



UNITED NATIONS
UNIVERSITY

UNU-INWEH



criobe@mail.pf

Connectivity in Coral Reef Systems Lessons to Date and Goals for the Future

A Workshop for
the Connectivity Working Group of the
Coral Reef Targeted Research (CRTR) Program

Venue

**Le Centre de Recherches Insulaires et Observatoire de
l'Environnement
CRIOBE**

Opunohu Bay, Moorea, French Polynesia

7th to 11th March 2009

.....
Final Report

Summary of the Workshop

This was a small scientific workshop attended by 16 scientists from 5 countries whose research concerns coral reef connectivity. Most were individuals whose primary geographic focus has been the Pacific. The group included 6 scientists with no prior experience of the Connectivity program or the Coral Reef Targeted Research (CRTR) project. Several others had had only indirect participation in Connectivity activities. Five members of the Connectivity Working Group participated. The list of participants is attached as Annexe 1.

The workshop comprised two long days of presentations and discussions followed by a day-long field trip to acquaint individuals with the marine environment of Moorea. An informal reception initiated the workshop on the evening of 7th March. Individuals departed for Papeete to commence their homeward journeys on 11th March (although some individuals chose to stay on for individual research purposes).

All logistic and other details, including arranging flights between Moorea and Papeete, were handled by the capable CRIOBE team, led by Dr. Serge Planes, CRIOBE Director, and member of the Connectivity Working Group.

Objectives

There were four objectives in holding this workshop. These were:

1. To update on progress of the research, and to acquaint those not participating in the CRTR with the Connectivity program
2. To help finalize a statement to be submitted from the Connectivity Working Group to the CRTR Synthesis Panel as a proposal to guide development of Phase Two of CRTR
3. To explore merits of, and potentially to identify a writing team for a review of genetic techniques with applicability in the general field of populational connectivity in coral reef systems. The goal is a peer-reviewed paper on the topic late in 2009 or early in 2010.
4. To identify potential participants in preparing a handbook for reef managers on connectivity issues.

Results of the Workshop

All four objectives were achieved. The first day and a half of the workshop provided an excellent overview of work being done in connectivity of reef organisms. The Agenda is attached as Annexe 2.

Discussions on the draft document for the Synthesis Panel led to a significantly improved final version which was transmitted to the Synthesis Panel on 30th March 2009. A copy is attached as Annexe 3.

The geneticists present at the meeting agreed to participate in a review paper, to be led by Dr. Serge Planes, and submitted to Molecular Genetics. He had recently been invited by the journal to produce an article on the topic. The timeline for completion of the manuscript is to be autumn of 2009.

A draft outline for a document directed to reef managers, as a 'connectivity handbook' was developed, with a potential authorship of 10 members of the group. This will be produced as a formal product of the Connectivity program within the CRTR project, and timed for completion by late 2009, when we have a final Caribbean workshop with managers scheduled. Peter Sale will lead on developing this manuscript.

Annexe 1. List of Participants

Participant	Contact Information	E-mail
Dr. Cecile Fauvelot	Centre de Biologie et d'Ecologie Tropicale et Méditerranéenne Universite de Perpignan 52 Av. Paul Alduy 66860 Perpignan cedex, France + 33 4 68 66 20 55	cecile.fauvelot@univ-perp.fr
Dr. Michael Berumen	Biology Dept. Woods Hole Oceanographic Inst. Marine Research Fac. 212, MS#50 Woods Hole, MA USA 02543 +1 508 289 3963	mberumen@whoi.edu
Dr. Derek Hogan	Great Lakes Institute for Environmental Research University of Windsor Windsor ON Canada N9B 3P4 +1 519-253-3000, ext. 3752	hoganh@uwindsor.ca
Dr. Jesus Ernesto Arias Gonzalez	Dpto. Recursos del Mar, CINVESTAV-Unidad Mérida A.P. 73 CORDEMEX (Ant. Carr a Progreso Km 6) 97310 Mérida, Yucatán, México + 52 999 1 24 21 53	earias@mda.cinvestav.mx
Dr. Jelle Atema	Boston University Marine Program 5, Cummington Street, BRB 307 Boston MA USA 02215 + 1 617-358-4392	atema@bu.edu
Dr. Claire B Paris- Limouzy	Rosenstiel School for Marine and Atmospheric Sciences Dept of Applied Marine Physics University of Miami 4600 Rickenbacker Causeway Miami FL USA 33149 +1 305-421-4219	cparis@rsmas.miami.edu

