Presentations

Connectivity Science & Coastal Reef Management in the Caribbean

Best Western Belize Biltmore Plaza, Belize City
9-11th November 2009

Tuesday, 10th November

Session 3: Connectivity Needs for Managing the Mesoamerican Reef

Mesoamerican reef ecoregional assessment
Julie Robinson Stockbridge, The Nature Conservancy, Belize

Genetic tools and applications in connectivity science & coastal reef management in the Caribbean
Derek Hogan, Tulane University, New Orleans LA, USA

Libreta de calificaciones sobre la salud ecológica del sistema arrecifal mesoamericano (SAM)
Melanie McField, Healthy Reefs for Healthy People, Smithsonian Inst., Belize City, Belize

Next steps for the CRTR, considerations for a second phase
Anthony J. Hooten, AJH Environmental Services, Bethesda MD, USA

Building scientific capacity for reef management Connectivity in the CRTR project
Peter F. Sale, UNU-INWEH, Chair, Connectivity Working Group, Hamilton ON, Canada

Wednesday, 11th November

Session 4: Connectivity, Coral Reefs and Climate Change

Connectivity, coral reefs, and climate change, why not just give up?
Peter F. Sale, UNU-INWEH, Chair, Connectivity Working Group, Hamilton ON, Canada

Connectivity, coral-algal symbioses and climate change
Mary Alice Coffroth, SUNY Buffalo, Buffalo NY, USA
Mesoamerican Reef Ecoregional Assessment

Belize City, November 9th - 11th
Julie Stockbridge

Connectivity Science and Coastal Reef Management in the Caribbean

Outstanding Features

- Great diversity of barrier, fringe and patch coral reefs in a relatively small area
- Estuaries, coastal lagoons, mangrove forests and seagrass beds
- Marine turtles, crocodiles, dolphins, more than 500 fish species, whale sharks and the largest population of manatees in the Western Caribbean
- More than 2 million people living in the coastal area

Overview

- Largest reef system in the Americas
- Global conservation priority
- High marine productivity & biodiversity

ERA Objectives

- Develop a portfolio of priority conservation sites
- Threats analysis
- Strategies development
Second iteration of the Mesoamerican Caribbean Reef Ecoregional Planning (WWF, 2002)

Incorporates new information
- Millennium Reef Maps
- Seagrasses
- SPAGs
- Whale sharks

Participatory process
(75 persons representing 27 organizations)
- national and international experts,
- government agencies
- stakeholders

Use of a decision support tool for the development of the

Challenges

Four countries,
- México
- Belize
- Guatemala
- Honduras

Two languages
- Spanish
- English

Large watershed area

Threat variability

First Step: Planning area delimitation
200 m depth contour (continental shelf)

Yum Balam MPA

Coast line including mangroves, coastal lagoons and estuaries and manatee habitat

Cabo Camarón, Honduras
The beginning of the Miskito Keys Bank

Terrestrial area of influence: watersheds draining into the MAR

Marine area of influence: countries’ EEZ

Stratification
- Factory
- Reef type
- Oceanic islands
- Continental shelf
- Atolls
- River input
**Conservation Targets**

- Manatee habitat
- Mangroves
- Estuaries and coastal lagoons
- Reefs
- Sandy beaches
- Crocodile nesting sites
- Seagrasses
- SPAGs
- Sea turtle nesting sites
- Seabird nesting sites
- Whale shark feeding areas

**Prioritization goals (% in portfolio)**

<table>
<thead>
<tr>
<th>Conservation target</th>
<th>Strata</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
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<tr>
<td>manatee habitat</td>
<td>70</td>
</tr>
<tr>
<td>mangrove forest</td>
<td>55</td>
</tr>
<tr>
<td>estuaries &amp; coastal lagoons</td>
<td>30</td>
</tr>
<tr>
<td>Non reef flat</td>
<td>65</td>
</tr>
<tr>
<td>Reef flat</td>
<td>65</td>
</tr>
<tr>
<td>Beach</td>
<td>60</td>
</tr>
<tr>
<td>Seagrass meadow</td>
<td>70</td>
</tr>
<tr>
<td>SPAG</td>
<td>80</td>
</tr>
<tr>
<td>Sea turtle nesting beach</td>
<td>50</td>
</tr>
<tr>
<td>Seabird nesting site</td>
<td>60</td>
</tr>
<tr>
<td>Whale shark feeding areas</td>
<td>80</td>
</tr>
<tr>
<td>Crocodile nesting site</td>
<td>70</td>
</tr>
</tbody>
</table>

