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Coral Reef Targeted Research and Capacity Building for Management: Improving scientific information and management for coral reef ecosystems around the world.

THE CORAL REEF TARGETED RESEARCH AND CAPACITY BUILDING FOR MANAGEMENT (CRTR) PROGRAM IS A PROACTIVE RESEARCH AND CAPACITY BUILDING PARTNERSHIP DESIGNED TO IMPROVE THE SCIENTIFIC KNOWLEDGE NEEDED TO STRENGTHEN MANAGEMENT AND POLICY. THE CRTR IS FILLING CRUCIAL KNOWLEDGE GAPS IN THE TARGETED RESEARCH AREAS OF CORAL BLEACHING, CONNECTIVITY, CORAL DISEASES, CORAL RESTORATION AND REMEDIATION, REMOTE SENSING AND MODELING AND DECISION SUPPORT. THIS EXPERIENCE NOTE PRESENTS PROGRESS ON THREE OF THE SIX THEMATIC WORKING GROUPS: CORAL REEF DISEASES, RESTORATION, AND REMOTE SENSING, AND DISCUSSES HOW THE FINDINGS CAN BE USED TO STRENGTHEN MANAGEMENT AND POLICY FOR A KEY GLOBAL ECOSYSTEM—ONE IN WHICH A LARGE NUMBER OF TROPICAL DEVELOPING COUNTRIES DEPEND FOR LIVELIHOODS AND ECOSYSTEM SERVICES.

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Coral Reef Targeted Research & Capacity Building for Management

EXPERIENCE OF THE GEF

GEF/WB: CORAL REEF TARGETED RESEARCH AND CAPACITY BUILDING FOR MANAGEMENT PROGRAM

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PROJECT DESCRIPTION

The Coral Reef Targeted Research and Capacity Building for Management (CRTR) Program is a proactive research and capacity building partnership designed to improve the scientific knowledge needed to strengthen management and policy. The CRTR is filling crucial knowledge gaps in targeted research areas such as Coral Bleaching, Connectivity, Coral Diseases, Coral Restoration and Remediation, Remote Sensing and Modeling and Decision Support. Each research theme is facilitated by Working Groups underpinned by the skills of many of the world's leading coral reef researchers. The CRTR Program also supports four Centers of Excellence (COEs) in priority regions that serve as focal points for building confidence and skills in research, training and in building capacity to sustain coral reefs and the ecosystem services that they provide to people. The CRTR is envisioned as a three-phase initiative that 1) lays the scientific foundation, 2) builds capacity in key coral reef regions across a range of stakeholders, and 3) works to integrate findings and improved information into management and policy. The CRTR has completed its third year of operation of Phase 1.

The World Bank's role is crucial in this program given its routine policy discourse with approximately 100 countries possessing coral reefs and the natural capital and services that they provide to people, especially in developing countries.

THE EXPERIENCE

The year 1998 witnessed an unprecedented climatic event in the world's oceans when a strong El Niño-Southern Oscillation episode caused abnormally high sea surface temperatures and affected more than 16% of the world's coral reefs. This was a crucial alarm for understanding the differences between climate-related versus local stresses and how management responses can be appropriately framed. Rather than committing resources towards reactionary response models that only assessed where damage occurred from this single event, the CRTR program was designed as a proactive initiative targeting investigations in key world regions. The program's

Map showing the locations of the CRTR Centers of Excellence.

purpose is to gain information and understanding about the range of impacts and interactions between stressors—from climate change to the more direct local stresses, like coastal development, pollution, catastrophic storm events, and over-use and extraction of resources from a range of practices, including impacts from tourism—and the synergistic effects these have on the sustainability of entire reef ecosystems.

Since 1998, the impacts of climate change have become increasingly clear, and additional high ocean temperatures have occurred in various ocean regions in 2000, 2002, 2005 (which experienced the highest temperature in the Caribbean Basin in more than 100 years) and in 2007 in the South China Sea. These events, which appear to be increasing in frequency, are accelerating the urgency to protect natural resources and their ecosystem services, and in preparing coastal-dependent people to adapt. However, human population growth in tropical coastal zones is also causing tremendous use and transformation pressure that confounds the impacts to coral reefs and associated resources.

