Incorporating Ecosystem Services into Coastal and Watershed Management

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ESRP Coral Reef Project

Objective: Provide information and tools that support evaluation of trade-offs among reef ecosystem services under alternative decisions

U.S. Virgin Islands

Puerto Rico
Virgin Islands Case Study

Can expanded Clean Water Act water quality standards (biological criteria) protect fisheries, tourism/recreation and shoreline protection values of USVI coral reefs?

U.S. Virgin Islands Department of Planning & Natural Resources
EPA Region 2
Biocriteria - thresholds established to protect the biological condition of aquatic life inhabiting waters of a given designated use. [Clean Water Act]
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Puerto Rico Case Study

Will implementation of the Guánica Bay Watershed Management Plan improve fisheries, tourism/recreation, and shoreline protection value of coral reefs in Southwestern Puerto Rico?

Puerto Rico Department of Natural & Environmental Resources
EPA Region 2
Nonpoint Pollutant Discharge
• Shade-grown coffee
• Cover crops
• Hydroseeding
• Dredge reservoirs
• Remove relic irrigation
• Lagoon restoration
Research Approach

Decisions → Stressors → Reef Attributes → Ecosystem Services

Cost/Benefit Comparisons
Research Approach

1. Understand priorities of decision-makers

- Decisions
- Stressors
- Reef Attributes
- Ecosystem Services

Cost/Benefit Comparisons
Research Approach

1. Understand priorities of decision-makers
2. Link stressors to reef attributes

Decisions → Stressors → Reef Attributes → Ecosystem Services

Cost/Benefit Comparisons
Research Approach

1. Understand priorities of decision-makers
2. Link stressors to reef attributes
3. Connect reef attributes to ES

Decisions → Stressors → Reef Attributes → Ecosystem Services

Cost/Benefit Comparisons
Research Approach

1. Understand priorities of decision-makers
2. Link stressors to reef attributes
3. Connect reef attributes to ES
4. Develop models to evaluate alternative scenarios
Research Approach

1. Understand priorities of decision-makers
2. Link stressors to reef attributes
3. Connect reef attributes to Ecosystem Services
4. Develop models to evaluate alternative scenarios
5. Build decision-support tools
DPSIR Framework

**Driving Forces**
Socioeconomic sectors and cultural factors that drive human activities (causes)

**Pressure**
Human activities that place stress on the environment (pollutants)

**Response**
Response of society to the environmental situation (policies, decisions)

**State**
Condition of the environment (composition, distribution, quality)

**Impact**
Effects of environmental degradation (changes in attributes, services)

Yee et al. in press
1. Understanding Decisions

2007: US Virgin Islands
2009: Florida Keys National Marine Sanctuary
2010: Puerto Rico

- Identify priority issues
- Elaborate potential management options
Demonstrate a tool and let them apply it

- DPSIR Framework
  - Encourages whole-systems thinking
  - Consider purpose/consequences of proposed actions
Demonstrate a tool and let them apply it

- Social Network Analysis
  - Understand the critical players & relationships
Demonstrate a tool and let them apply it

- Decision Analysis
  - Understand the decision-making process
  - Identify alternative management strategies

Rehr et al. In review
Benefits of the process

• Participants
  • Opportunity to learn about decision support tools

• Organizers
  • A task to get the conversation going
  • Elicit information on their priorities/concerns
After the workshop...

• Expand objectives of original plan to reflect workshop

**Management Actions**

- Hydroseeding
- Cover Crops
- Shade-grown coffee
- Lagoon restoration
- Dredge reservoirs
- Reservoir releases
- Rainwater collection
- Riparian plantings
- Remove relic irrigation structures
- Pet waste cleanup
- Wetland treatment of sewage effluent

**Rationale**

- Reduce physical/chemical stressors in water
- Maximize ecological integrity
  - Coral reefs
- Reduce biological stressors in water

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*Carriger et al. in prep.*
After the workshop...

- Expand objectives of original plan to reflect workshop
After the workshop...

- Expand objectives of original plan to reflect workshop

<table>
<thead>
<tr>
<th>Management Actions</th>
<th>Rationale</th>
<th>Objective</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroseeding</td>
<td></td>
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<td>Agriculture economy</td>
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<tr>
<td>Cover Crops</td>
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<td></td>
<td>Drinking water supply</td>
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<td>Shade-grown coffee</td>
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<td>Tourism economy</td>
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<td>Lagoon restoration</td>
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<td>Fishing economy</td>
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<tr>
<td>Dredge reservoirs</td>
<td>Reduce physical/chemical stressors in water</td>
<td>Maximize ecological integrity</td>
<td>Shoreline protection</td>
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<td>Reservoir releases</td>
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<td>Streams &amp; rivers</td>
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<td>Rainwater collection</td>
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<td>Reservoirs</td>
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<td>Riparian plantings</td>
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<td>Estuaries</td>
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<td>Remove relic irrigation structures</td>
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<td>Wetlands</td>
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<tr>
<td>Pet waste cleanup</td>
<td></td>
<td>Coral reefs</td>
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<tr>
<td>Wetland treatment of sewage effluent</td>
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</table>

- Reduce biological stressors in water
After the workshop...