**Development of the cost surface**
(a proxy for target’s viability):

- Human footprint
River’s sediment discharge

Cost layer

Mesoamerican Reef (MAR) Marxan Analysis
Planning Units: 500 Ha hexagons
Total planning units: 14,284
Total area: 7,142,000 has (71,420 km²)

Arrecife Mesoamericano Análisis de MARXAN
Irreplaceability

how irreplaceable it is: number of times it was picked

Portfolio

• Key ecological processes
• Priority conservation targets

Results
Development of a network of priority conservation areas (Best solution)

Revised Portfolio

Our portfolio is only as good as our science

Priority Sites
Threats analysis

Identify stresses and sources of stress on conservation targets
Stress: damage/degradation of targets
- e.g. habitat loss
Source (Threats): incompatible uses that give rise to stress
- e.g. Coastal development
Ranked on severity and scope

<table>
<thead>
<tr>
<th>Threats to Long-term Systems</th>
<th>Amozones</th>
<th>Pastos</th>
<th>Manglares</th>
<th>Estuarios</th>
<th>SPAGs</th>
<th>Técnica Ballena</th>
<th>Valores</th>
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<tbody>
<tr>
<td><strong>Global Climate Change</strong></td>
<td>Alto</td>
<td>Medio</td>
<td>Bajo</td>
<td>Alto</td>
<td>Medio</td>
<td>-</td>
<td>Alto</td>
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<tr>
<td><strong>Aggressive Tourism Practices</strong></td>
<td>Bajo</td>
<td>-</td>
<td>Bajo</td>
<td>Medio</td>
<td>Bajo</td>
<td>Alto</td>
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<tr>
<td><strong>Development of Urban Infrastructure</strong></td>
<td>Alto</td>
<td>Alto</td>
<td>Alto</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Alto</td>
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<tr>
<td><strong>Inadequate Sedimentation</strong></td>
<td>Alto</td>
<td>Alto</td>
<td>Bajo</td>
<td>Medio</td>
<td>Bajo</td>
<td>Medio</td>
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<td><strong>Urban Coastal Development</strong></td>
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<td>Medio</td>
<td>Bajo</td>
<td>Medio</td>
<td>Medio</td>
<td>Bajo</td>
<td>Medio</td>
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<tr>
<td><strong>Overfishing and Inadequate Fishing Practices</strong></td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Bajo</td>
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<tr>
<td><strong>Use of Agrochemicals and Pesticides</strong></td>
<td>Alto</td>
<td>Alto</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
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</tr>
<tr>
<td><strong>Navigation</strong> (oil spills, boat groundings, etc.)</td>
<td>Bajo</td>
<td>Medio</td>
<td>Bajo</td>
<td>Medio</td>
<td>Medio</td>
<td>Bajo</td>
<td>Medio</td>
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<tr>
<td><strong>Acumulation of Solid Waste</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
<td>Medio</td>
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</tbody>
</table>

Main threats:
- Global Climate Change
- Aquatic tourism practices
- Tourism infrastructure development
- Coastal urban development
- Sewage discharge
- Sedimentation and agrochemical discharge
- Overfishing and inadequate fishing practices
- Navigation (oil spills, boat groundings, etc.)

Strategies
17 strategies developed under 5 themes:
- **Marine Protected Areas**
  - Legislation revision, increase MPA network
- **Sustainable Fisheries**
  - Revision of no-take zones, awareness & education
- **Resilience to Climate Change**
  - Mitigation of SLR, awareness & education,
- **Land Use Planning**
  - Legislation for land use planning, best practices, wastewater & solid waste management
- **Research and Monitoring Needs**
  - Regional research priorities, revision of threat related data, carrying capacity assessments
Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it’s the only thing that ever has.

Margaret Mead
Genetic tools and applications in connectivity science & coastal reef management in the Caribbean

J. Derek Hogan
Tulane University,
New Orleans, Louisiana, USA

What can we learn from Genetics?
• Understand patterns of gene flow (long term connectivity)
• Find unique or isolated populations (little or no connectivity)
• Identify dispersal of individuals (contemporary connectivity)

Types of Connectivity
• Evolutionary Connectivity
  – How different are populations after years of connectance?