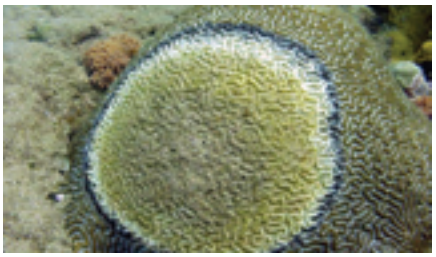
This Experience Note presents progress on three of the six CRTR thematic working groups: Coral Reef Diseases, Restoration, and Remote Sensing.

Addressing the Issue

Disease: As of 2008 targeted research for coral disease has continued to address and develop five priority areas of investigation: Global Assessment of coral diseases and anthropogenic facilitators, impacts of coral disease on coral diversity, community diversity and population growth, the epidemiology of coral diseases, mechanisms of coral disease resistance, and building international capacity to assess coral disease.

Within these priority areas the Disease Working Group (DWG) has taken additional steps to address the link between thermal stress and coral disease in collaboration with the Remote Sensing Working Group, and is constructing a model of the impacts of reef protection on coral disease prevalence. The DWG is also focusing on the various roles that local water quality has on coral health and disease. An area of special interest is the role that Marine Protected Areas have on the health of coral reefs and coral disease dynamics.

The DWG is applying previously developed coral resistance assays to investigate how temperature stress and disease influences coral physiology and to address the huge information gaps: which disease syndromes



An example of Black–Band disease on a Caribbean coral species, *Diploria strigosa* ©E. Weil.

TARGETED RESEARCH ON CORAL DISEASE-PRIORITY AREAS FOR INVESTIGATION:

MPAs: Do Intact Ecosystems have lower disease prevalence?
Philippines, Australia, Palau

Aquaculture: Do fish farms incubate and convey coral disease?
Philippines

Coral Resistance to Disease: How to detect and characterize immune compromise in a coral?
Caribbean, Philippines, Australia

Coral Epizootiology: continue isolating causative agents
E. Africa, Australia, Caribbean, Philippines, Palau, Israel

Climate and Disease: examine 2005 Caribbean event and disease surveys to assess causal links

are infectious, which COEs have the largest coral disease problems, which COEs environments would be the most tractable for identifying local factors that might impact coral disease, and whether climate factors would affect coral disease levels? At the end of year three, the DWG has found answers to many pressing questions and has published 15 peer-reviewed papers directly supported by the CRTR and 15 peer-reviewed papers that were partially supported by the CRTR or have contributed substantially to the activities and goals of the Program.

Restoration: The CRTR has defined three main programs of investigation concerning the restoration and remediation of coral reefs, combined with the enhancement of capacity through training, engaging students and conducting specific workshops on restoration and remediation activities. Within the Restoration and Remediation Working Group (RRWG), the three programs involve 1) examining the long-term efficacy and cost-effectiveness of restoration interventions, 2) Enhancing larval recruitment and 3) enhancing recovery by culture and transplantation of corals.

Program 1 includes long-term studies of invertebrate settlement and growth, and the varying potential of locations conducive to restoration attempts. If water quality and other parameters remain negatively influenced by human activity affecting near shore coral reefs, then restoration will not likely be successful in the long term. The RRWG is characterizing the rates of key processes influencing recovery: recruitment, survival, growth, and grazing (such as snails, urchins or fish) and ultimately these outputs will assist in modeling restoration scenarios.

Program 2 has a primary aim of understanding constraints on site-specific coral recruitment rates and the influence of larval supply on subsequent reproductive success. There are three primary objectives in this second program: i) to investigate the consequences of enhancing larval supply to defined areas of natural and artificial reef substrate (placed on a damaged reef), ii) to develop a comprehensive database on larval competency for a taxonomically diverse range of broadcast spawning coral species and iii) to investigate the relationship between the abundance of local stocks and recruitment. Studies are being carried out in Palau, a satellite site for the CRTR program, and Bolinao, Philippines. In the Philippines, the first study is examining the effects of fragmentation and transplantation on reproduction in corals with growth, fecundity and survival of transplants and donor and control colonies being monitored. The second examines the rates of coral recruitment on settlement tiles and monitoring coral community structure on

