievements (published in peer-reviewed literature), and the biophysical modeling framework developed by Claire Paris and others, partly with CRTR funding, now being made available to the community via the web (initially in a password protected mode, but ultimately as freeware).

In addition to the research undertaken, the CWG has also been involved in discussions concerning inappropriate coastal development, and has been responsible for the production of an advisory brief on this issue. The arguments against inappropriate coastal development all relate to the need to maintain connectivity both among populations and between habitats used by different life stages of coral reef species. The need to ensure firm policy decisions are taken to protect these habitats has been highlighted in Belize where



legislation has been passed to ban the landing of fish fillets as a way of preventing fishing for parrotfishes and other grazers. This legislative change has come about as a direct consequence of interactions between managers and members of the connectivity and remote sensing programs.

Research findings from the CWG have included the advances made in testing approaches to explore connectivity in a common, sedentary reef fish with demersal eggs, through the use of natural otolith tags (trace elements). It has been found that genetic approaches, particularly assignment techniques that relate individual recruits to likely natal populations were more useful, although the need for relatively large samples of adults and recruits, collected over a large region demonstrated the logistical demands of these approaches. The project has provided new detail on the scale of connectivity in this common species.



Barracudas. Photo: Ernesto Weil

Work on the development of immunogenetic tags to identify coral planulae to species has continued. This project has now developed a novel 'magnetic particle' technique for measuring movement of water and particles away from spawning sites of corals. It also extended knowledge of coral genetics in the Mesoamerican region, and advanced knowledge of coral larval biology and behaviour that could be important in developing new models of coral dispersal.

Whilst the research components have provided new information for use in understanding the connectivity between species and habitats, the CWG has also continued to make important advances in communicating the science to management audiences. Along with the activities mentioned earlier, the CWG has also produced a number of training workshops and written products for managers. Attempts have been undertaken to educate the management community in the Mesoamerican region concerning issues of connectivity as they relate to coral reef management. The challenge of linking science to management, and of having a real impact on management actions,

has been met with some success with long-term connections between scientists and managers forged. In particular, managers in the Mesoamerican region are now comfortable with contacting members of the Working Group for advice on a broad range of topics, some of which concern connectivity.

Of particular note in linking the science to management actions, the CWG held a workshop at the CRILOBE facility, Moorea, French Polynesia, 7-11 March, 2009, immediately following the Pacific Science Congress meeting in Tahiti. Titled "*Connectivity in Coral Reef Systems – Lessons to Date and Goals for the Future*", this meeting brought together 10 members of the CWG 'family' and six scientists with no prior contact with the CRTR Program, but working on issues in connectivity at Pacific locations.

Planning is also now complete for the final workshop to be held with managers in the Mesoamerican region, in Belize City, 9-11 November. Belize Department of Fisheries and The Nature Conservancy are collaborating with the CWG in delivering the workshop.

Coral Disease

Working Group Members:

Prof C. Drew Harvell, Chair – Section of Ecology and Evolutionary Biology, Cornell University, USA

Prof Bette Willis, Co-Chair – School of Marine Biology and Aquaculture, James Cook University, Australia

Dr Garriet Smith, Co-Chair – Department of Biology and Geology, University of South Carolina-Aiken, USA

Dr Eric Jordan Dahlgren – Instituto de Ciencias del Mar y Limnología,
Universidad Nacional Autonoma de Mexico

Prof Farooq Azam – Scripps Institution of Oceanography, University of Southern California, USA

Dr Laurie Raymundo – Marine Laboratory, University of Guam, USA

Prof Eugene Rosenberg – Department of Molecular Microbiology and Biotechnology,
Faculty of Life Sciences, Tel Aviv, Israel

Prof Ernesto Weil – Department of Marine Sciences, Universidad de Puerto Rico Mayaguez, Puerto Rico

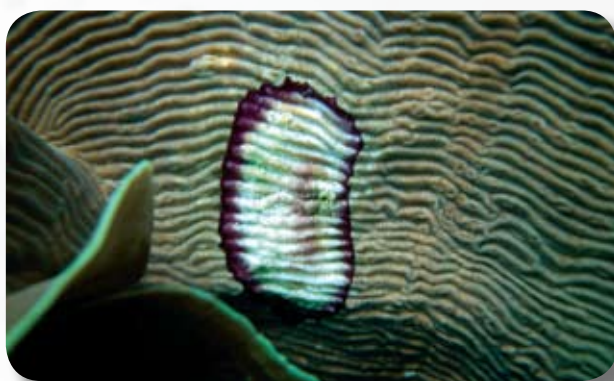


Photo: Ernesto Weil



Photo: Andy Hooten

As disease plays an increasing role in changing the structure and function of some coral reefs, we need to consider how management actions influence outbreaks. Exploring even basic questions is hampered by (i) the global nature of the problem; (ii) overall lack of resources; and (iii) a lack of expertise and technology in developing countries where many reefs are located. In response to these gaps, the goal of the coral disease program is to fill critical information gaps about coral reef disease to assist in the development of management and conservation strategies that protect reef ecosystems from damage due to disease.

During the past five years of research, the Coral Disease Working Group (DWG) has made significant advances in all five-priority areas of its work program, and the DWG will continue working on products even after the completion of the Phase. The DWG's three most significant accomplishments of 2009 are (i) the Pan-Pacific Coral Health and Disease Workshop, (ii) publication of the study in PNAS showing that coral disease prevalence is lower in some types of Philippines MPAs than adjacent fished areas, and (iii) publication of research documenting the transportation of aquaculture-associated bacteria onto the adjacent reefs and recovery of coral-associated bacterial communities following exposure to aquaculture effluent in Bolinao.

The Group's three most important projects under development are (i) analysis of the global prevalence data, (ii) linking coral disease with water quality in Mexico, and (iii) developing forecasting models of coral disease with temperature anomalies. The initial manuscript submission of all three of these projects is expected in January 2010.

One of the primary goals of the year was to complete the final year of coral disease monitoring, and organise data management and analysis for the Group's long-term sites under its global assessment of coral disease project. The Pan-Pacific Coral Health and Disease Workshop facilitated discussions on the development and implementation of coral disease management techniques and resulted in significant advances in data sharing and plans for future collaboration. A clear indication of uptake was the follow-up meeting hosted by NOAA in August in Hawaii to advance forecasting approaches to coral disease in the Pacific.

A framework for development of a global coral disease prevalence database to facilitate data analysis is now underway following these workshops, with the database being compiled and developed with analysis of the global spatial and temporal patterns of disease now taking place. Additionally, the development of a model to forecast future disease prevalence based on environmental factors for the Caribbean region is underway.

New tools to predict disease outbreaks

New tools continue to be developed, including a modelling tool which predicts white syndrome outbreak likelihood on the Great Barrier Reef. The tool uses satellite SSTs to identify areas of high-accumulated heat stress and produces outbreak likelihood maps in Google Earth. The website for this tool is scheduled to be launched late in 2009.

Furthermore, Jeff Maynard from the Great Barrier Reef Marine Park Authority (GBRMPA) is collaborating with Dr Bette Willis to develop "Reef Temp," a disease-forecasting program for Australia. These data are currently being incorporated into three papers: a global coral disease prevalence paper; a Pacific coral disease prevalence paper; and a paper on the spatio-temporal patterns of prevalence and severity of disease along the Yucatan Peninsula.

The impacts of coral disease on coral diversity, communities and populations have also been a key focus for the DWG throughout the past five years. To

determine the impacts of coral disease on coral diversity, community structure and populations, temporal trends need to be followed in a long-term data set. The main goal for this project in the past year was to commence data analysis and manuscript preparation for several of the Centres of Excellence. This has resulted in several publications now in preparation based on the comprehensive monitoring program established in the Yucatan. The publications include (i) Deriving Yucatan yellow band disease incidence values from prevalence values; (ii) Coral reef community shifts from diseases; (iii) The relationship between partial mortality and size structure in *Montastraea annularis* species complex; and (iv) The differential effects of hurricane Deane and coral disease patterns.