• Ecological (contemporary) Connectivity
  – What is the connectance between populations now?

Various Genetic Analyses
• Population genetic studies
  • Population differentiation
  • Evolutionary connectivity

• Parentage analysis
  • Find the parents of recruits
  • Ecological connectivity

• Assignment tests
  • Which population do recruits belong to
  • Ecological connectivity
Population genetic studies

• Sample multiple reefs and analyze frequency of alleles at multiple genes/loci.

• Fst statistics tell you how different the “populations” are from each other.

Population level studies

• The greater the difference between two populations = less connectivity

• Tells you the historical view of connectivity among reefs

Temporal variation in connectivity

• Temporal changes in genetic differentiation may be common

• Stegastes partitus – differentiation between reefs changes year to year
  – Indicates variation in connectivity
What is required for this analysis?

• **MINIMUM** 30 samples from each reef
• Multiple reefs sampled
• Temporal replication (at least yearly)

Parentage Analysis

• Use multilocus genotype to identify parents of individuals
• Used to determine contemporary connectivity
• Can be very accurate at identifying natal origins of larvae

Parentage Analysis

• Can identify dispersal of individuals at very small scales (If parents do not move very far)
• Can identify levels of self-recruitment very accurately (If reefs are sampled extensively)

Planes et al. 2009
Planes et al. 2009

- 40% self-recruitment to a reef
- Found larvae disperse to adjacent reefs
  - Contribute up to 10% of recruitment in other reefs

What is required for this analysis?

- Requires intensive sampling of populations (> 50% of adults sampled)
- Requires sampling of larvae or juveniles

Assignment Tests

- Use multilocus genotypes to identify populations
- Used to determine contemporary connectivity
- It is as easy to do as population genetic studies (can be replicated)

Assignment Tests

- Best suited for large scale studies of connectivity
- Not as accurate as parentage analysis at ID individual level dispersal. Does not work well at small spatial scales
- Can generate general patterns of connectivity (e.g. dispersal kernels)
Sampled 100 adults and 100 juveniles at each reef over three years.

Self-recruitment occurred at all reefs (mean 15%, range 0 – 50%)

Self recruitment at Turneffe atoll was 56% (Hogan et al. in review)

Average larval dispersal distance = 75km

Longest larval dispersal distance >200km

Direction of dispersal varied

Assignment Tests

- May underestimate levels of self-recruitment (Saenz et al. 2009).

- Works best if there is strong population genetic structure
### What is required for this analysis?

- Requires minimum of 50 adult samples from each reef (more is always better for genetics)
- Requires sampling as many reefs as possible
- Requires sampling of larvae or juveniles
- Works best with strong population structure

### Quick Summary

#### Population genetic structure studies:
- Used for large scale, long term studies of connectivity
- Can ID isolated populations

#### Parentage analysis:
- Best for small scale studies of contemporary connectivity.
- Best for determining self-recruitment

### Quick Summary

#### Assignment tests:
- Best for mid to large scale studies of contemporary connectivity
- Best for determining general patterns in connectivity
- Easy to replicate (e.g. year to year)
- May underestimate self-recruitment

### Implications for Management

#### Self-recruitment is common and higher than once thought
- Higher self recruitment means local management has a bigger role

#### Larvae can disperse long distances (>200 km)
- Larvae can provide recruitment to other reefs

#### Connectivity is temporally variable
- Must account for variation in management plans
Implications for Management

• “Average larvae” is necessary info for MPA network design
  – How big does and MPA need to be to be self sustaining?
  – How much spacing between MPAs is appropriate?
• Need modeling and replication to determine average dispersal
• Connectivity varies among species
  – How to manage for variation in connectivity?
Promover con los directores de áreas marinas protegidas, tomadores de decisiones, y otros líderes encargados y preocupados con la integridad del Sistema Arrecifal Mesoamericano, el uso de los indicadores determinados por Healthy Reefs.

Promover análisis estandarizados de datos científicos confiables para mejorar el manejo del ecosistema de arrecifes coralinos.