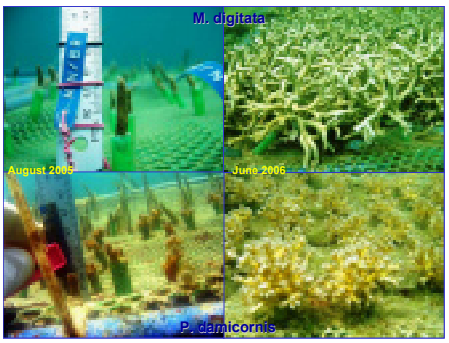
KEY RESEARCH QUESTIONS FOR CORAL REEF RESTORATION:

- To what degree do restoration interventions significantly enhance recovery of coral reef communities in comparison to what would be achieved by natural recovery processes over a 5-10 year time-scale?
- Does enhancement of coral larval recruitment significantly enhance efficacy of restoration on a 5-10 year timescale and is it cost effective?
- How important is the choice of coral species on both the success of transplants and the sustained growth and reproduction of the donor colony?
- What is the relative efficacy of restoration using coral fragments, with and without *in situ* nursery rearing?
- What is the impact of the initial size and structure of pruned coral fragments or nubbins on subsequent growth and colony development?

adjacent reef. The comparison of processes between Bolinao and Palau should greatly improve our understanding of natural recovery and assist in modeling likely outcomes of restoration under different conditions.

Program 3 examines the enhancement of recovery by corals, but is studying the long-term efficacy and cost-effectiveness of restoration. This line of targeted research should result in better informed judgments about what interventions may achieve above natural recovery over the course of five to ten years. Given the tremendous variability in natural reefs worldwide, the RRWG is investigating these questions by using standardized artificial structures of sufficient scale and replication to allow long-term, statistically rigorous comparisons between outcomes of natural processes against a range of interventions. These studies have been established at all COE locations.

Remote Sensing: To manage coral reefs effectively, practitioners need an array of spatially-explicit information to support resource management decisions, such as designing effective Marine Protected Areas,



Examples of progress with growing and transplanting coral fragments to restore coral reef areas from 2005 to 2006. Significant growth can be seen in less than one year. ©RRWG

The deployment of artificial reef structures used to standardize the types of surfaces that corals may settle upon. These are being used by the RRWG in all COE locations. ©K.Kilfoyle.

monitoring the health of coral reefs to set environmental standards for use, and to provide an early warning system of major sources of stress. However, reefs are complex systems, affected by multiple natural and anthropogenic processes which operate across many scales. Remote sensing provides the only practical means to measure such processes and quantify their effects on coral reefs at meaningful, and often large, spatial scales.

Remote sensing is a technology-driven practice and there has been a tendency in the past for new technologies to be oversold to decision-makers. Overselling has occurred in part because of the high cost of sophisticated new sensors, which often had to be deployed on a case-by-case basis. In 1995, when sixty coastal managers were asked their opinion of remote sensing, 70% believed high cost to be the main hindrance to uptake of the technologies. However, over the last decade there has been a vast improvement in access to remotely sensed data and innovation continues. This revolution of information is the result of heavy investment in new technology by governments and industry, rapid developments in computing power and storage, and easy dissemination of data over the internet. Today, remotely sensed data are available to virtually anyone with a desktop computer.

Recent developments in remote sensing will enhance the cost-effectiveness of coral reef management. First, the cost of conducting many routine remote sensing tasks is falling because data are becoming less expensive and easier to manipulate. Second, and perhaps more importantly, the effectiveness of management will increase. Improved technology allows several time-consuming management

A Fijian fisherman benefiting from remote sensing technology by looking for vessels of illegal poachers. ©C.Roelfsema

tasks, such as environmental monitoring, to be undertaken remotely, thereby freeing up staff and resources. Moreover, new technology provides fresh insight into coastal impacts and the vulnerability of coastal resources to such impacts. These insights enrich the knowledge-base for management, which, together with more detailed spatial information, will lead to better decision-making.

The Remote Sensing Working Group (RSWG) is developing a multi-scale physical and biological observing system for coral reefs, with the aim to improve the efficacy of coral reef management using three approaches:

1. *Provide better information for managers* by developing and testing the tools necessary to measure and monitor the status of coral reef ecosystems at multiple ecological, spatial and temporal scales

2. *Improve the use of spatial information* by developing the application of remote sensing products for conservation science and spatial decision-making