In addition to this monitoring and data analysis work, researchers have completed a large modelling effort based on a decade of monitoring the Caribbean sea fan *aspergillosis* epizootic which is currently in review. This demographic model is useful for investigating questions about the evolution of resistance and recovery time in populations experiencing varying levels of disease impact.

"Lab in a Box"

The DWG has developed the proposed "Lab in a Box" enabling cutting-edge real-time advanced microscopy and molecular microbiology in coral disease research in remote field settings. This capability of working with fresh material and in tightly iterative mode has dramatically changed the depth and quality of data and observations able to be made in field-based coral microbiology. Given the limited resources that most remote island and reef managers have at their disposal, this toolkit could serve as a model for field coral microbiology.

Several fine scale temporal assessments of coral disease outbreaks in the Great Barrier Reef (GBR) and Indo-Pacific have also taken place. On the Great Barrier Reef, researchers tracked lesion growth rates and disease spread for a black band disease (BBD) outbreak in the Palm Islands and found that BBD affected 10% of the population and was positively correlated with seasonal temperature fluctuations. White syndrome and black band disease outbreaks in Palau and Indonesia have also been monitored for the past two years. With these long-term data sets, the DWG has been able to assess the genera-specific disease susceptibility across geographic regions within the Great Barrier Reef and the Caribbean.

The resilience of coral reefs to disease continues to be studied in the Philippines by members of the DWG in

collaboration with the Southeast Asian Centre of Excellence. This work into the impacts of fish farm effluent on the nearby coral reefs has found an unexpected degree of resilience in coral-associated bacterial communities that was previously completely under the detection limits of any established disease survey method or "coral health monitoring" effort. The discovery was enabled by the emphasis on hypothesis testing at timeframes that are short enough to resolve time-varying microbial community responses to environmental stress.

Resilience of coral reefs to disease has also been connected to the establishment of MPAs. During the past three years, DWG researchers have found lower disease prevalence within MPAs than the adjacent fished areas, which was strongly correlated with fish functional diversity. This work continues to be communicated to local community leaders and fisherman in the Philippines to assist local communities with the establishment of effective MPAs.

Lastly, the flagship products developed by the DWG, *A Coral Disease Handbook: Guidelines for Assessment, Monitoring and Management* and the *Underwater Cards for Assessing Coral Health* continue to be in high demand, and have been applied by the DWG to obtain a baseline level of coral disease in many regions worldwide. These data will be invaluable as a benchmark against future disease outbreak events.

Furthermore, the collection of data, and corresponding workshops with the local scientists, helped to develop a worldwide network of researchers that have been trained at the CRTR Centres of Excellence. Many managers now have the tools in place to study future outbreaks and contact information for coral disease experts willing to provide assistance.

Modelling and Decision Support

Working Group Members:

Prof Roger Bradbury, Chair – Research School of Pacific and Asian Studies,
Australian National University, Australia

Dr Pascal Perez, Co-Chair – Research School of Pacific and Asian Studies,
Australian National University, Australia

Dr Porfirio Alino – Marine Science Institute, University of the Philippines, Philippines

Dr Ernesto Arias – Lab. Ecología de Ecosistemas de Arrecifes Coralinos, CINVESTAV-U, Mexico

Dr Peter Campbell – Advanced Computer Applications Center, Argonne National Laboratory, USA

Dr Bohdan Durnota – Tjurunga Pty Ltd, Australia

Prof Rob Seymour – University College London, UK

In the final year of the Program's Phase One, the Modelling & Decision Support Working Group (MDSWG) has continued to maintain the momentum from previous years. One of the major strengths of the MDSWG lies in its PhD and Masters students, and the network is continuing to work effectively and productively. One student has submitted his doctoral thesis, another his masters thesis, while another is preparing her doctoral write-up. A new doctoral and a new honours student have also begun to undertake research within the Group's auspices.

Work on the local and regional models has continued over the reporting period with instantiation, calibration and validation of regional models for Mexico and the Philippines now completed. The local models have been fully parameterized and ported to user-friendly environments. The post-hurricane Dean survey of the Costa Maya has been completed, the data analysed, and a report prepared. These new regional models for Mexico and the Philippines allow realistic policy-relevant scenarios to be tested at the regional scale. The models are uniquely realistic (being validated for each region), and general (being built from fundamental ecological and economic process models rather than empirically fitted to data). No other models available today match their performance or scientific power. The local models allow users to explore prognoses for their reefs based on current and expected future conditions. Both regional and local models will be available as interactive online tools in March 2010.



Models and tools from the MDSWG can predict the impact of coastal developments and climate change on coral reefs.

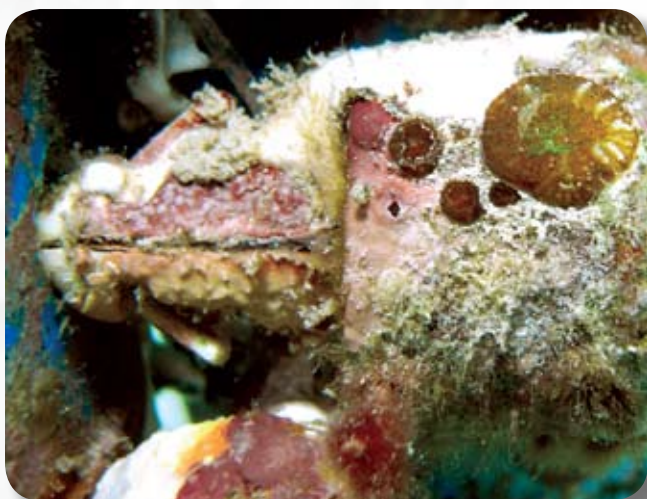


Tulum, Mexico – Bathers near Mayan Ruins. Photo: Mark Paterson

Coral Restoration and Remediation

Working Group Members:

Dr Alasdair Edwards, Chair – School of Biology, University of Newcastle, UK
Emeritus Prof Ed Gomez, Co-Chair – Marine Science Institute, University of the Philippines, Philippines
Dr Richard Dodge – National Coral Reef Institute, Nova Southeastern University, USA
Dr Richard Speiler – National Coral Reef Institute, Nova Southeastern University, USA
Dr Aileen Morse – Marine Biotechnology Center, Marine Science Institute, University of California-Santa Barbara, USA
Dr Buki Rinkevich – National Institute of Oceanography, Haifa, Israel
Dr Makoto Omori – Akajima Marine Science Laboratory, Japan
Dr Tadashi Kimura – Japan Wildlife Research Center, Japan
Dr Andrew Heyward – Australian Institute of Marine Science, Australia
Dr James Guest – University of Singapore
Prof Loke Ming Chou – University of Singapore



10 month *Favites halicora*. Photo: James Guest

a Coral Reef Restoration and Remediation Training Course in Eastern Africa was held at the East African CoE from 27-31 July 2009 with trainees from Kenya, Tanzania, Seychelles and Mauritius, among others. This greatly benefited from inputs from colleagues from the European Union REEFRES project. A regional reef restoration network was set up and the RRWG has received requests for assistance from Nature Seychelles with respect to rehabilitating a 30 hectare area of reef in the Cousin Island MPA that has not recovered from the 1998 bleaching and appears to have shifted into a macroalgal-dominated state. This request is being considered as part of a Phase Two integrated project for the region.