Funcionar como un foro abierto para compartir información y construir una red entre la ciencia y los socios conservacionistas.
Healthy Reefs Indicators

Índice Integrado de la Salud del Arrecife; incluye siete indicadores

Cubierta de coral
Índice de enfermedades del coral
Reclutamiento del coral
Índice de la Biota Arrecifal
Índice de Macroalgas carnosas
Abundancia de peces comerciales
Abundancia de peces herbívoros
Abundancia de erizo Diadema

Esfuerzo científico para entrenar, recolección de datos (326 sitios), y el desarrollo del criterio de evaluación para cada indicador.
Los datos fueron colectados en 2006 a través de Nature Conservancy / World Wildlife Fund, Rapid Reef Assessment, usando el protocolo de AGRRA e involucrando a participantes de organizaciones locales e internacionales incluyendo a: Greenreef, Belize Audubon, Friends of Nature, TASTE, TIDE, UB, Earthwatch, WCS, y ASK.

Índice Integ. de la Salud Arrecifal

<table>
<thead>
<tr>
<th>Subregion</th>
<th>CHN</th>
<th>COAR</th>
<th>COAZ</th>
<th>GLOV</th>
<th>NQRO</th>
<th>NBAR</th>
<th>LIHO</th>
<th>INBI</th>
<th>SUBR</th>
<th>NOPR</th>
<th>OTHR</th>
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<table>
<thead>
<tr>
<th>Índice</th>
<th>2006 MAR avg (326 sitios)</th>
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<tbody>
<tr>
<td>Indicador</td>
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<tr>
<td>INDICE CORALINO</td>
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<tr>
<td>Cubierta de coral</td>
<td>9.9% cobertura</td>
</tr>
<tr>
<td>Incidencia de enfermedades del coral</td>
<td>1.9% colonias afectadas</td>
</tr>
<tr>
<td>Reclutamiento de coral</td>
<td>3.5 # por m2</td>
</tr>
<tr>
<td>INDICE DE BIOTA ARRECIFAL</td>
<td></td>
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<tr>
<td>Índice de macroalgas</td>
<td>55.8% cobert. x altura (cm)</td>
</tr>
<tr>
<td>Abund. peces comerciales</td>
<td>1085.5 g/100m2</td>
</tr>
<tr>
<td>Abund. Peces herbívoros</td>
<td>2642.3 g/100m2</td>
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<tr>
<td>Abund. de erizos</td>
<td>1.3 #/m2</td>
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Herbivorous Fish - 2006
Integrated Reef Health Index (IRHI)
Thresholds used to determine grades

<table>
<thead>
<tr>
<th>INDEX/INDICATOR</th>
<th>VERY GOOD</th>
<th>GOOD</th>
<th>FAIR</th>
<th>POOR</th>
<th>CRITICAL</th>
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<tr>
<td>Coral cover (%)</td>
<td>&gt; 40</td>
<td>30-40</td>
<td>20-30</td>
<td>40-50</td>
<td>50-60</td>
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<tr>
<td>Coral disease prevalence (%)</td>
<td>&lt; 0.1</td>
<td>0.1-1</td>
<td>0.5-1</td>
<td>1-2</td>
<td>&gt; 2</td>
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<td>Coral recruitment (m²)</td>
<td>&gt; 10</td>
<td>5-10</td>
<td>0-5</td>
<td>0-2</td>
<td>0-1</td>
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<td>Reef fish Index</td>
<td>&gt; 50</td>
<td>40-50</td>
<td>30-40</td>
<td>20-30</td>
<td>0-10</td>
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<td>Healthy fish abundance (1000m²)</td>
<td>&gt; 100</td>
<td>50-100</td>
<td>20-50</td>
<td>0-10</td>
<td>0-1</td>
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<tr>
<td>Commercial fish abundance (1000m²)</td>
<td>&gt; 150</td>
<td>100-150</td>
<td>50-100</td>
<td>0-50</td>
<td>0-5</td>
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<tr>
<td>Diatoms abundance (m³)</td>
<td>&gt; 20</td>
<td>10-20</td>
<td>4-10</td>
<td>0.5-40</td>
<td>0-10</td>
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CONCLUSIONS

ABOUT REEF HEALTH
• The Mesoamerican Reef (MAR) is not healthy on average scoring only about half the ideal Integrated Reef Health Index (IRHI).
• More than half the reefs sites are compromised, with 47% in poor and 6% in critical condition.
• Many reefs (42%) are in fair condition and could easily change for better or worse, depending in part on the effectiveness of management actions.
• Only 6% of the 326 reef sites evaluated are in good condition—and none ranked as very good.
• Healthy and unhealthy reefs can be found throughout the region, illustrating the importance of local management actions.
• Signs of poor reef health include low coral cover, low fish and invertebrate abundance, diseased corals, and relatively high amounts of algae.
• Even remote reefs, like the four atolls, are impacted, likely by overfishing and storm damage.