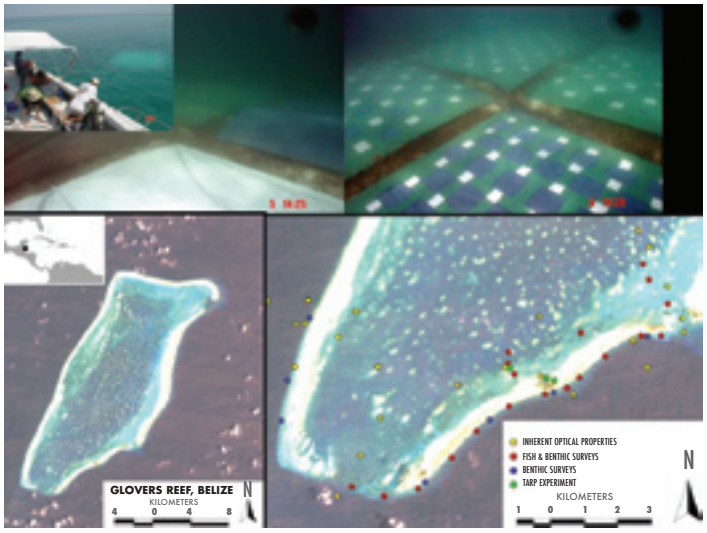
3. Critically examine the *cost-effectiveness* of new methods to ensure that overselling does not occur.

Issues and Challenges

Disease: The DWG has continued to investigate the processes of coral immune response to disease, and has developed methods to induce cellular immunity in response to pathogens and temperature stress (for example, with gorgonian sea fans) and is in the process of developing these methods for reef-building corals. The cellular immune response may serve as a tool to assess conditions that compromise immunity in corals. However, isolating all causative agents continues to pose significant challenges given the many syndromes. The DWG has gained more insight into how the bacterial communities of coral change when challenged with pathogens and environmental stress, but is an example of work that will need an extended time horizon before it can be applied to specific management recommendations.

The Working Group is confronting the reality that infectious disease is a moving target, it can be infectious at one time and not at others. Virulence and infectivity of microorganisms as well as coral resistance to disease are all evolutionary and ecological moving targets, influenced by pathogen genotype, host genotype, environment and all the interaction factors.

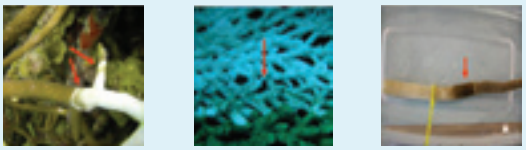
To improve our understanding of mechanisms behind infectious diseases the DWG is working closely with other scientists evaluating various terrestrial wildlife diseases and have held and attended series of meetings and workshops over the past several years on the ecology and evolution of infectious disease.



Field experiments conducted by the RSWG in Belize to examine the optical properties of water to "see" coral reef formations. This experiment used canvass "tiles" (above left & right) to test satellite sensors.©RSWG

CORAL REEF DISEASES/SYNDROMES IN WESTERN INDIAN OCEAN

***Porites* ulcerative white spots (PUWS)**: Affects mostly massive and branching *Porites*. White spots have Depressed center with or without dead area. Spots can coalesce when dense. Possibly caused by a *Vibrio*



***Acropora* Brown band (BrB)**: Affects mostly staghorn and tabular acroporids. Band is formed by dense population of ciliates, moving along the branch. A narrow white band between ciliates and live tissue may be present

© Ernesto Weil and Bette Willis, Disease Working Group, CRTR.

Restoration: The RRWG studies in the field are not without risks. In 2007, Hurricane Dean damaged the Akumal study site in Mexico, destroying three artificial substrates (heavy concrete pallet balls; see picture on preceding page) and moving others up to 30 m across the seabed. However, the studies have been reset and continue along with similar investigations at the other COE sites.

In the Philippines coral bleaching and a Crown-of-thorns starfish outbreak have killed large numbers of corals being used in experiments at Bolinao. However, the research has gained valuable information about which species have been able to survive stress and may serve as preferred restoration candidates in the future.

Remote Sensing: Testing remote sensing technologies also carry risk and the RSWG has had to face challenges with weather, cloud cover and other logistics in conducting aerial over flights or capturing the appropriate satellite images for analysis and use. However, persistence has been rewarded and the working group has been able to address such obstacles in furthering technological development for coral reefs thus far in the CRTR program.

RESULTS AND LEARNING

So what does all of this targeted research mean in the context of improving management, policy and the sustainability of resources? These groups' findings are providing a strong, coordinated foundation of information that address long-standing unknowns—ones in which current management efforts have either never considered, or have used limited knowledge or even guesswork in attempting to address coral reef decline. While actions to protect coral reef resources should continue based on what is already known, these investigations improve the knowledge base with a focus on management relevance.