The worldwide degradation of coral reefs has prompted greater attention to restoration and remediation activities. During the past five years, the Restoration & Remediation Working Group (RRWG) has focused its efforts on: (i) integrated long-term monitoring of natural recovery processes and selected restoration interventions on standardised substrates; (ii) enhancing coral larval recruitment, and (iii) enhancing recovery by culture and transplantation of corals.

Within the Phase One work program the RRWG is now collating data and results, and finalising the *Reef Rehabilitation Manual*, which is to be companion-piece to the 2007 *Reef Restoration Concepts and Guidelines*. In addition to the research outputs, the RRWG has been involved in a number of capacity building and communication projects. For example,



Floating reefball. Photo: Kirk Kilfoyle

Under the work program, research has continued into the monitoring of the Standardised Modules (SMs – pallet balls) used in the long-term experiments at Palau and Bolinao in the Pacific, and at Puerto Morelos and Akumal in the Caribbean. All surveys planned for 2009 were successfully completed, with the data from Palau and Bolinao entered into the project databases and analysis of the data underway. Journal articles for the peer-review literature have been submitted and published in *Coral Reefs*, *Restoration Ecology*, *Marine Pollution Bulletin* and *Marine Ecology Progress Series*. One paper on self-attachment rates of transplants, largely derived from the REEFRES work but partly supported by CRTR, was also published in *Restoration Ecology*.

Under the coral larval recruitment program, the “larval flypapers” research by Dr Morse at Palau was completed in April 2009. The final surveys revealed that survival of 5000 sexual recruits outplanted on artificial reefs (pallet balls) was poor (1.5% after one year), although there was good natural recruitment to the same pallet balls. However, much better survival (up to 80%) was found for asexual fragments of *Acropora digitifera* outplanted to the natural reef and growth was found to be positively correlated with mean water velocity. Comparisons of survival of fragments of six species of *Acropora* between natural reef and pallet balls indicated 50% lower survival on the pallet balls.

A dedicated coral larval rearing facility has now been constructed at the Bolinao Marine Laboratory (BML) of the Southeast Asian CoE and is fully functional. The facility will be used for further larval rearing work planned for 2010 and beyond by students and other researchers. Another major attempt at spawning corals for larval rearing for restoration was made in May 2009 with a focus on two faviid species (*Favites halicora*, *Montastrea colemani*). Spawning and larval rearing for both species was successful despite a major typhoon hitting Bolinao just a few days before the spawning event. The majority of coral spat are currently being reared in the newly constructed tanks at the hatchery facility at BML and some will be outplanted to in situ nurseries in November 2009. Corals reared in 2009 are being co-reared ex situ with juvenile topshells (*Trochus niloticus*) following the methods developed by Prof. M. Omori and co-workers in Okinawa. An experiment to test the effect of surface refugia on coral spat survival was also carried out with ‘grooved’ and ‘smooth’ coral plug-ins transplanted to an in situ nursery at Malilnep channel approximately one month after fertilisation in 2009.

The efficacy of the “coral peg” as a substrate for culture of sexually reared coral spat was tested at the Akajima Marine Science Laboratory in Okinawa with corals on the pegs being transplanted to the reef at Akajima. Again, nibbling by fish was a serious problem for survival of colonies, particularly during the first month after transplantation. Separately from the CRTR research at Palau, many juvenile colonies of *Acroporatenuis* that had been cultured from eggs in June 2005 at Akajima were transplanted onto bommies in December 2006. About ten 4-year and 5-year old colonies spawned for the first time on June 8, 2009. This is the first record of successful rearing of reef-building corals from gamete to spawning adult and demonstrates the potential of using the present culturing technique to assist local reef restoration. A note entitled “A novel substrate (the “coral peg”) for deploying sexually propagated corals for reef restoration” has been published in *Galaxea, Journal of Coral Reef Studies*.

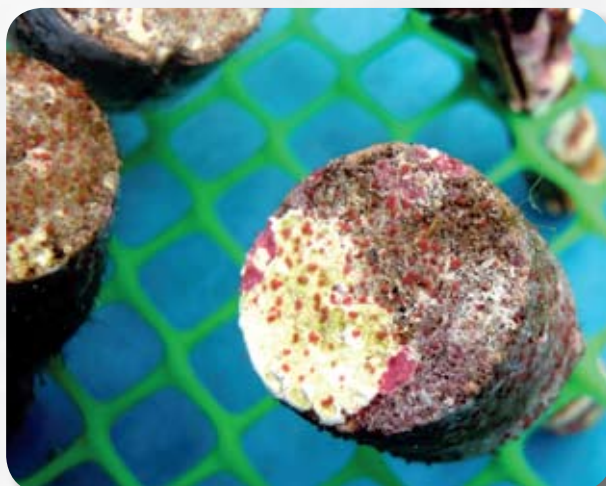
The final component of the RRWG’s five-year workplan, enhancing recovery by culture and transplantation of corals, has continued to progress with the year seeing the completion of the single and mixed species experiments and the piloting of transplantation of corals involving the local communities. The latter showed good results and much promise with the potential for scaling up. Using principally a locally available resilient species, *Porites cylindrica*, local volunteers transplanted more than a thousand second generation transplants and locally available ‘corals of opportunity’ successfully, with a high degree of survival. The activity used no scuba and no adhesives, strictly volunteer time, and generated much interest for future expansion. A prototype agent-based model for single species transplantation has been completed. It incorporates coral recruitment and interactions between transplants of the same species,



Favites halicora spawning. Photo: James Guest



Floating nursery. Photo: Gidi Levi



Montastrea colemani spat. Photo: James Guest



Collection of coral slicks at Aka Harbour for use in coral restoration research
Photo: M Hatta

algae and gastropod (*Drupella*) predation. There is good agreement between model output and results of field experiments. The model will be extended to include interactions among transplants of different species as well as effects of environmental factors.

RRWG members continued to maintain the nurseries at Bolinao and at Zanzibar and Mafia Island in Tanzania and it is clear that the techniques for nursery rearing at a significant scale are now well-developed. Most of these coral colonies, upon reaching sizes suitable for transplantation, have been transplanted onto study reefs. A new approach for transplanting the corals reared in rope nurseries was tested. This involved towing the entire nursery and submerging it onto the substrate where it was attached using masonry nails. Initial results have not been encouraging partly due to a typhoon.

The results of the last five years suggest that coral nurseries are central to achieving active reef restoration at any meaningful scale and that farming of thousands of coral colonies is achievable by local communities. Unfortunately, methods of transplantation have lagged behind the fast development of nursery methodologies. However, the last three years have seen achievements in transplantation. Almost 20,000 colonies of more than a dozen coral species had been transplanted using several novel attachment methodologies (power drilling into substrates, hand-drilling, gluing, etc.) in various transplantation protocols (monocultures, polycultures, randomly arranged colonies, aggregates of same species/genotypes vs. mixed species/genotypes, and more), coral colony sizes and locations.

Remote Sensing

Working Group Members:

Prof Peter Mumby, Chair – Marine Spatial Ecology Lab, School of Biological Sciences,
Hatherly Laboratory, University of Exeter, UK

Dr Laura David, Co-Chair – Marine Science Institute, University of the Philippines, Philippines

Prof Stuart Phinn – School of Geography, Planning and Architecture, The University of Queensland, Australia

Prof Ellsworth LeDrew – Faculty of Environmental Studies, University of Waterloo, Canada

Dr Mark Eakin – Marine Applications Science Team, Coral Reef Watch Project, NOAA, USA

Dr William Skirving – Coral Reef Watch Project, NOAA, Australia

Dr Alan Strong – Marine Applications Science Team, Coral Reef Watch Project, NOAA, USA

Over the past five years, the Remote Sensing Working Group (RSWG) has been developing and testing a wide range of remote sensing tools, including satellite, airborne, acoustic and in-field methods. The Group has quantified the limitations of coral reef remote sensing by combining modelling and field experiments. The final year of the project has witnessed the realisation of the RSWG goals: (i) creation of a decision-support and analysis software for monitoring the health of coral reefs using remote sensing; (ii) development of methods to detect changes in coastal environments; (iii) application of remote sensing to the inventory, monitoring and management of biodiversity, and; (iv) creation of an Ocean Atlas and tools to manage coral bleaching.