Belize, 140 sites
Guatemala 69 sites
Honduras 60 sites

Percent of MAR Reefs in Different Conditions

Integrated Reef Health Index (IRHI)
- Very good (>2.2-5)
- Good (>1.1-2.2)
- Fair (>2.6-3.6)
- Poor (>3.8-4.2)
- Critical (<1.1)
RESULTADOS EN CINCO MESES

- Protección total de los peces loro y cirujanos en Belice

- Creación de la zona de “no extracción” más grande de Belice (50% incremento)

- Prohibición de pesca con arpón en AMP’s
Next Steps for the CRTR

Considerations for a second phase

End of Phase 1 - November 30th, 2009

• All projects as currently structured will come to an end with Phase 1.
• Some extension for a few projects still completing activities & expenditures
• End of February is absolute
• Synthesis of diverse findings into summaries for different audiences

• There will be a hiatus between Phases 1 & 2 between 12 and 18 months, although some planning activities may take place during this period.

CRTR www.gefcoral.org

• Global Environment Facility & the World Bank
• Three Phases over 15 years
• More than 70 scientists
  – A network of students – future leaders
• Filling knowledge gaps in six key areas:
  • Coral Bleaching
  • Disease
  • Connectivity
  • Restoration
  • Remote Sensing
  • Modeling and Decision Support
• Building Capacity through Four Centers of Excellence
• More than 25 scientific training and capacity enhancing workshops held across all COEs during Phase 1

• More than 390 publications that include refereed journal articles, books and book chapters, and symposium proceedings

• Information products translated for different policy and management audiences

• Local Government Initiative

Mid-Term Review

• “The key scientific questions, as reflected by the working group subjects and organization, address some of the most relevant issues of concern regarding coral reefs. The research could further increase relevance by including elements targeting over-fishing, ocean acidification and land-based sources of pollution and stress. The relevance of the Programme would be increased by future efforts to achieve outcomes (e.g. scientifically-based policy recommendations and an accompanying set of implementation strategies) in addition to outputs. There is a need for bridging activities, from science to policy.”

Phase 2 of the CRTR is dependent upon the Global Environment Facility (GEF) for support
Global Environment Facility, 5th Replenishment

- Every four years, contributions by member governments
- Three possible funding options for GEF 5
  - 5, 7, or 10 B
  - IW Component for any of these is likely $500 Million (for all IW programs)
- CRTR Phase 1:
  - $11 million GEF
  - $3m World Bank
  - $2.9 m ($AUD) University of Queensland

Shallow-water coral reefs

25%
Of Marine Biodiversity

If all the world’s coral reefs were crammed together …

Lower Estimate
284,300 km²

Higher Estimate
527,072 km²

Map Source from ReefBase.org
• The World Bank was specifically chosen for implementation because of policy discourse with more than 184 member countries of which more than 100 have coral reefs. More recent examples:
  - Groundwater in the Yucatan - policy change
  - New coastal development program in Kenya (KCDP)
  - Maldives Environmental Management Project ($23 M IDA credit)
  - Mesoamerican Barrier Reef System (Phase 2)
  - Protection of herbivores through legislation (e.g. Belize)
  - Coastal and Marine Resources Management in the Coral Triangle: Southeast Asia (2008)

• The CRTR has been designed to make important points from a scientific perspective first, and using COEs as focal points for activities and training that enable us to increase capacity (e.g. planting seeds), which transcend into management and policy.
  - However, the ultimate objective is to bridge information into management and policy. During Phase 2, the CRTR must move to a more integrated & inclusive model and do so with more on-the-ground activities specifically relevant to management objectives.

Phase 2

CRTR Network (Phase 1 Working Groups)

Synthesis Panel

Additional Targeted Research - Social Sciences, Economics

Integrated, on-the-ground demonstration projects within the CoE Regions or satellites.
Key Services provided by coral reefs (both ecosystem & economic)

- Protein (fisheries yield)
- Important repositories of Biodiversity
- Role in Tourism
- Coastal Defense

Possible Revised Focal Areas/Themes:
1. Climate Change and forcings
2. Spatial Planning & Management
3. Ecological Dynamics and Resilience
4. Water Quality and Disease
5. Restoration
6. Economics and Social Sciences

Contracts to Integrated project activities and Network members for specific tasks.