Disease: The data produced by the DWG suggests coral disease exists in all ocean regions and has been more prevalent in some areas than previously known. Prior to the CRTR global surveys, it was believed that coral reef diseases were largely confined to the Caribbean Basin. This new knowledge heightens the urgency needed to address the causative factors and develop interventions to strengthen recovery and immunity. Working group surveys at the Centers of Excellence continue to be an important group initiative as they not only provide invaluable empirical data on changes of coral community structure and disease syndromes over time, but also allow identification of just a few syndromes that will serve as models of how infectious diseases affect reef sustainability. Among the tractable syndromes the DWG has worked with include *Aspergillosis*, Yellow Band Disease, Black Band Disease, *Porites* Ulcerative White Spots (PUWS), Bacterial bleaching, and *Porites* Tumors and *Echinopora vibrio* infections in Eastern Africa. The DWG has identified a significant number of Caribbean and Indo-Pacific and Eastern African disease syndromes that are infectious and is working with a range of scientists in identifying the new causative agents.

Research in fish pens has uncovered strong influence on the free living and attached bacterial population, nutrient input, primary production and the patterns of energy and carbon flux in the surrounding waters. In a qualitative sense the fish pens create a nutrient and productivity hot spot and thus raise the question as to whether the reefs fall within its region of influence. The results show that the near-field effects are very strong. We will know the identity of specific bacteria exported from fish farms to reside on the surface of reef corals within the next few months. Aquaculture may play a role as an incubator, conveyor and facilitator of disease into natural populations. Therefore, the DWG is focusing additional effort on this investigation and is working in partnership with the Philippine Center of Excellence Bolinao, and with the Restoration Working Group. The goal is to produce significant new scientific knowledge that may feed directly into policy in an area of developing concern: sustainability of aquaculture adjacent to coral reef systems.

The DWG now has two full years of consistent data, from carefully paired MPA and non MPA locales in the Philippines, controlled for similar environments (except fish). On these paired reefs, significantly fewer coral diseases occur on many of the MPA reefs, compared to non MPA reefs. Continuing to collect this kind of careful data and testing hypotheses about the causal explanation will be a priority area for research and these studies have received much enthusiasm and discussion from the local Filipino managers and could have a future impact on management and policy making decisions regarding MPAs. Therefore a future focus will be to understand what aspects of these MPAs result in lower levels of coral disease. The DWG is also developing a model with the RSWG to highlight some of the potential influences of MPAs on coral health.

Fish pens located in the Caquiputan Channel between the Bolinao mainland and the islands of Santiago and Cabarruyan Islands, adjacent to the Bolinao Marine Laboratory, Philippines ©AJH

The DWG has also made significant discoveries in the Caribbean and Australia regarding the potential impacts of climate warming events on the outbreak of coral disease. As a result, the group has developed a productive collaboration with the Remote Sensing Working Group to create new algorithms to predict outbreaks of coral disease, using a combination of monitoring data from Australia and from the Caribbean as well as satellite temperature data.

As of the end of Year 3, the DWG has held workshops and completed research at all Centers of Excellence, and one of the major priorities has been to study how local environmental issues, such as water quality, are impacting coral health and diseases. During January 2007, the DWG conducted workshops and research in Bolinao, Philippines where the group developed initial methods for evaluating the influence of fish farms on coral reef health.

2006 Disease Working Group workshop participants in Zanzibar, Tanzania. ©DWG

Restoration: The loss of experiments from unexpected bleaching and crown-of-thorns starfish outbreaks were a temporary set back in planned research, but the events have lead to important lessons. For example, as a result of the 2007 bleaching event in Bolinao, the RRWG now has new data on which coral fragments are more resistant to bleaching versus those that are more susceptible.