In achieving the first goal, the Working Group has created the Reef Observer software tool that uses a state-of-the-art model of radiative transfer, together with a large spectral library of coral reef substrata, to quantify the feasibility of any coral reef remote sensing project. The radiative transfer software used to power Reef Observer is now complete and is being disseminated free of charge.

Impacts on Belize Policy

CRTR-sponsored research has informed the legislation to ban herbivore exploitation in Belize by providing a compelling report to Government on the drastic decline of parrotfish over the last seven years and corresponding rise in macroalgae.



The dominant spotlight parrotfish is targeted by Belize fishermen. Photo: B. Steneck

The Group's online Reef Remote Sensing Toolkit has also been extended to help practitioners match their remote sensing objectives to the appropriate technologies (the Toolkit covers a wide range of mapping problems and essentially stops short of making prescriptive predictions for more detailed remote sensing problems – for which Reef Observer is used). The upgraded Toolkit is due for release on the website in December 2009.

Under the 'tools to detect change in coastal areas' component of the Group's workplan, RSWG members have recently published the results of a simulation model in *Remote Sensing of Environment* (RSE) and revealed that 1m resolution imagery is about optimal for detecting changes in coral reef environments. In the paper, researchers have shown that coral reef habitat mapping can be improved significantly by combining acoustic sonar with optical satellite data. The sonar provides data on depth and rugosity whereas the satellite data provides continuous data on spectral properties of the seabed.

Furthermore, the Reef Observer software tool also has a capacity to identify whether particular changes in coral reef state can be detected using remote sensing. The user can specify the type of change (% substrata), the depth, the clarity of the water, and type of sensor. The third goal of mapping of biodiversity and resource management has also been achieved with a new technique developed to identify areas of the coastal zone that have particularly benign physical conditions in terms of coral bleaching. The method also includes important new advances to the design of marine reserves such that connectivity and different reserve design criteria can be incorporated explicitly into the algorithm. The methods have been showcased for the Bahamas and Belize.

The RSWG has also demonstrated that acoustic remote sensing methods can be used to map benthic habitat structure and reliably predict patterns in the density and biomass of many reef fish. Further, acoustic remote sensing can be used to discriminate coral reef microhabitats and used to predict the distribution of juveniles for many reef fish species. Lastly, the work on mapping the physical environments of coral reefs has demonstrated



Coral bleaching. Photo: Kathryn Rosell

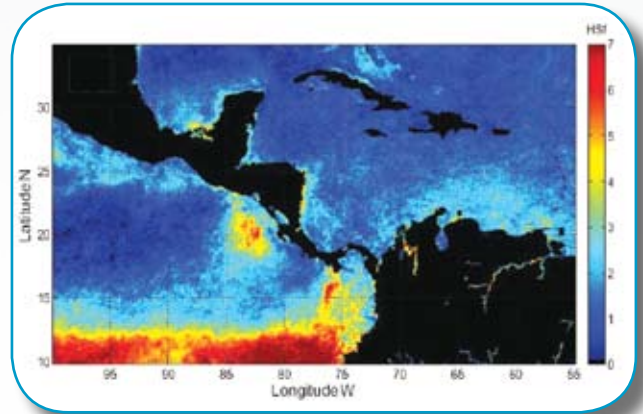
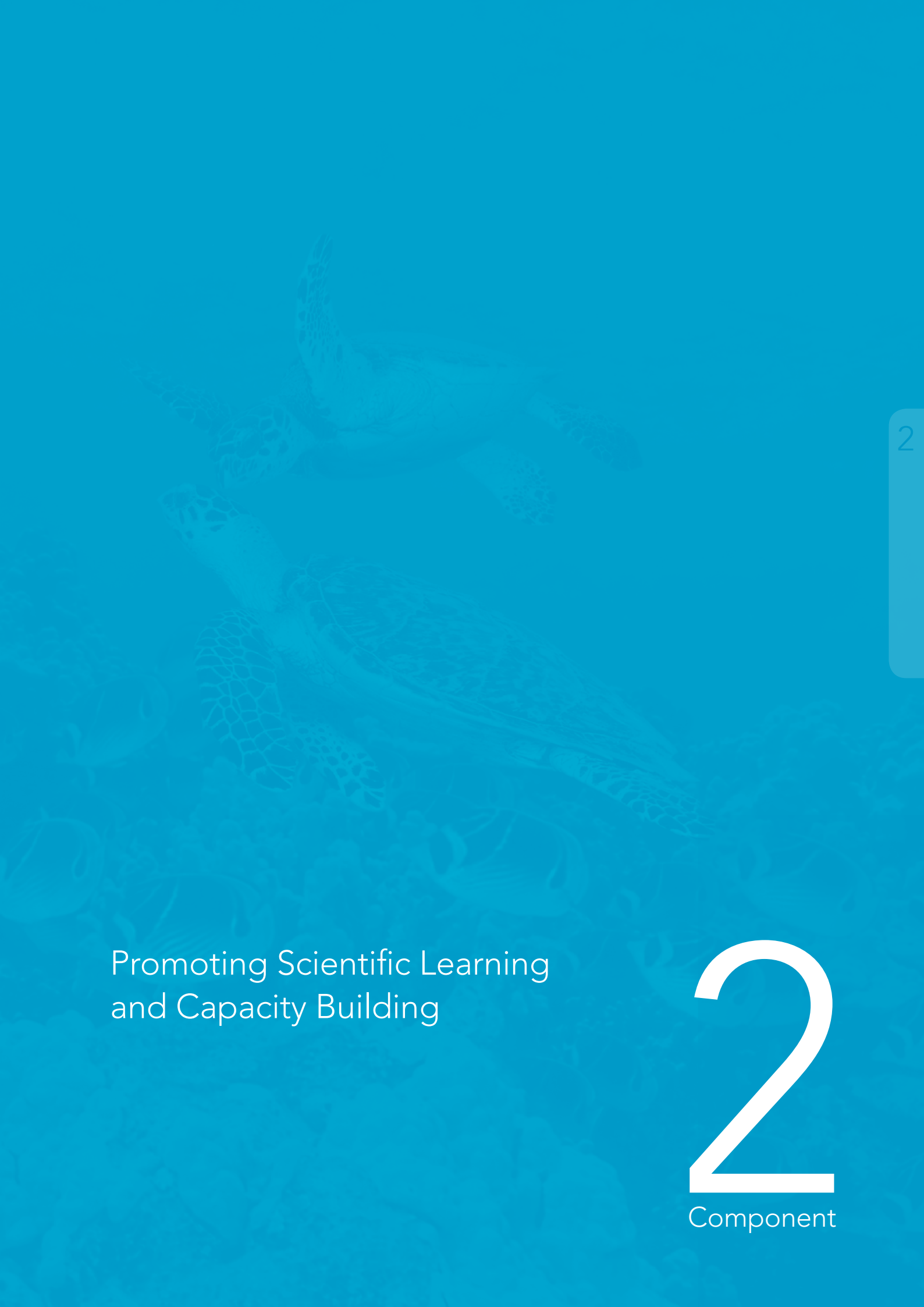


Image: Iliana Chollett

that rates of warming of ocean temperature vary strikingly across the Coral Triangle region. These results have recently been published in *Coral Reefs*, and are now beginning to inform conservation considerations in the Coral Triangle.