Phase 2 – integrated/demonstrations

- Mesoamerican-related Issues defined thus far:
  - Coastal development intensity, footprints & pollutant loads
  - Groundwater and eutrophication
  - Disease
  - Distribution of economic benefits
  - Public perceptions of reef-related relevance
  - Restoration Potential & potential manipulations
  - Marine Spatial Planning (and Connectivity considerations)
  - Calcification and impacts to reef framework, infauna & coastal defense

Phase 2

- Some Network members will be invited by Chairs to participate in integrated project activities
- Other members will participate in planned Network meetings to offer review assistance and preparation of review papers and briefs, or will be involved in training
- There will be some core support for Centers of Excellence & some core activities
  - i.e. Important role for regional communication and outreach
  - e.g. special project activities determined by the SP
- Synthesis Panel meetings annual + video conferencing to reduce carbon footprint.
Next Steps

- PIF (Project Information Form) to be submitted to the GEF
  - Early submission for review/comment between now and July, 2010
  - Implementation-Completion Report required to be completed before official submission is eligible for Phase 2 – WB-supervised
  - “Official” submission not eligible until July
- Scoping of the preferred integrated concepts with local communities for feedback
- World Bank has its own submission requirements to its Board (can take up to 1 year) “PAD” Project Appraisal Document

Next Steps

- How much are we talking about?
  - GEF requires 1:1 co-financing
  - Phase 1: Excellent track record of in-kind & cash co-financing
  - The CRTR has and will continue to seek more than GEF support as co-financing (current economics)
Building scientific capacity for reef management

Connectivity in the CRTR project

Peter F Sale
UNU-INWEH

What is connectivity? Why is it important for management?

• “the flux of stuff”
• Connections between populations or places because of transfer of items between them
• Transfer of nutrients or pollutants between sites
• Transfer of eggs, larvae or older organisms between populations
• Must be maintained

What science did we attempt?

• Nassau Grouper “flux” experiment
• Connectivity in Bicolor damselfish
• Coral post-settlement survivorship
• Genetic studies of coral connectivity
• Coral “flux” experiment
• Lobster larval biology & recruitment
• Modeling of lobster connectivity
And what worked?

- Nassau Grouper ‘flux’ experiment
  - very high cost
  - recruits few and cryptic
  - sometimes the science cannot be done

- Connectivity in Bicolor damselfish
- Coral post-settlement bottlenecks
- Genetic studies of coral connectivity
- Coral ‘flux’ experiment
- Lobster larval biology & recruitment
  - White rats can be useful
  - Modeling of lobster connectivity
Putting Science into Management

- Seven workshops with cadre of managers from region
  - Akumal, Dec 2004
  - Calabash Caye, June 2005
  - Akumal, April 2006
  - Miami, September 2006
  - Roatan, April 2007
  - Fort Lauderdale, June 2008
  - Belize City, November 2009
- Managers assisted in two projects
- Pamphlets and handbooks
- Personal interactions

Do our Managers now Understand Connectivity?

Do our Scientists now Understand Managers’ Needs?

Do we have a Framework for Future Cooperation to Build Sustainability?

This Workshop

- Our final chance to interact in a workshop environment during Phase One of CRTR
- Update on what has been achieved
- Refresher on how connectivity science contributes to good management
- Some reflections on management issues beyond connectivity
Connectivity, Coral Reefs and Climate Change

Why not just give up?

Peter F Sale
UNU-INWEH

Why climate change?

- Climate change is happening
- There are dire predictions for coral reefs
- What should managers do?