Dr. Carmen Ablan Lagman	Biology Department De La Salle University Manila 2401 Taft Avenue, Manila 1004 PHILIPPINES Phone: +632 524 4611 ext 460	lagmanc@dlsu.edu.ph
Dr. Daniel Heath	Great Lakes Institute for Environmental Research University of Windsor Windsor, ON, Canada N9B 3P4 +1 (519) 253-3000, Ext 3762	dheath@uwindsor.ca
Dr. Hannah Stewart	Currently CRIOBE Shortly to UBC Fisheries Centre Vancouver BC Canada	hannahcriobe@gmail.com
Dr. Ken Lindeman	Division of Marine and Environmental Systems Florida Institute of Technology 150 W. University Dr. Melbourne, FL USA 32901 +1 321-271-7547	lindeman@fit.edu
Dr. Michael Domeier	Marine Conservation Science Institute Offfield Center For Billfish Studies 2809 South Mission Road Fallbrook CA USA 92028 +1 760 721-1440	ml.domeier@gmail.com
Dr. Paul H. Barber	Dept. Ecology & Evolutionary Biology 621 Charles E. Young Dr. South University of California Los Angeles Los Angeles, CA USA 90095 +1 310-794-5349	paulbarber@ucla.edu

Dr. Peter Sale	<p>International Network on Water, Environment and Health United Nations University 175 Longwood Rd. S., Suite 204 Hamilton ON Canada L8P 0A1</p> <p>Personal address: 1047 Brandy Crest Road Port Carling, ON Canada P0B 1J0 +1-705-764-3359</p>	sale@uwindsor.ca
Dr. Serge Planes	<p>Centre de Recherche Insulaire et Observatoire de l'Environnement (CRIOBE) BP 1013 - 98 729, Papetoai, Moorea, Polynésie française + (689) 56 13 45</p> <p>Centre de Biologie et d'Ecologie Tropicale et Méditerranéenne Universite de Perpignan 52 Av. Paul Alduy 66860 Perpignan cedex, France + 33 4 6866 1711</p>	planes@univ-perp.fr; planes@mail.pf
Dr. Tonya Shearer	<p>School of Biology Georgia Institute of Technology 310 Ferst Dr. Atlanta, GA USA 30332-0230 +1 404 385-4434</p>	tonya.shearer@ biology.gatech.edu
Dr. Brian Bowen	<p>Hawaii Institute of Marine Biology University of Hawaii P.O. Box 1346 Kaneohe, Hawaii USA 96744 +1 808-236-7426</p>	bbowen@hawaii.edu

Annexe 2. Agenda

1800hr to 2000hr, Saturday 7th March

All workshop participants welcome

Sunday 8th March

0830hr

Welcome to workshop, Introductions, Goals.

Peter Sale, UNU-INWEH, Hamilton, Canada

Session 1: Recent Advances in Connectivity Science?

0845hr

Connectivity research in Kimbe Bay: lessons and implications

Michael Berumen, WHOI, Woods Hole, USA

0915hr

*The role of olfaction among other senses in the recruitment and survival of larval reef fishes (with a direct link to lobsters, *H. americanus*)*

Jelle Atema, Boston University, Boston USA

0945hr

Coupled bio-physical models of larval dispersal: a Spiny Lobster demonstration

Claire Paris, RSMAS, U. Miami, USA

1015hr

COFFEE BREAK

1030hr

Approaches to Study the Connectivity of Adult Reef Fishes: Improving Old and New Concepts

Michael Domeier

Marine Conservation Science Institute, Fallbrook CA USA

1100hr

Assessing connectivity among Marine Protected and Unprotected Areas in the Mesoamerican Reef System (MAR).

Ernesto Arias, CINVESTAV, Mérida, México

1130hr

Temporally variable connectivity among populations of the Bicolor damselfish

Derek Hogan, U Windsor, Windsor, Canada

1200hr

LUNCH

Session 2: What promise from genetic approaches?