Additionally, the RSWG has created a new suite of online products that provide levels of solar insolation. An algorithm to combine data on sunlight with that of sea temperature in order to predict coral bleaching is at an advanced stage through collaboration with the Bleaching Working Group.



Promoting Scientific Learning and Capacity Building

2

Component

Promoting Scientific Learning and Capacity Building

Component Two of the Program is aimed at capacity building outcomes through the promotion of scientific learning and linking scientific knowledge to management and policy. Sound management and policy tools will shape and change the way policy and decision-makers view and approach coral reef management. The Program is achieving this aim through:

- Building or enhancing the capacity of institutions across four regions to serve as regional Centres of Excellence (CoEs); and
- Developing information, products and networks from the research that can lead to better management and strengthened policies regarding coral reefs in the regions.

The four Centres of Excellence are based in major coral reef regions (three are in developing countries) around the world, and are hosted by leading research institutions in those regions:

- Southeast Asia: Marine Science Institute / Bolinao Marine Laboratory, University of the Philippines.
- East Africa: Institute of Marine Sciences, University of Dar es Salaam, Tanzania.
- Western Caribbean/Mesoamerica: Unidad Academia Puerto Morelos, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México (UNAM).
- Australasia/South Pacific: Centre for Marine Studies / Heron Island Research Station, The University of Queensland, Australia.



Southeast Asian CoE Chair Professor Ed Gomez and CRTR scholars inspecting the nets, Bolinao. Photo: M King

Australasian Centre of Excellence

Centre for Marine Studies and Heron Island Research Station, The University of Queensland



Rarotonga, Cook Islands – Agriculture and tourism create pressure on delicate coastal ecosystems. Photo: Melanie King

The Australasian Centre of Excellence has used the past year as a consolidation of its research projects - (refer to the Bleaching Working Group report), and its capacity building activities. Work has been completed on the Local Government Initiative project in the Makira Province in the Solomon Islands. The project consisted of surveys and information collected through on-site observations, discussions with Kahua Association (KA) members, and community meetings on the present state of the coastal and marine environment. Following the survey, the project team made up of Centre for Marine Studies experts determined indicators of present environment stresses and identified potential future changes to the natural environment as a result of present and projected human development. Recommendations were then developed for future activities to be undertaken and implemented by the KA.

The recommendations included the development and implementation of 'no-take' zones for shellfish and the provision of educational materials to schools and communities. Materials on coastal and marine resources have been provided to the Kahua Association for distribution, and the local communities have also agreed to establish 'no-take' zones for shellfish in the region. The communities are now working together to implement the zones with technical advice from the project team.



Local fisherman-Kahua Province Makira, Solomon Islands.
Photo: Geoff Dews

Progress is also continuing on the 'Planning for Ecosystem-based Management: Managing the Environment in Small Island States' course and Pacific Leadership Forum to be held in Rarotonga, Cook Islands in January 2010, as the final CoE activity. The 12-day interactive course involving a number of external experts and Pacific Island counterparts in seminars, case-study and fieldwork scenarios will explore the issues facing the Pacific Islands and how an ecosystem-based management (EBM) approach can be implemented to improve the management of these issues. The main aim is to provide decision-makers and practitioners with the tools and information to gain a better understanding of the elements required in the modern concept of integrated coastal management.



Village children – Kahua Province, Makua, Solomon Islands. Photo: Geoff Dews

The elements covered will provide participants with the knowledge and tools to develop and implement EBM Plans into their coastal communities. In conjunction with the *Planning for Ecosystem-based Management* course, the Pacific Leadership Forum will be conducted concurrently for Heads of the environment and fisheries departments from Pacific countries. The Forum: 'Policy & Planning for Ecosystem-based Management', is an intensive, interactive three-day program to address the integrated policy approaches and options for achieving the technical competencies and support needed to plan and implement EBM for coastal areas. It is aimed at high-level senior executives that are in a position to implement changes, develop and implement effective policy and policy processes, and to ensure future sustainable development of these critical resource bases. The intention is that Heads of Departments will be better placed to empower and support implementation of EBM in their own country.

The Australasian Centre of Excellence will continue to develop relationships and projects in the Pacific region and beyond through the Global Change Institute (GCI) at the University of Queensland.

East African Centre of Excellence

Institute of Marine Sciences, University of Dar es Salaam, Zanzibar

The East African Centre of Excellence has continued to serve as a research hub for capacity building and information outreach for users in the East African region during the final year of the Program. During the reporting period the CoE has continued to act as a support-base for local and visiting researchers and students; organised training workshops; and completed the local research projects.

Visiting researchers have been involved in the monitoring of spatial patterns in coral population; rates of recruitment, partial mortality and mortality; relationships between processes and state variables; and the effect of macro-processes on coral populations, under the 'Common Sampling' project, and the results of this can be viewed in the Bleaching Working Group report. Further to acting as support centre for visiting researchers, the CoE has also continued to provide scholarship support to three PhD students whose studies are focusing on coral restoration, disease and bleaching. These students were supported to travel abroad to analyse their samples in specialised laboratories and to assist with their specific research requirements. Mohammed Suleiman and Leonard Jones are currently finalising fieldwork whilst N.E. Mbiye has completed his fieldwork and is now finalising and writing up his research findings.



Fishing harbour, Stone Town. Photo: Mark Paterson

Training workshops on the latest research techniques into impacts on coral reefs have always played an important role in the region. The CoE collaborated with experts in the field of remote sensing and GIS as well as experts in biological connectivity, restoration and remediation to learn new emerging techniques that will better equip them with the skills to assist with coral reef research and management in the region. In July 2009, the CoE also played a critical role in organising a major regional training workshop on coral reef restoration.

Regionally-relevant coral reef research has continued in the region with all aspects relating to nutrient analysis, sedimentation rates, primary productivity, ocean current measurements and the recording of fish landed have progressed well with some results have been published and presented at the 6th WIOMSA conference.



Institute of Marine Sciences Laboratory, Zanzibar
Photo: Mark Paterson

The CoE has also continued to maintain and develop new links with policy and management decision makers, with research information being provided to various forums for inclusion into decisions. Examples of this include:

- Coral health data from coral assessment (Sub-Project A) has contributed in determining the status of coral reefs in Tanzania, which has had a positive impact on coral reef management in Tanzania. Some of this information was included in the *Status Report of Coral Reefs of the World*.
- Coral reef research results were used in deciding the boundaries of two new marine conservation areas in Zanzibar (Tumbatu and Changuu-Bawe Conservation Areas) this year.



Dhow boats, Zanzibar. Photo: Mark Paterson

- CoE research activities have raised the level of coral reef knowledge in many sectors in Tanzania and the Western Indian Ocean through presentation of results at Government, local authority and community meetings.
- CoE staff are being consulted and contribute directly to integrated coastal management policy and management decisions.
- Results from pollution studies have raised awareness within the community on all levels which has caused positive behavioural changes and consciousness toward marine conservation issues.

The Centre of Excellence has also continued to strengthen its links with the Marine Parks and Reserve Unit in Tanzania, which is responsible for managing marine parks, reserves and conservations in the region, and continues to make an active contribution in ongoing preparations toward the declaration of the Tanga Coelacanth Marine Protected Area.

Southeast Asian Centre of Excellence

Marine Science Institute / Bolinao Marine Laboratory, University of the Philippines

The Southeast Asian Centre of Excellence has gone from strength to strength over the past five years and has continued to make substantial progress on its local research projects and outreach activities, as well as instigating new investigations into issues that have arisen out of the scientific studies of the Working Groups, and the local projects.

