Australian Institute of Marine Science

Monitoring Coral Reef Marine Protected Areas

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Version 1

A practical guide on how monitoring can support effective management of MPAs

IUCN
The World Conservation Union

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

GCRMN
Global Coral Reef Monitoring Network

The research reported herein is based on early analyses of complex data sets and should not be considered definitive in all cases. Institutions or individuals interested in all consequences or applications of this research are invited to contact the authors.

Acknowledgements: Special thanks go to all those people who contributed case studies and other material. Support for this book came from the US Department of State, the National Oceanographic and Atmospheric Administration and AIMS. Additional funds were provided by the IUCN Marine Programme, the ICRAN project, Ministry of the Environment, Japan, and the Great Barrier Reef Research Foundation. UNEP, IOC-UNESCO, IUCN, the World Bank, the Convention on Biological Diversity; AIMS, WorldFish Center and the ICRI Secretariat support the GCRMN as the Management Group. Anne Caillaud, Jos Hill, Will Oxley and Madeleine Nowak assisted with proof reading. Finally, we owe a special vote of thanks to the Science Communication team at AIMS - Steve Clarke and Wendy Ellery; they turned chaos into this valuable product – thank you.

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ISBN 0 642 32228 7

Cover Photographs from right to left, top to bottom from the front: Pulau Redang fishing village, Malaysia (Chou Loke Ming); flourishing table *Acropora* corals on Great Barrier Reef (Lyndon Devantier); *Eleutherobia aurea*, endemic soft coral, St Lucia MPA, South Africa (Michael Schleyer); coral reef shells for sale, Tanzania (David Obura); flourishing branching *Acropora* corals on GBR (Lyndon Devantier); children in dugout canoe, Toliana Madagascar (Pierre Vasseur); shipwreck on Rose Atoll, American Samoa (James Maragos); scientists monitoring the GBR (AIMS); Carrie Bow Cay research station, Belize (Clive Wilkinson); beach on Ant Atoll, Federated States of Micronesia (Clive Wilkinson); repairing fine mesh fishing nets, Kenya (David Obura); women and children gleaning on coral reef flats in Toliana, Madagascar (Pierre Vasseur); monitoring deep reefs in the Bahamas (Clive Wilkinson); plague of crown-of-thorns starfish on the GBR (Peter Moran); spearfishing on coral reef flats East Africa (Bernard Salvat); Buginese (sea gypsy) fishing boat in Indonesia (Sue English).

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Summary

Marine Protected Areas (MPAs) are an important tool for marine conservation and management; monitoring plays a critical role in managing these MPAs. Monitoring provides the essential information required to make management decisions and determine if the decisions are working. Without monitoring, managers are essentially operating in the dark! This book was written in response to requests from many managers of MPAs from around the world who asked for advice on how to design and implement monitoring programs that can help them manage their MPAs more effectively.

The goals of this book are to:

- Demonstrate how monitoring can play a major role in the effective management of MPAs;
- Provide advice on which monitoring programs to use to facilitate effective management; and
- Demonstrate how monitoring has played an important role in the effective management of MPAs using case studies from around the world.

Coral reefs around the world are at risk from many threats including global warming causing coral bleaching, over-fishing or destructive fishing, pollution by sediments, nutrients and toxic chemicals, coral mining and shoreline development, and unregulated tourism. Monitoring the ecology of the reefs and the socio-economics of the people is the only way to understand the extent, nature and causes of the damage, and to identify ways to address these threats.

How can monitoring assist in the effective management of MPAs? Monitoring assists through the following tasks:

1. Resource Assessment and Mapping
2. Resource Status and Long-Term Trends
3. Status and Long-Term Trends of User Groups
4. Impacts of Large-Scale Disturbances
5. Impacts of Human Activities
6. Performance Evaluation and Adaptive Management
7. Education and Awareness Raising
8. Building Resilience into MPAs
9. Contributing to Regional and Global Networks

This book will provide practical advice on how to design and implement ecological and socio-economic monitoring programs aimed at addressing these issues. Many useful references are included at the back along with Internet sites.

We have used case studies from around the world to illustrate how others have used monitoring to assist them in managing MPAs. There are many useful lessons from these case studies and all contain recommendations for other MPA managers.