1330hr

Applications of genetic connectivity to understanding evolution and conservation of marine biodiversity in the Coral Triangle

Paul Barber, UCLA, Los Angeles, USA

- 1400hr *The complexity of assessing biological connectivity: the case with corals*
 Tonya Shearer, Georgia Institute of Technology, Atlanta USA
- 1430hr *Influence of fragmentation on the connectivity of *Dascyllus aruanus* populations within three reef systems*
 Cecile Fauvelot, U Perpignan, Perpignan France
- 1500hr COFFEE BREAK**
- 1515hr *Assessing utility of genetic markers for establishing population structure and connectivity in populations of some coral reef species*
 Menchie Ablan, De la Salle Univ, Manila, Philippines
- 1545hr *Discussion of genetic approaches, followed by General Discussion: Where are the gaps? Can we see the cutting edge?*
 led by Daniel Heath, U Windsor, Windsor Canada
- 1700hr Close of day**

Dinner at local restaurant at 2000hr

Monday 9th March

Session 3: Planning for the future

- 0830hr *Connectivity and management: knowledge gaps, action gaps, and steps forward.*
 Ken Lindeman, Florida Institute of Technology, Melbourne USA
- 0900hr *Goals for today*
 Peter Sale
- 0915hr Split into working groups
 Group 1: Scoping out a definitive statement as a journal publication on how genetic tools can inform reef managers about connectivity (may split further if other topics have arisen)
 Group 2: Drafting advice to managers about how to incorporate connectivity into planning of MPA networks
- 1030hr COFFEE BREAK**
- 1100hr *Group 1 report*
 Serge Planes, U. Perpignan, Perpignan, France
- 1120hr *Group 2 report*
 Brian Bowen, U Hawaii, Honolulu USA

1140hr *Discussion –Documents to advance application of Connectivity Science*
led by Peter Sale

1200hr LUNCH

Session 4: Research to fill the gaps.

1330hr *A strawman proposal for the CRTR project*
Peter Sale

1345hr *General Discussion – Strengths and Weaknesses of the Strawman*

1500hr COFFEE BREAK

Session 5: Planning for 2010.

1530hr *Summary of the modifications to the strawman*
Peter Sale

1600hr *General Discussion, Any final thoughts (open mike)*

1700hr Close of day

Dinner at local restaurant at 2000hr

Tuesday 10th March

Field trip to see an eastern Polynesian reef

0830hr *Depart from CRIOBE*
SCUBA, snorkeling, and lunch at islet restaurant

FINAL TASKS

1730hr *Delivery of Marching Orders*
Your Marching Orders will include the following:
1) A revised copy of the draft project proposal, to be approved, and then sent to CRTR Synthesis Panel as a recommendation for Phase 2
2) An abstract/outline of one or more journal articles to be produced as products from the workshop, with intended authors listed
3) An abstract of a non-technical product, “Advice for Managers – Connectivity and Coral Reefs”, with intended authors listed

2000hr Workshop Dinner at local restaurant

Annexe 3: Submission to CRTR Synthesis Panel

Building Management Science and Improving Coral Reef Management

A Proposal for Consideration for Inclusion in CRTR Phase Two

This proposal arises from discussions within the Connectivity Working Group and with the participants of our Connectivity Workshop held in Moorea, March 7th through 10th, 2009.

Preamble

1. Connectivity

In many ways, connectivity is the glue that holds coral reef systems together. Genetic connectivity molds the biogeographic patterns of species distributions across tropical seas as well as influencing patterns of evolution of reef species. Demographic connectivity specifies the links among local populations of organisms on nearby or distant reefs, and the pathways by which species complete their life histories as they move from larval to juvenile to adult habitats on reefs. Connectivity is critical to the spread of diseases, or of introduced species in reef regions, as well as to the recovery of reef systems seriously impacted by bleaching events, storm damage, or Crown-of-Thorn starfish outbreaks. Connectivity also determines the linkages between reefs and other coastal systems such as seagrass beds, mangroves, and estuaries, and the movement among these of nutrients, pollutants and organisms.

Spatially explicit reef management, by means of designated areas of protection from specific human activities, relies on connectivity to spread the various benefits of protection beyond the borders of the protected sites. In many cases, networks of no-take fishery reserves are established with the specific goal of sustaining or improving fishery yield in the area surrounding the protected sites. They rely on connectivity patterns to achieve this goal.