Following incidences of mortality on the Restoration & Remediation Working Group's coral transplant sites on the reef flats off Santiago Island at Bolinao, Pangasinan, the Centre of Excellence and RRWG collaborated on a new research activity to understand submarine groundwater discharge, which was believed to be the cause of the coral mortality. This work was also part of research being undertaken to better understand the land sea connectivity of water and pollutants. The spatial variability of the submarine groundwater discharge (SGD) was mapped using radon measurements, electrical resistivity (ER) survey, CTD (conductivity, temperature, depth) profiling, and water sampling for nutrient analysis. The results of the study revealed widespread occurrence of SGD within the reef flat. Nitrate and radon in sites with potentially high SGD have values that are two to three orders higher than typical seawater values. Seepage rates determined through radon flux and manual measurement were higher for the dry season than the wet season, which may be due to the pumping effect of waves. Manuscripts are currently being prepared for publication or presentation at conferences detailing the findings of this research.



Bolinao Marine Laboratory.

In addition to the new research activity, the three local CoE Projects have continued to achieve results over the final year. **Project A (Taxonomy)** conducted three coral taxonomy training sessions during this period with participants from academe, local government units, government agencies and non government organisations attending. The training was aimed at coral identification, survey methodology, coral disease identification and molecular techniques. Photo-documentation of coral collections in the UPMSI, UP Institute of Biology and Silliman University museums have also been completed and photos prepared for posting on the web-based 'virtual museum'. Manuscripts for the molecular identification of many species including the new Philippine record of *Euphyllia paraglabrescens*, coral community structure of the Bolinao Reef System and a framework for the survey of coral communities using digital phototranssects is currently in preparation.

Project B (Coral Disease) continued outdoor tank experiments for *Porites* ulcerative white spot (PUWS) infection. Studies were modified to allow for a greater number of replications using the same space to reduce the risk of airborne particles. Lower temperatures during the trial period dictated delayed responses to the spread of disease compared to that of higher temperature results. Unfortunately, due to the devastation caused by typhoon Emyong in May 2009 the microbiological monitoring of coral reef and fish farming sites at Bolinao had to be abandoned.

Under **Project C (Connectivity)** experiment results indicated that the patterns of genetic structure of phylogeographic analysis carried out may be attributed to historical barriers to



Milkfish farm, Bolinao reef flats. Photo: Gabrielle Sheehan



Coral gardening – experimental transplants, Bolinao.



Coral nursery, Bolinao. Photo: Dexter dela Cruz

dispersal as the spatial genetic structure of *S. fuscescens* driven by the distribution of two distinct mtDNA lineages (clades) estimated to have diverged during the Pleistocene. Nonetheless, significant structure detected based on microsatellite data suggest limited demographic connectivity of *S. fuscescens* across western Luzon.

Analysis of 144 individuals representing four western Philippine sites, and three out-group sites reveals that the western Luzon samples are not genetically structured indicating high gene flow in the region. This is in contrast to the observed limited genetic connectivity of *S. fuscescens* populations from the same geographical area. The contrasting patterns of genetic connectivity of the two species are attributed to their differing dispersal potential as a function of life history traits.

Lastly, the **Local Government Initiative (LGI) Project** conducted a workshop on “Reducing Environmental Impacts of Marine Fish Cage/ Pen Culture” on 30 January 2009 in Bolinao, Pangasinan. The workshop trained selected stakeholders including operators, caretakers and core LGU personnel on sustainable mariculture practices and encouraged cooperation among the stakeholders with respect to sustainable mariculture management in their respective localities.

Outreach activities have also been a prominent role for the CoE and in 2009 the CoE supported three community-based transplantation training sessions conducted in Bolinao and, as part of the Information, Education and Communication (IEC) initiative, CRTR information packages were distributed at the general assembly of the League of Municipalities of the Philippines (LMP) held in Manila.



Linking Scientific Knowledge
to Management and Policy

3
Component

Linking Scientific Knowledge to Management and Policy

Under Component Three: Linking scientific knowledge to management and policy, the final year of the CRTR Program's first phase has been a period of consolidation and distribution of research outputs to target audiences. The year has seen the consolidation of research under the 'Common Sampling' project with monitoring sites established at all four Centres of Excellence, as well as the dissemination of research and results to International Waters projects and GEF personnel at the 5th GEF International Waters Conference in Cairns.

'Common Sampling' Project

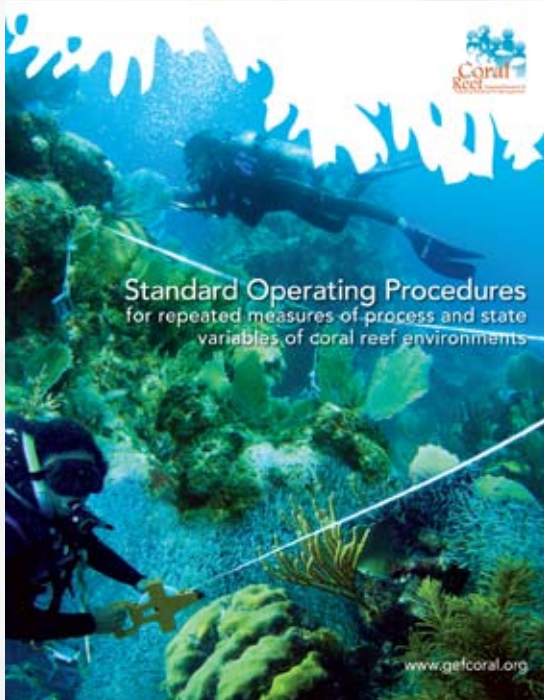
Population dynamics of coral populations under environmental change

The 'Common Sampling' project, under the guidance of Professor Robert van Woesik has been examining the population dynamics of coral populations at all four Centres of Excellence. The primary task was to assess the dynamics of coral populations and associated coral-reef organisms by defining the key ecological processes that regulate the populations. Understanding these processes, assessing their spatial variation and their relationship with state variables, including size-frequency distributions, leads to predictive models of population trajectories, relative population size distributions, and community change under different climate change scenarios. The project team predicted that size-frequency distributions coupled with partial mortality information could provide a reliable indicator of coral stress and provide insight into the future of coral reefs.

Specifically the team examined:

- Spatial patterns in coral population size-frequency distributions and temporal changes of the populations at three CoEs;
- Scale dependence of key process variables, including rates of recruitment, partial mortality, and mortality;
- Relationships between processes and state variables and whether size-frequency distributions reflected population performance; and
- Effect of macro-processes, including herbivory (i.e., density and composition of urchins and fishes), on coral population vital rates and diseases.

Outcomes included corrections developed to eliminate biases that occur because of boundary effects when measuring the size of benthic organisms, as well as a series of relationships between 2-dimensional and 3-dimensional estimates of coral growth. Several important ecological phenomena were also identified, including two modes of partial mortality-affected coral species in the Caribbean; with some species rapidly losing colony integration while others maintained integration and sacrificed marginal tissue.



Research within this group also identified the critical observation that mild thermal stress events showed different responses than extreme events. During extreme events, small colonies do better than larger colonies, while during mild events, colony size did not influence bleaching. In both cases massive corals were found to be more sensitive than branching corals. The research within this project also identified the important influence of substrate reflection, for example from sand, increasing available light and exacerbating the risk of coral bleaching. Indeed, corals growing on and near sand showed more intense bleaching than those growing on or near substrate with lower reflectivity. The group also made some interesting long-term observations, such as sea urchin densities on the western reefs of Zanzibar increased 6-10 fold since 1996; with fish on the same reefs increasing considerably in the last three years.

More detailed information on this project can be viewed in the 'Bleaching and Related Ecological Factors: CRTR Working Group Findings 2004-2009' report available on the CRTR Program website at www.gefcoral.org.