- Organize information in an objectives hierarchy
  - What are the fundamental objectives & how to measure?
After the workshop…

- Organize decision options in Means-Ends Network
  - Are the options adequate or are new options needed?

Objectives

- Maximize ecological integrity
- Maximize economic benefits
- Enhance social well-being
- Minimize threats to human health
- Meet political and legislative requirements

Means

- Enforce sediment erosion regulations
- Maximize planting of cleared home sites & dirt roadways
- Minimize pet waste
- Treat sewage effluent
- Restore lagoon marshes
- Dredge reservoirs/ sustain releases
- Treat stormwater outflows
- Encourage hydroseeding
- Enhance riparian planting/ cover crops
- Create incentives for shade grown coffee
- Remove relic irrigation structures
- Establish rainwater collection systems

Reduce physical/chemical/bacterial stressors from municipal loadings

Conserve freshwater supplies
2. Link Stressors to Reef Attributes

- Dose-response relationships
- Human-disturbance gradients
- Linking landscape activity to coral condition
Dose-response Relationships

2-week sediment exposure period

3-D growth in mm²

![Graph showing 3-D growth in mm² over different sediment exposure periods (Control, 1/2 hour, 5 hour, 24 hour).]
Human-disturbance Gradient

St. Thomas, USVI

1 km from cruise ship lanes

0.1 km from cruise ship lanes
Linking Landscape Activity to Reefs

Landscape Development Intensity Index

\[ y = -1469.6x + 5502.4 \]

Oliver et al. in review
Link between human activity & reef condition but….

What are the consequences on provisioning of ecosystem services?
3. Connecting Reef Attributes to Ecosystem Services

Literature Review

• What services have been identified?
• How were services measured?
• How can reef attributes be translated into services?
• What indicators estimate delivery of services?

Principe et al. EPA Report 2010
ECOSYSTEM SERVICES RESEARCH PROGRAM

Tourism & Recreation

Fishing

Shoreline Protection

Natural Products
Tourism & Recreation

Shoreline Protection

Ecosystem Integrity

Natural Products

Fishing
**Tourism & Recreation**

- Survey and valuation methodology

<table>
<thead>
<tr>
<th><strong>Biotic Features</strong></th>
<th><strong>Natural Features</strong></th>
<th><strong>Abiotic Features</strong></th>
<th><strong>Social Features</strong></th>
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<tbody>
<tr>
<td>Species richness (coral, fish, sponges, etc.)</td>
<td>Warm ocean temperatures</td>
<td>Water clarity</td>
<td>Perceptions of crowding</td>
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<td>Variety of species characteristics (coral, fish, sponges, etc.)</td>
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<td>• # of divers/snorkelers</td>
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<td>• colorful</td>
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<td>• rare</td>
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<td>Charismatic megafauna species diversity (birds, marine mammals, turtles)</td>
<td>Calm waters</td>
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<td>Lack of pollution</td>
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<td>Coral health</td>
<td>White coralline sands</td>
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<td>3-dimensional reef structure</td>
<td>Proximity to deep ocean &amp; waves</td>
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<td>Coral/macroalgae ratio</td>
<td>Connectivity with the adjacent tropical ecosystems</td>
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</table>