Despite the importance to reefs of connectivity, it is a difficult attribute to measure, and our ability to specify patterns of connectivity is in its infancy. Despite considerable discussion about applying connectivity principles in the design of networks of MPAs, those principles have yet to be specified in other than very general terms. And despite the many networks of MPAs that have been established, there exist few appropriately designed studies of their effectiveness, or even of the role of connectivity in determining species population dynamics within them. While there has been a burst of fundamental research on connectivity over the last decade with some impressive results, those results have not yet been effectively transferred to the management community. We remain far

from being able to apply connectivity principles to build effective management, and the management community is poorly informed about the complexity of the tasks remaining before that will be possible.

The following proposal seeks to build the science of connectivity as it applies to management of coral reefs while also building the effectiveness of spatially explicit reef management. It provides room for exploration of patterns of disease spread, of reef regeneration/restoration following disease or bleaching, and for exploration of the effectiveness of spatially explicit reef fishery management. It works with managers to extend their understanding of connectivity and of how to apply science to making their management actions more effective.

2. The need to improve reef management

Our collective experience in coral reef regions over the past decade or so has amply confirmed that:

- most developing nations have rather limited capacity for coastal marine management,
- despite the continued infusion of funding and training in the form of international development projects targeting aspects of coastal marine management, little tangible progress is being achieved,
- the need for more effective management is growing steadily due to increased populations, increased coastal development, and increased use of the coastal ocean for fisheries and tourism, and
- climate change is now exacerbating the deficiencies in management in place.

Coastal marine environments typically generate well in excess of 50% of GDP in developing nations with reefs, from tourism, fisheries, and marine shipping. They also provide immensely valuable environmental services, particularly coastal protection (a service that grows in value as climate change brings more severe storms and rising sea levels). Recognizing the economic and cultural importance of the coastal ocean, we believe it is critical to substantially improve the effectiveness of coastal marine management in the short term if tropical countries with coral reefs are to have any chance of establishing sustainable delivery of environmental goods and services from their vital coastal ecosystems. This environmental sustainability is critical to their future success in reaching their MDG targets, and a better quality of life for their people.

Critical to improving coastal marine management is the simultaneous full engagement of local coastal communities in projects that bring change, and effective regional integration of management policy in order to manage on a scale that is ecologically appropriate for coastal ocean ecosystems. Top-down national- or regional-scale projects are seldom sustained once external funding ceases and are too remote to achieve effective buy-in by local communities. Bottom-up, locally-driven projects seldom grow to a scale appropriate to the problem and lack the resources available at the regional or national level. We propose a new sideways-in approach that marries the effectiveness of top-down and bottom-up while reducing their deficiencies.

This proposal also addresses some of the root causes of the failed management now in place. These are:

- lack of understanding that management is an active process that reduces deleterious human impacts so that ecosystem functions are sustained,
- lack of appreciation of the need for effective integration of efforts directed to management of fisheries, of biodiversity, of pollution, and for other management objectives,
- lack of awareness of the enormous market and non-market value of sustainably managed coastal ocean ecosystems, or of the difference in value between these and degraded ecosystems, and
- lack of effective application of the capacity that does exist in local management, NGO and academic communities to bring about improvements.

One area in critical need of attention is the generally poor integration of management effort targeted at fisheries, conservation, environmental quality/pollution, and coastal development. We suggest that a connectivity focus can lead to more effective integration of these superficially different forms of management, around a spatially explicit management paradigm that builds on the widespread enthusiasm for MPAs.

The proposal

The proposal is structured as a set of quasi-independent local “demonstration projects” each with a variety of elements and planned in close collaboration with the local community. These local demonstration projects are integrated into a larger, regional program (hence ‘sideways-in’) with complementary actions taking place at a number of sites across a coral reef region, perhaps including a set of neighboring countries. Our goal is to manage in such a way that the local projects develop significant buy-in from the community, while achieving demonstrably positive results, and garnering a real chance for continuation. The regional integration will result in a program that can be demonstrated to be effective in improving environmental management throughout the region, and will facilitate the changes in attitude, understanding, and action that will be needed to make the program a living (therefore sustainable) part of the environmental management of the countries participating. Built into the project, by means of adaptive management approaches, and through high-level ‘think-tank’ workshops, are real opportunities to advance coral reef science and connectivity science in particular.