GEF International Waters Conference

The 5th Biennial GEF International Waters Conference, hosted by the Government of Australia in Cairns, North Queensland took place from the 26-29 October 2009. The Conference was designed around a number of participative learning opportunities. A key objective of the GEF International Waters portfolio learning event is to promote sustainable development in basin and coastal communities sharing natural resource systems, to achieve Millenium Development Goals through the benefits of transboundary cooperation in ecosystem-based management. With an eye to integrated-ecosystem based management and mainstreaming climate variability and change, this meeting builds on 2009's key freshwater and marine meetings with an eye to preparing the GEF IW portfolio for the future.

The CRTR Program was an active participant, with representation at the pre-conference technical workshops, plenary sessions and conference technical workshops. The pre-conference technical workshops (24-25 October) featured leading Australian and international experts in complex basin and marine systems, dealing with resolving conflicting demands among diverse stakeholders, and coping with water scarcity and the technical as well as societal impacts of climate change. The CRTR Program was well represented at the marine workshop with many of the Synthesis Panel either presenting or contributing as Panel members during the discussion periods.



CRTR Masters Scholar Deborah Cleland addresses an IWC workshop.

Synthesis Panel members presented at the conference and technical workshops, with Professor Paul Greenfield and Professor Roberto Iglesias-Prieto addressing a plenary session, and chairs Dr Alasdair Edwards (RRWG), Prof Ed Gomez (RRWG) and Dr Roger Bradbury (MDSWG) presenting during the technical workshops. Deb Cleland and Jess Melbourne-Thomas, two scholars from the MDSWG, also presented during the modelling workshop.

The CRTR Program showcased its many and varied research outputs at the exhibition booth. Social media techniques, including Twitter and web-based news and video updates, used to promote the Program's participation in IWC to CRTR and external stakeholders.

2009 Annual Synthesis Panel Meeting

The CRTR Program's international Synthesis Panel met from the 21-23 October 2009, in Brisbane, Australia, prior to the 5th GEF International Waters Conference. The focus of the meeting including final discussions concerning ongoing projects (due to be completed in early 2010); the completion of Phase One and continuation plans; and Phase Two planning discussions.



Publications

Over the past five years, the CRTR Working Group and Centres of Excellence have been responsible for over 600 publications. This includes publications which have been either fully supported, or partially supported by the Program, or publications which have been influenced by work from the CRTR Program, or which has in turn influenced the CRTR Program's Working Groups.



A fisher from Zambales, the Philippines tries his luck in the open ocean during a ReefGame session at a multi-sectoral workshop in November 2009 run by the Southeast Asian CoE. Photo: K Balajadia

Events

The CRTR Working Groups and Centres of Excellence have been responsible for over 230 events since the Program commenced in late 2004. These events include participation at, and contributions to, annual meetings, workshops, conferences, science meetings and media events.

Program Management

4
Component

Program Management

The Program Management component of the CRTR Program has progressed satisfactorily throughout the five years of the phase, and is now in the final months of finalising the administrative components of the Program. The management and communication components of the Program have been strong elements throughout the Phase, and the final months will see the final suite of products produced, showcasing the work undertaken by the Working Groups and Centres of Excellence.

Disbursements

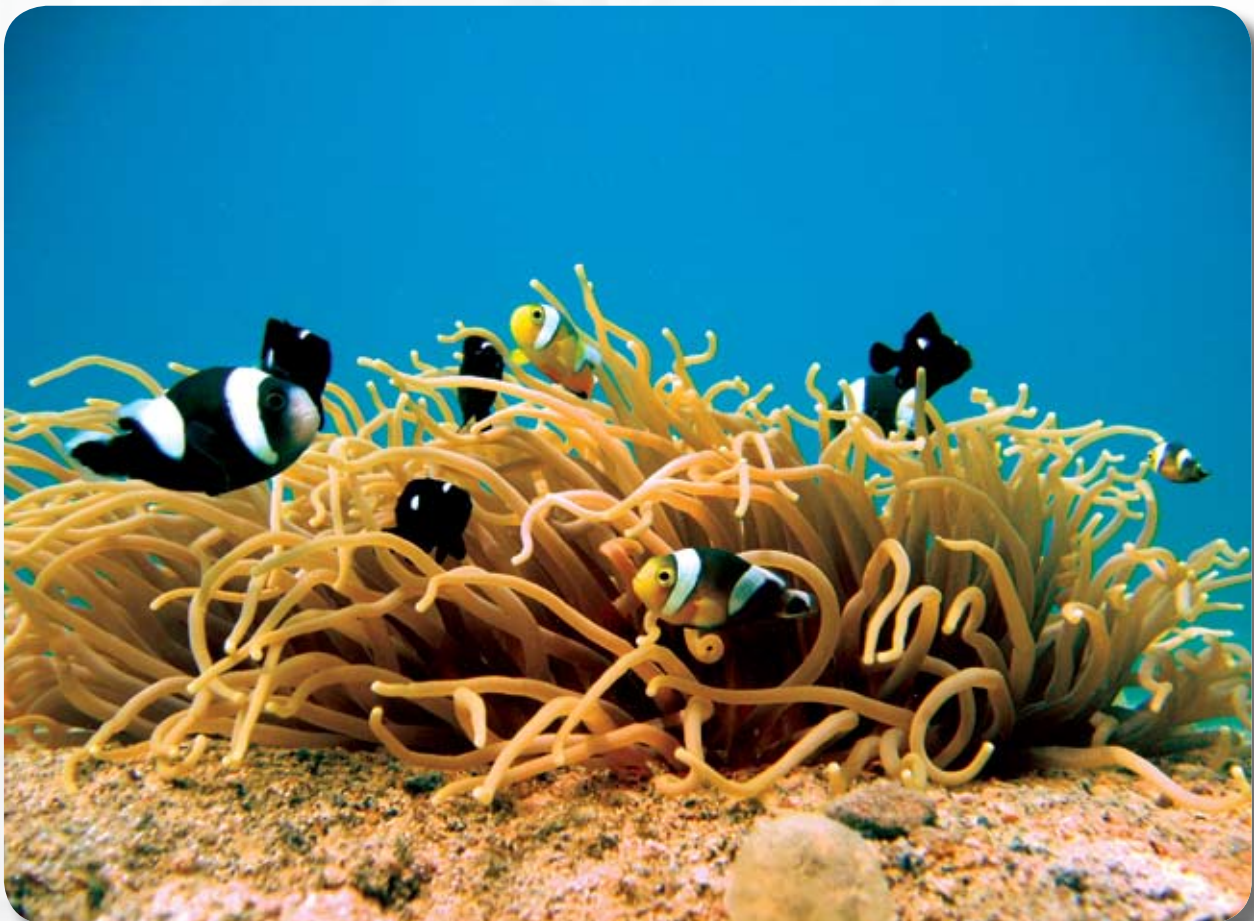
Disbursements for 2009 have continued at a steady rate, with approximately 95% of the overall funds now disbursed. Despite a slight delay in some sub-grant disbursements due to institutions not meeting their obligations under the contractual arrangements, these are now completed and all sub-grants will have been fully disbursed by the 30 November 2009. The remaining GEF funding relates to the production of communication outputs from the research, and it is expected that these funds will be fully disbursed by the end of February 2010.

Disbursements for the GEF and UQ funds for the five-year period, up until 31 October 2009 are as follows:

- GEF funds approved for the period 1 December 2008 to 30 November 2009 is USD\$1,759,370.
- UQ funds approved for project administration for the period 1 January 2009 to 31 December 2009 is AUD\$739,957.

GEF Funding

The GEF funding allocations are on-target to be fully disbursed by the 31 December 2009. As mentioned, there has been some delay in some sub-grant disbursements due to contractual obligations and reporting not being met, however these are expected to be fully disbursed by 30 November 2009. The remaining GEF funds relate to Synthesis Panel meeting expenditure, communication expenditure and peer review processes, and the expectation is that these funds will be expended by 31 December 2009.