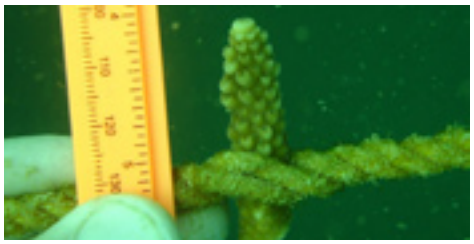
The timing of coral reproduction around Bolinao has been established (the first detailed data on this ever for the Philippines) with a total of 36 reef-building species belonging to 14 genera and 7 families observed to broadcast spawn in April-June period. Already, interesting results on the effect of fragmentation on reproduction are beginning to emerge with a clear effect of size of transplant fragments on reproduction but not on survival. Gravid coral colonies were also successfully spawned in the Bolinao outdoor hatchery and spat were settled onto conditioned tiles in order to study how (a) herbivory and (b) spat density affects post-settlement survival.

Remote Sensing: The RSWG research has enabled the ability to prioritize the importance of particular considerations when carrying out airborne remote sensing. The table at right summarizes progress to date.

SCIENTIFIC PROGRESS	MANAGEMENT APPLICATION
Define limitations of optical remote sensing (RS) for coral reef mapping and prioritize the importance of each source of potential error	More cost-effective deployment of RS for reef assessment; allow better matching of management goals to appropriate technology and techniques
Quantify the efficacy of algorithms that predict changes in reef ecosystems from archived imagery	Provide tools to detect areas of coast that have exhibited the greatest change over ecological and management time scales
Develop software capable of automating the prediction of coral cover from towed video	Increase cost-effectiveness and scale of coral reef monitoring.
Develop acoustic remote sensing methods that can be used to complement optical RS and map substrate rugosity (i.e. three dimensional relief).	Increase cost-effectiveness of remote sensing, particularly in turbid environments.
Link acoustic data on substrate rugosity to the microhabitat characteristics of reefs and associated fish communities	Map the distribution and dynamics of the habitat for juvenile and small-bodied reef fish in both the Caribbean and Pacific. Measure loss of substrate complexity rapidly and over large scales (e.g. after a disturbance)
Convert fish census data on parrotfish communities to a direct metric of grazing potential that incorporates species, body size, time of day and tidal height	Make better use of monitoring data or baseline surveys to compare potential patterns of grazing over time or among sites. Help interpret the impacts of fishing and the selection of management zones.
Develop new algorithms to predict the likelihood of coral bleaching incorporating both light and temperature	Better predictive accuracy, empowers managers with credible, real-time information. Allows stratification and targeting of field survey and monitoring.
Develop algorithms to design connected systems of management zones (e.g. marine reserves) based on the local thermal regime, bleaching-stress, and larval connectivity	Practical tools to help select networks of marine reserves that explicitly attempt to incorporate the impacts of rising temperature and bleaching on coral reefs
Model impacts of coral disease, bleaching and hurricanes on Caribbean coral reefs	Provide tools to assess the efficacy of altering the grazing level and algal growth rate of reefs through management action. Identify areas most at risk of climate change and vice versa.

The main technical outcomes thus far have been (1) modeling of the remote sensing of coral reef waters which provided new technical insight into the planning of airborne remote sensing campaigns (for example, to maximize spatial resolution and fly with a sun zenith angle of 45 degrees and low wind speed), (2) new video-based methods to increase the efficiency of in situ data on coral reefs, (3) model to convert in situ fish census data of Pacific reefs into predicted grazing intensity with insight into spatial variation in model parameters, (4) successful modeling of fish density from acoustic remotely-sensed data, (5) model of coral reef processes highlighting the importance of coral cover, size distribution and aggregation for discrimination, and (6) generation of new algorithm to predict coral bleaching from temperature and solar insolation. Each of the projects involves the work and activities of PhD and post-doctoral students from developing countries.

In this regard, many capacity building activities have taken place with the RSWG. The Working Group has conducted training of CRTR students in remote sensing with special application to their research throughout Phase 1 and divided among Working Group member's institutions.



Example of a coral fragment inserted into a polypropylene line and suspended for growth. Research has shown that about 80% of such corals (9 different species) can survive over one year and can be successfully placed onto degraded reefs.