The project, which could be replicated at two or more locations around the world, will draw upon our recent experience in CRTR Phase One to set up a number of local demonstration projects to integrate marine protected area/conservation/fisheries/pollution management in an appropriate Indo-Pacific location. Chosen locations must already have, or have plans for management by means of networks of MPAs, and should be served by one of the regional Centers of Excellence. The number of demonstration projects at a location will depend on its spatial extent and geography. We anticipate locations of 200-500km in maximum diameter, with human population centers scattered through them, and supporting >5 and <20 demonstration projects at appropriate points within them. The active and effective presence as a formal partner by an NGO or an

entity such as the CRISP project or the Secretariat of the South Pacific (SPC) will be vital. Connectivity WG members know of several suitable places with potential partners present, including Palau, Papua New Guinea, Fiji, French Polynesia, and Samoa. Southern Philippines is another possibility, with management issues typical of densely populated coastal states.

While tropical coasts are peppered with marine protected areas especially around reefs, the management of nearly all of these is minimal at best, and despite the numerous publications on the topic there is very little science to guide how such spatially explicit conservation management or fisheries management should be done. Management of pollution is similarly limited because of lack of expertise in monitoring for presence of most potential pollutants, and lack of administrative links between those responsible for coastal management and those with technical skills appropriate to analyze samples for trace pollutants. Conservation management (habitat and biodiversity) is subsumed in MPA management, while fisheries management is rudimentary in many locations and frequently assumed to be provided by MPA management. Each form of management needs significant capacity-building, and integrating these makes sense because none is adequate on its own. Each demonstration project will include:

- Knowledge-building as well as knowledge-transfer activities addressing aspects of coral reef management relevant to our capacity-building goals.
- Local public education programs, in association with the demonstration projects, to build public understanding of the value of sustainably-managed coastal waters, and public buy-in for management policies being introduced.

The knowledge-building and -transfer activities will be driven by the needs of the local management agencies with support from the partner NGO and input from experts from the local and international science communities as appropriate. Details will be determined in early workshops with relevant partners and there will be several activities within a single demonstration project. Some will focus on MPA design, implementation, and management, some on pollution monitoring and mitigation, and some on aspects of reef fisheries management. There is room for important new science in each of these. Some examples of activities that build knowledge of connectivity are listed below; however, we anticipate that scientist participants will include members of several of the current Working Groups as well as new additions to the CRTR family and that other questions will also be explored including ones centered on social sciences or economics. Every demonstration project will participate in a regional-scale ('location'-wide at minimum), scientifically informed environmental monitoring program with a common, open-access database. The monitoring results will be used to guide local management decisions, measure effectiveness of management actions, and improve understanding of how the system really works. The success of each demonstration project will depend upon the effectiveness of the integration of the science (and the scientists) with the management activities (and the managers). At least one graduate student, post-doc, or qualified NGO staffer should be on-site long-term to ensure this integration at every demonstration project.

The public education programs will be led by management agency or locally based NGO personnel at each local demonstration project with guidance from scientists participating in the project. The goal is to ensure that the local coastal community and all stakeholders are full participants in each demonstration project and in the overall regional project. Education programs will include conferences and workshops, school programs, reports written in a style appropriate for managers and politicians, and materials for local media, and we anticipate that core materials will be shared across, but fine-tuned to each demonstration project. The intention is that this public education effort will be in depth and sustained over the life of the project. The goal is to build sustained buy-in for the idea of active, sustainable reef management. The critical and growing need for more effective management, due to changing conditions, will be highlighted.

In addition to the local demonstration projects, we intend to extend some of the synthetic work undertaken within Connectivity WG and the SP during CRTR Phase One. This component will be a global think-tank on spatially explicit management as it relates to reef, and tropical coastal management. It will include:

- Intensive capacity-building workshops for agencies (including local NGOs with delegated responsibilities) responsible for MPA management in each region, to build their understanding of what management of MPAs involves, and to guide them in putting effective management in place,
- Annual advanced scientific workshops involving members of the local and international academic communities that will serve to advance the theory of MPA management with particular reference to connectivity and network function.

The capacity-building workshops will be a teaching tool based on a curriculum that will be tailored to the general region, and presented in local workshops organized in conjunction with each demonstration project. The goal will be to teach topics that are relevant to the particular activities being undertaken within that demonstration project, so that new knowledge can be applied in local management actions.