Local management is more important than ever

- Warming and acidification are new stresses on coral reefs
- Unless we take firm steps globally to reduce CO₂ concentrations in the atmosphere, the future for coral reefs is grim
- Reefs are immensely important to coastal states: food, fishery products, tourism, coastal protection
- Now is not the time to give up

Local management is more important than ever

- By managing reefs to reduce old stresses, we should make reefs better able to cope with new stresses
- Old stresses: overfishing, pollution, habitat destruction, inappropriate coastal development
- Over the years we have done a poor job of managing these older stresses
- It's more important than ever before to do a better job locally
Local management is more important than ever

• This session is intended to open this topic up for discussion
• And to provide some clarification regarding the science
• And to provide encouragement for local as well as global action
Connectivity, Coral-algal symbioses and Climate Change

Mary Alice Coffroth
Buffalo Undersea Reef Research (BURRE) Dept. of Geology
University at Buffalo

Symbioses involving Symbiodinium

The Symbiosis

ALGAE (AA, CH₂O)

CORAL (N, CO₂, PROTECTION)

Normal Coloration

Photo: Michael ten Lohuis
Coral Bleaching

A whitening of the tissue due to loss of algal symbionts and/or pigment (chlorophyll)

Global Warming

- Mass bleaching events on the GBR in '98, '02 and '06 and in the Caribbean in '05
- Coral reefs predicted to bleach annually by 2050

Temperature and Bleaching

- 2-3º C above seasonal maxima
- 1-2º C above normal over weeks-months

Coral Bleaching: A response to Climate Change

Coral-algal response - Change or “move”? 
Clade B

Clade C

Symbiodinium

DIVERSITY

Clades B or C

Clade B

Clades A or B

Symbiodinium

DIVERSITY

Clade B

Clade A

Clade B

Clade C

Symbiodinium

DIVERSITY

Clades A or B

Symbiodinium

DIVERSITY

Clade B

Clade A

Clade C

Symbiodinium

DIVERSITY

Clades B or C

Clade B

Clades A or B

Symbiodinium

DIVERSITY

Clade B
Considerations

- Mode of transmission
- Host-symbiont selectivity
- Host-symbiont fitness

Symbiont transfer

- Vertical (closed)
- Horizontal (open)
Swimming larvae

Horizonal (open)

Spawn

Newly settled polyp

Acropora palmata
Acropora cervicornis
Porites astreoides

Diploria clivosa
Eusmilia fastigiata
Meandrina meandrites
Madracis decactis

Montastraea cavernosa
Montastraea annularis
Montastraea franksi
Porites porites

Siderastrea siderea
Acropora sp. (Japan)

Phylogenetic relationships inferred for Symbiodinium clade B from the concatenated flanking regions of microsatellite loci CA4.86 and CA6.38. Santos et al 2004
Fitness effects

Growth with different symbiont types

Percent Change

Treatment/replicate

Pseudoptergorgia elishabethae

Santos et al in 2003

Florida Gorgonia ventalina

Kirk et al in 2008

Gulf of Mexico

Atlantic Ocean
Montastraea faveolata

Thornhill et al in 2009

Symbiodinium populations differentiated
Limited dispersal

Symbiodinium microadriaticum

Possible scenarios --
Possible scenarios --

Possible scenarios --

Possible scenarios --

Larval Supply

- Adult abundance
- Adult fecundity
- Fertilization success
- Developmental success (% that reach competency)

All of the above are being affected by global warming

From Szmant
Effects of Climate Change on Larval Supply
- Adult abundance
- Adult fecundity
  - reduced fecundity of recently bleached corals (Szmant & Gassman 1999)
- Fertilization success
  - decreased % fertilization of gametes produced by recently bleached corals (Omori et al 2003)
- Developmental success (% that reach competency)

From Szmant

Effects of elevated SW temperatures on survivorship during development

Acropora palmata

Diploria strigosa

Randall and Szmant 2009
Szmant unpublished

Late summer temperatures in Northern Caribbean, 2005
Aug to Oct 2004 degree heating weeks
Aug to Oct 2005 degree heating weeks

From Szmant

Summary
- Symbiont dispersal is limited
  - within a reef tract – unique genotypes
- Natural selection acting on both partners?
- Also selectivity of adults
- Habitat is important

thesea.org
Geister, Jörn "Patch reefs and channels within the barrier reef and lagoon" Belize
Climate change – implications for coral-algal symbioses

- Bleaching = Loss of corals & substrate
- Larval production and development limited (= limited connectivity?)

Next steps?
- Much still unknown and uncertain
- Again – important to preserve local habitats
- Reduce other stresses to increase resilience

Map: Jim Stamos
Based on Nei’s unbiased (1978) genetic distances. Bootstrap values for 1000 permutations.

Results: Depth

$r^2_{x1, x2} = 0.255, p = 0.01$