Panda clownfish and three-spot damselfish juveniles sheltering in an anemone, Schuman Island, Papua New Guinea. Photo: S Planes.

Procurement

No procurement took place during the reporting period.

Sub-grants

There were no new sub-grants contracted during the reporting period.

Communication

The year has seen a marked increase in the number of research outputs developed and packaged for key management, policy and research audiences. The Communications Team of Mark Paterson and Gabrielle Sheehan, have worked with the Project Executing Agency to implement a range of activities, in order to (i) encourage the application of CRTR research outcomes by reef managers and policy makers; and (ii) develop and enhance networks between program members and with external stakeholders.

In the final year of Phase One, communications activity focused on producing a suite of products aimed at sharing knowledge generated by the program, including:

- *The Science of No-Take Fishery Reserves: A Guide for Managers*. This booklet developed by the CWG examines the science underlying use of no-take fishery reserves as a management tool for coastal fisheries.



CoE Chair, Professor Ed Gomez, talks with local government representatives and others at the Coastal Resources Management Forum, Bolinao 2008 as part of the CRTR Local Government Initiative, profiled in a case study and online.

- *Advisory Paper: Conserve coastal habitat today, preserve income for tomorrow*. This paper from the CWG provides advice for planners and policy makers on long-term approaches to coast development and actions that can be taken today to preserve coastal habitats.
- *Bleaching and Related Ecological Factors: CRTR Working Group Findings 2004-2009*. This report details the findings of the Bleaching Working Group, including major contributions to understanding the impact of climate change on coral reefs.
- *Research update: New frontiers of remote sensing for reef management*. This update informs resource managers about valuable remote sensing tools that can be used at all stages of coral reef conservation.
- *Standard Operating Procedures for repeated measures of process and state variables of coral reef environments*. The CRTR Program has developed a set of procedures with which to collect state and process variables, allowing data comparison and combination across regions.



University of Queensland's Geoff Dews worked with the community of Makira Province, Solomon Islands, on conserving their marine resources.



Case studies were developed to demonstrate the CoEs 'in action', working with local governments and communities. These include:

- *Community-based restoration - the Bolinao experience.* CRTR researchers at the Southeast Asian CoE are training local communities to restore live coral cover to the reefs of Bolinao, Pangasinan Province by sharing low-cost reef restoration techniques.
- *Taboos, customs hold key to managing Tanzania's reefs.* The East African CoE has investigated how indigenous knowledge contributes to coastal management in local communities. Customs, taboos and beliefs, used in conjunction with scientifically-developed and improved technology, promise to help protect and sustain fish stocks and coastal habitat.
- *Managing marine resources at the local level – Makira Province, Solomon Islands.* Under the CRTR Local Government Initiative, the Australasian CoE worked with communities in the Makira Province, Solomon Islands to determine coastal impacts and prioritise an action list on how the community can work towards reducing them.

- *Local governments critical to effective management and protection of coral reefs – Lingayen Gulf, the Philippines.* This case study reviews the Southeast Asian CoE's work under the CRTR Local Government Initiative with coastal municipalities surrounding the Lingayen Gulf to improve management and protection of reefs.

In the completing Phase One, several communications activities are planned over the next three to four months. A five-year 'synthesis' report, summarising key research findings from the CRTR Program is anticipated early in 2010. This report will focus on the baseline of what was known in the key CRTR research-targeted areas at the commencement of the Program to what is now known after five years of targeted research.

In addition to this synthesis report, products under development include tools for management such as a remote sensing guide; a reef restoration manual; a connectivity handbook, and various advisory or update papers. An anthology of papers and articles from CRTR scholars is also being compiled, showcasing the science capacity built through the Program.

To maintain the strong connections that have been built across the CRTR network, communications activity will continue through the interim phase, including continued distribution of *CRTR e-news* and updating the website with relevant developments and material.

Information Dissemination

In addition to the production and dissemination of research outputs, the CRTR Program has also focused on targeting media efforts, and in utilising the website as the key portal for information dissemination from the Program.

Throughout the year, the CRTR website, www.gefcoral.org, was updated with various products, announcements and stories. At the International Waters Conference, the site was updated with articles on CRTR presentations, and supporting materials including video footage. Sections of the website were also enhanced to highlight results from projects, and other activities.

The estimated number of visits to the site from November 2008 to October 2009 was 22,353; with an estimated 15,500 unique visitors; 859,782 hits; 288,455 pages accessed; and 23.91 gigabytes of data downloaded. The highest number of visits in any one month was recorded in October (2684 visits) coinciding with the International Waters Conference.

Members of the CRTR Program have been very active in ensuring various audiences are in receipt of critical information on the importance of marine habitats, including coral reefs, and the impacts of environmental and human impacts on these ecosystems. In terms of Program media, the Program has been targeted in its messages and responses to issues arising throughout the year. With coral reefs worth an estimated \$170 billion worldwide, the CRTR Synthesis Panel made a public call via the media for the world's oceans to be high on the agenda at the Copenhagen meeting of the United Nations Framework Convention for Climate Change (UNFCCC) in the lead up to the December meeting.

Another media announcement focused on the launch of the "Reefs for People" tool developed by the MDSWG. The model will allow coastal communities and policy makers around the world to predict the impact of coastal developments and climate change on their coral reefs and coastal environments.

Both of these media announcements were distributed using traditional methods and supported by promotion through social media channels.

Lastly, given its broad global focus and membership, the CRTR Program has continued to communicate with its network through two electronic newsletters. Three editions of *CRTR e-News* were distributed to stakeholders, highlighting progress and achievements with contributions from program members. Two editions of the Communications Team's bulletin *Coralert!* advised program members of communications activities and opportunities, and invited their ideas and participation.



CRTR E-news, the program's online newsletter.



Artisanal fishing, Yucatan Peninsula. Photo: Ken Drouillard

Abbreviations

ACEP - African Coelacanth Ecosystem Programme

AIMS - Australian Institute of Marine Science

BWG - Bleaching Working Group

CoE - Centre of Excellence

CRTR - Coral Reef Targeted Research & Capacity Building for Management Program

DWG - Disease Working Group

EBM - Ecosystem-based Management

ECONAR Project - Ecological Connections Among Reefs Project

ESA - European Space Agency

GCI - Global Change Institute, The University of Queensland

GEF - Global Environment Facility

GBRMPA - Great Barrier Reef Marine Park Authority

HIRS - Heron Island Research Station

ICRS - International Coral Reef Symposium

IWC - International Waters Conference

KA - Kahua Association, Solomon Islands

LGI - Local Government Initiative

LGU - Local Government Unit

MACEMP - Marine & Coastal Environment Management Project

MPA - Marine Protected Area

MDSWG - Modelling & Decision Support Working Group

NGO - Non-government Organisation

NOAA - National Oceanic & Atmospheric Administration

PEA - Project Executing Agency

PEDs - Parrotfish exclusion devices

REEFRES -

RRWG - Restoration & Remediation Working Group

RSWG - Remote Sensing Working Group

SMs - Standardised Modules

TNC - The Nature Conservancy

UNAM - Universidad Nacional Autonoma de Mexico

UNU-INWEH - United Nations University International Network on Water, Environment and Health

UPMSI - University of the Philippines, Marine Science Institute

UQ - The University of Queensland

WIOMSA - West Indian Ocean Marine Science Association



The Coral Reef Targeted Research & Capacity Building for Management (CRTR) Program is a leading international coral reef research initiative that provides a coordinated approach to credible, factual and scientifically-proven knowledge for improved coral reef management. The CRTR Program is a partnership between the Global Environment Facility, the World Bank, The University of Queensland (Australia), the United States National Oceanic and Atmospheric Administration (NOAA) and approximately 50 research institutes and other third-parties around the world.