The advanced science workshops will convene annually, and results will be published in leading peer-reviewed journals to help build a global science of MPA network design and management. Each workshop will meet at a different demonstration project, and will include an open session targeted to managers (particularly those participating in demonstration projects), and closed scientific sessions for invited participants. There will be considerable, but not total, overlap from year to year in the membership of these workshops so that a cadre of participants will be developed during the course of the project. The science community contributing to these scientific workshops will include: reef ecologists, physical oceanographers, metapopulation ecologists, fisheries scientists, theoretical ecologists, modelers interested in complex system behavior, fisheries economists, and social scientists interested in community responses to environmental and fisheries management. The goal is to go well beyond the current state of play in MPA network design and coastal marine management.

The extension of this think-tank approach to include topics beyond connectivity is encouraged, however we propose at minimum that there be one advanced science

workshop on connectivity issues every year and that other topics be dealt with by scheduling a greater number of events.

Some examples of activities within demonstration projects

The following examples are intended to show the possible scope of connectivity-related activities that could be undertaken within a demonstration project. All involve the generation of new scientific data, while also answering important questions to guide local management. Each will be set up to include direct participation of international and local scientists, NGO personnel, and managers, so that, through continuous mentoring and active learning, there is effective transfer of knowledge and of scientific approaches to answering management questions. Each example is a logical extension of work done during Phase One.

1. Water flow and patterns of connectivity

The modeling approach pioneered by Claire Paris, Bob Cowen and colleagues will shortly become accessible on the web for anyone to use. This significant product, supported by the CRTR Phase One Connectivity program, has obvious uses in any management planning effort in a region.

A demonstration project which centered on the early development of management strategies for a region would logically begin with an intensive application of this model, coupled with some oceanographic data collection from the region in order to build a map of water flows, likely connectivity pathways, and possible connectivity linkages for populations with given larval life history characteristics. Ideally the model would be presented initially in a workshop setting, and managers would be encouraged to use the model as a permanent characterization of their management area(s) that would help guide management decisions regarding population linkages, patterns of spread of pollution, disease or invading species, and so on.

This modeling approach would likely also form an important underpinning for any science questions explored in a demonstration project.

2. Demersal (juvenile and adult stage) connectivity

Demersal connectivity associated with ontogenetic, seasonal, reproductive, or diel movements of reef-associate species is a poorly studied and perhaps underappreciated aspect of connectivity, but one that epitomizes the inter-connections (demographic, nutrients, energy) that exist among coral reefs and adjacent marine ecosystems. In recent years, it has been largely ignored while larval dispersal captured attention. Tagging studies, done in collaboration with managers can reveal connections and pathways. These tagging studies are relatively easy to mount compared to studies of larval connectivity, so serve as a particularly valuable way of conveying the essence of connectivity to the managers and to the local community.

A demonstration project could undertake such tagging and use the results to guide management measures that help maintain demersal connectivity by:

- identifying critical migration routes and periods and restricting activities (e.g., fishing, public access) that impede their function,
- enhancing physical features of the environment that promote demersal connectivity, and
- managing the integrity of adjacent habitats used by reef-dwelling species.

3. Determination of larval connectivity

Significant work remains to be done to quantify patterns of larval connectivity, but much of this science requires contemporaneous collection of large numbers of recently settled juveniles, either previously tagged, or naturally marked in some way that links them to parental sites or populations. Such distributed field activities lend themselves well to a close collaboration between scientists and managers, and the field effort can be combined with monitoring activities or routine patrol of a managed area. Efforts mounted at the appropriate spatial scale (large) to test/develop new techniques for tracking dispersal of larvae of species other than fishes are sorely needed, and can be done with a science/management collaboration.

4. Managing for larval connectivity

The challenges of directly managing to enhance larval connectivity are formidable, but some aspects of larval connectivity are amenable to management, particularly those centered on measures that enhance demographically relevant connectivity by:

- increasing spawning stocks and perhaps larval quality (i.e., improve sources of dispersing larvae),
- increasing the probability that larvae arrive in protective habitats, and
- improving receptivity of nursery habitat for those larvae that arrive, thus enhancing post-settlement survival.