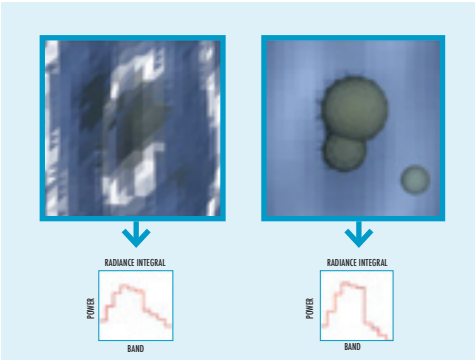
In 2007, four students contributed two draft papers at the first national marine habitat map being created for the government of Palau. The RSWG conducted two full CRTR workshops for coral reef managers and technical staff; one in Puerto Morelos, México that concentrated on remote sensing products for coral reef bleaching, and the second in Zanzibar, Tanzania that was organized by the COE. The latter workshop took place over 7 days and was co-taught by Dr Alasdair Edwards, Chair of the RRWG. Additional workshops were carried out in Fiji and in Australia. In the Philippines, the RSWG initiatives can be of value to the national and local government by providing the basis for maps of coastal resources for coastal use zoning, MPA planning, and management.

A series of new data products have been generated including a web-portal for directing users to sources of satellite data on factors affecting coral reefs and new bleaching metrics for use around COEs. Inter-working group activities have included work with the DWG to convene a meeting that led to new algorithms being identified for coral disease prediction and new parameterization for modeling, and a joint meeting was held with the Bleaching Working Group in Hawaii to develop new algorithms for coral bleaching.

REPLICATION

The DWG has developed a set of guidelines entitled *A Coral Disease Handbook: Guidelines for Assessment, Monitoring and Management,* that will be available to the management community in mid-2008.

An area of special interest is the hypothesis that corals in MPAs may benefit from a healthier, more intact reef ecosystem. Continuing to collect this kind of careful data and testing hypotheses about the causal explanation will be a priority area for research. The DWG is developing a model with the RSWG to highlight some of the influences of MPAs on coral health. This is an area where new scientific knowledge could assist management and policy decisions about MPAs, and therefore is crucial to understand what aspects of MPAs result in improved coral health. If the results continue to show a role for MPAs in coral health, this will provide additional support for one of the main



A new model developed by the RSWG has enabled the filtering of light spectra so that a clearer identification of coral reef features using remote sensing is now possible. ©P.J.Mumby/J.Hedley, RSWG

management tools for reef managers and could be replicated in practice.

Restoration: In 2006, the RRWG developed a manual for restoration entitled *Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty*, and offers guidance to managers about what is currently known and advised for approaches to restoration of coral reefs. The document is downloadable from the Internet (www.gefcoral.org)

Remote Sensing: Since 2005 the RSWG has replicated a course in training managers in accessing and using a broad range of the US National Oceanic and Atmospheric Administration (NOAA) remote sensing products, such as sea surface temperature, coral bleaching hotspots and degree heating weeks. The training has been replicated at all COEs.

SIGNIFICANCE

The CRTR program offers the ability to develop a rigorous foundation of targeted scientific information on which to base stronger management interventions and policy. The enhancement of capacity though training opportunities and collaborative research among leading international and regional scientists and students strengthens the parity among a truly global research network that has only been made possible through GEF catalytic support. This program is strengthening global response through collaborative research and learning together, using the same techniques and tools that enable unprecedented comparisons in regions where coral reefs provide key assets and services for people. The proactive nature of the Targeted Research—even in the face of a changing climate and human population expansion in the world's tropical coastal zones—offers perhaps the best chance to collaboratively build information, capacity and the will necessary to work together locally in solving a global challenge. The CRTR also offers the opportunity to build future leaders not only among scientists, but also scientifically trained students who will move into future management, governance and decision-making roles in their respective countries and regions.

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CONTACT INFORMATION

Marea E. Hatziolos, Team Leader
Senior Coastal and Marine Specialist
Environment Department
The World Bank Group,
MSN MC5-523
1818 H St., N.W.
Washington, D.C. 20433
+1.202.473.1061 (tel)
+1.202.522.0367 (fax)
Email: mhatziolos@worldbank.org

Melanie King, Executive Officer
Project Executing Agency
Coral Reef Targeted Research
& Capacity Building for
Management Program
C/-Centre for Marine Studies
The University of Queensland
St Lucia QLD 4072
+61.7.3346.9942 (tel)
Email: m.king4@uq.edu.au
www.gefcoral.org

Anthony J. Hooten, Synthesis Panel
Executive Secretary & U.S. Coordinator
Coral Reef Targeted Research
& Capacity Building for
Management Program
c/o AJH, Environmental Services
4900 Auburn Avenue, Suite 201
Bethesda, Maryland 20814 USA
+1.240.395.0250 (tel)
+1.240.395.0252 (fax)
Email: ajh@environmentservices.com
www.gefcoral.org