Table 2-1. *Features relevant to the perceived value of coral reefs*
Fishing

- Essential fish habitat
- Fisheries models

McClanahan 1994
Shoreline Protection

- Hydrodynamic models
- Anecdotal evidence

Modified from Monismith 2007

Modified from Kunkel et al. 2006
Natural Products

- Reviews of existing products derived from reefs

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Chemical Class</th>
<th>Source</th>
<th>Latin Name</th>
<th>Photo of Source</th>
<th>Location</th>
<th>Specific Application</th>
<th>Status</th>
<th>Structure</th>
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<tr>
<td>1-β-D-glucosylxylotriose</td>
<td>C-molecules (derived from P. hexadactyla)</td>
<td>sponge</td>
<td>Cryptophora notoidea</td>
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<td>Caribbean</td>
<td>antiviral &amp; anticancer</td>
<td>clinical use</td>
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<tr>
<td>adenine derivative (Ara-A, Vidarabine®)</td>
<td>C-molecules (derived from gorgonian)</td>
<td>gorgonian</td>
<td>Entacmaea quadricornis</td>
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<td>Mediterranean</td>
<td>anticancer</td>
<td>clinical use</td>
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<tr>
<td>agelaspin derivative (KR27-7000)</td>
<td>alpha-galactosylceramide (first known extraction from natural source)</td>
<td>sponge</td>
<td>Agelas vonnoda</td>
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<td>Mediterranean</td>
<td>antineoplastic; stimulates lymphocytic proliferation under certain conditions;</td>
<td>Phase I trial showed</td>
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<td>appears to stimulate the production of natural killer T (NK1) cells in the body</td>
<td>effects on patients</td>
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<td>withdrawn in 2002</td>
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<td>Ecosystem Services</td>
<td>Biodiversity</td>
<td>Fish Diversity &amp; Abundance</td>
<td>Coral Diversity &amp; Abundance</td>
<td>Coral health</td>
<td>Reef Rugosity</td>
<td>Reef Depth &amp; Slope</td>
<td>Reef continuity</td>
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<td>Recreational fishing opportunity</td>
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<td>Diving/snorkeling opportunity</td>
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<td>Underwater photography opportunity</td>
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<td>Reduction in rates of shoreline erosion</td>
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<td>Reduction in degree of coastal flooding</td>
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<td>Harvestable stock for seafood</td>
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<td>Material for curios and jewelry</td>
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<td>Marketable natural product or template</td>
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</table>
4. Developing models

Dynamic models
4. Developing models

Poster #19
Modeling Ecosystem Services with Bayesian Networks
Modeling Sustainable Delivery of Reef Ecosystem Services

- Many good existing models
  - Lack general applicability to range of management scenarios
  - Lack portability/scalability
  - Lack connection to ecosystem services
Connect land-based stressors to offshore water quality.
5. Decision Support Tools

Dynamic models

Bayesian Network
Reef ES & Decision Support Database

- Management options
- Legislation
- Clients and partners
- Scientific literature

- Jurisdiction- or topic-specific
Tutorial on Systems Thinking using DPSIR

- Web-based Tutorial
- Generic DPSIR words list
- Generic DPSIR conceptual models
DPSIR Framework

• Eliciting information from clients
• Identifying key stressors & services
• Synthesizing objectives & means to achieve them
• Building whole-systems models
• Organizing the state of knowledge
• Identifying knowledge and research gaps
• Systems-thinking linking human system to ecosystem
Coral Project Team

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Our Partners

- EPA
- National Oceanic and Atmospheric Administration (NOAA)
- USDA NRCS
- USGS Caribbean Field Station
- Caribbean Coral Reef Institute (CCRI), University of Puerto Rico
- National Coral Reef Institute (NCRI), Nova Southeastern
- The Nature Conservancy (TNC)
- Center for Watershed Protection (CWP)
- Carnegie-Mellon University
- University of Miami, Rosentiel School of Marine Sciences (RSMAS)
- University of the Virgin Islands
- National Fish and Wildlife Foundation (NFWF)
- USVI Department of Planning and Natural Resources (DPNR)
- Puerto Rico Departamento de Recursos y Ambientales (DNRA)
- Florida Department of Environmental Protection (DEP)
Demonstrate a tool and let them apply it

- Decision Analysis
  - *Understand the decision-making process*
  - *Identify alternative management strategies*
Agriculture Policies & Guidance

EPA, as a regulatory agency, has primary responsibility for enforcing the environmental statutes. Sometimes, however, that authority needs to be further issues policy or guidance to encourage compliance with environmental requirements.

- General Enforcement Policies
- Statute-Specific Policy Categories

Controls practices of

Agriculture

Emissions regulations

Improved technology

Ecosystem Services Research Program

Traveling regulations

Energy policies

Tourism regulations

Marine Protected Areas

Pharmaceuticals

Waste disposal

Tourism & Recreation

Culture

Fishing regulations

Boating regulations

Scientific monitoring

Restoration activities

Dredging

Vessel groundings

Trampling

Harvesting

By-catch

Ecosystems

Reduces flooding & benefits

Contaminants

Nutrients

Sediment

Pathogens

Temperature

CO2

Sea level

Hurricanes

Shoreline protection

Sand production

Fish & Invertebrate Habitat

Fishing stock

Biological diversity

Influences distribution of

Influences survival

Influences

Compete for space

Grazes & maintains

Provides

Essential for

Available as

Contributes to

Aesthetic value for

Research potential for


After the workshop…

• Remain engaged
  • Web-group for posting info
  • Newsletter of updates
  • Webinars
  • Vetting Objectives Hierarchy & Means-Ends Network
  • Follow-up workshop