An experimental management program with local as well as governmental buy-in and oversight, based on the best available connectivity science and incorporating the monitoring of appropriate response variables in a properly designed “management experiment” would be ground-breaking. An incomplete list of possible avenues of management and science to explore might include:

Increasing stocks & larval quality:

Increases in the size of spawning individuals have almost universal benefits on spawning success (egg production, fertilization rates) and often larval quality (larval size, swimming ability, resistance to starvation, etc.). Thus, the imposition of maximum size limits on exploited species that would benefit from such measures is a management measure that, in tandem with a sufficient number of no-take reserves, should boost larval supply. Research and population modeling to identify those species and those management scenarios (size limits, proportion of no-take areas) that would most benefit from this, followed by monitoring of recruitment success in reserve and non-reserve areas

where connectivity is likely (in association with projects below) would provide the test.

Increasing larval arrival:

Connectivity science in this regard has come a long way. It is now possible, for a given target species and area, to offer reasonable predictions of species-specific larval dispersal and potential connectivity among sites (even if, in some cases, the prediction is: “highly connected” vs. “largely unconnected”). Situating monitoring sites or reserves in such areas provides the test and is a sensible management design strategy.

We are still learning the science required to guide the size and number of reserves necessary to maintain locally viable populations. Predictions from theory can be applied to specific regions supplied by known spawning stocks (enhanced & unenhanced as presented above) and can be tested with monitoring of larval arrival, larval condition, larval source information, etc. to test if enhancement of larval supply is possible (based on increase in spawning biomass).

Such a project would integrate very effectively with the planned scientific workshop program to extend the science of MPA design and management.

Increasing habitat receptivity and post-settlement survival:

Nursery habitat quality is critical for realizing potential gains in larval production, quality, and probability of larval arrival. By comparing recruitment success of selected species where quality of nursery habitat varies, in regions of high and low projected larval supply, it should be possible to quantify this relationship. We might compare coral recruitment in reserves where parrotfish harvest is prohibited (thus less algal coverage) vs. others where it is not, or compare fish recruitment on reefs where structure has been enhanced (e.g., mimicking now degraded stands of erect corals) or not. Similar efforts could take place in adjacent habitats that support reef function (e.g., mangrove and seagrass restoration or enhancement areas).

5. Determining the “catchment area” for a spawning aggregation of a commercially important fishery species.

An experiment to explore the role of a spawning aggregation of a commercially important snapper or grouper species remains very attractive. This experiment would develop detailed ocean circulation data for the target aggregation site, tag the larval fishes produced at the spawning aggregation, determine where they settle at the completion of larval life, and determine the spatial range from which adults at that site come. Such a project would demonstrate clearly the importance of such spawning aggregations to a region. We suspect that such an experiment could only be done with significant funding outside the CRTR project, but the possibility of supporting such an experiment may prove particularly attractive to management agencies, NGOs, or other potential partners such as CRISP who might be able to bring match funds to the table in its support. Regardless of the funding details, mounting such a ‘big-science’ project in conjunction with the set of demonstration projects proposed here would be attractive, would give

CRTR Phase Two a unique stature, and would facilitate the linking of science with management.

Summary

This proposal is designed to improve coral reef management across a region by taking several crucial steps that have some real likelihood of achieving overall success. These steps are:

- mount a number of local demonstration projects, locally driven and with good buy-in from the entire community
- include several activities within each demonstration project, with some overlap across projects to achieve replication at a regional scale
- build hypothesis-testing activities into each demonstration project using adaptive management approaches to advance the science
- integrate the demonstration projects into a regional program (including a monitoring database) to ensure that the local management actions sum to have ecologically significant results at the larger scale. This produces positive outcomes locally and recognition nationally or regionally.
- provide a sustained and effective regionally-coordinated public education program at each demonstration project site to build awareness, interest, and buy-in.
- Develop and deliver a capacity-building curriculum to managers and others in conjunction with the demonstration projects. Focus this on aspects of coral reef management that relate to the activities within each demonstration project so that managers learn by doing.
- Convene an annual high-level science workshop bringing together the regional and the international science community and selected managers to extend knowledge of connectivity as it relates to coral reef management, and publish results in leading peer-reviewed journals.

By using connectivity as a core principle, this project could tackle a number of aspects of coral reef management including water quality, conservation, and fisheries management. It could also provide opportunities for participation for many members of the CRTR project, from several of the Working Groups.

Peter F. Sale
Chair, Connectivity Working Group
March 2009