The book provides information on many of the organisations involved in coral reef monitoring and management, along with the recommendations on coral reef monitoring and information processing from the recent ITMEMS2 (International Tropical Marine Ecosystems Management Symposium, 2003) meeting, which featured MPA managers from all over the world.

This is Version 1 of the book being released at the World Parks Congress in Durban South Africa, September 2003. Our intention is to keep it alive and continually update it. This copy will be lodged on the www.reefbase.org, www.gcrmn.org and www.aims.gov.au websites where we want to continually update it for use by MPA managers to improve their management and conservation of coral reefs.

Purpose of this Book (Version 1)

Without monitoring, MPA managers are essentially operating in the dark!

This book aims to help managers of coral reef MPAs understand the need for effective monitoring, determine how it can help them manage their MPA more effectively, and select the most appropriate methods to get good results. This book was written in response to requests from many managers of MPAs from around the world who asked for advice on how to implement a monitoring program. This book will help guide you through the literature and many manuals on monitoring. It is our goal to keep this document alive and continually update it with input from the users (the MPA managers) and new case studies. This is Version 1 - we will update it with your input, your case studies, and your suggestions. Please write to us at c.wilkinson@aims.gov.au and agreen@tnc.org

Coral reef managers around the world have similar problems and questions that monitoring can answer. Managers need to know if:

- Coral reefs are healthy and improving;
- Management actions have been successful;
- Fish populations are increasing:
- Economies of local communities are maintained or improved;
- Communities understand the need for management and want to assist;
- Tourism is a positive or negative benefit for the MPA, etc., etc.

These questions and many others can be answered with an effective monitoring program.

This book contains basic information on how to develop and implement monitoring programs to provide important information for the effective management of MPAs. We use case studies from around the world to demonstrate how others have used monitoring in the effective management of coral reefs, particularly MPAs.

Marine Protected Areas and Monitoring

Marine Protected Areas **(MPAs)** are an important strategy for the conservation of marine biodiversity and productivity, particularly for the maintenance of fish stocks. MPAs have been defined as "a*ny area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment*." (IUCN 1999).

An MPA is usually established to conserve resources by managing human activities; therefore there are many different types and names. Many MPAs contain zones with different activities allowed. These may preserve and enhance recreational, commercial, scientific, cultural, and conservation values. Within MPAs, some areas may exclude all fishing, collecting and mining; these are 'highly protected' or 'no-take zones'.

MPAs are only effective when there is an effective management plan that includes adequate ecological and socio-economic monitoring, as well as enforcement to ensure that the plan is enforced. Also MPAs only function well when the local user communities accept and support the need for management. Without planning, monitoring and enforcement, most MPAs will not achieve their objectives of conserving the resources and assisting the people.

This book specifically follows many of the recommendations from the Second International Tropical Marine Ecosystems Management Symposium (ITMEMS2), Manila, Philippines, March 2003. Recommendations for research and monitoring can be found in Appendix 1. All these recommendations are available from the ITMEMS2 website at www.icriforum.org/itmems.html.

What is Monitoring - Important Definitions

Monitoring is the gathering of data and information on coral reef ecosystems and its users on a regular basis, preferably for an extended period of time. Monitoring is essentially repeating the initial **coral reef surveys**, which gathered data and information on the coral reef ecosystem and its users on one occasion.

Ideally a MPA manager will perform a detailed baseline survey that includes many measures or parameters that may or may not change over time. These include:

- Mapping the extent and location of major habitats, particularly coral reefs;
- Measuring the size and structure of the human population using these resources;
- Understanding government rules and regulations on coral reefs and conservation;
- Determining the decision making process in local communities.
- Understanding the status of coral communities, fish populations and fishing practices.

The MPA manager has to select from these parameters the ones to put into a monitoring program. For this book, monitoring includes both the initial baseline survey and continued monitoring.

There are two main types of monitoring: **ecological monitoring** and **socio-economic monitoring**. Ecological and socio-economic parameters are often closely linked, therefore **ecological monitoring** and **socio-economic monitoring** should be done in the same place at the same time. For example, monitoring of fish populations should be directly linked to surveys of fish markets, fishermen and their catch. Similarly ecological parameters reflect the natural state of the MPA, which will have impacts on socio-economic factors such as income and employment.

Ecological monitoring: This includes both physical and biological (biophysical) monitoring and aims to assess the status and trends of the coral reef ecosystem.

Physical parameters measure the physical environment on and around the reefs. This provides a a physical description of the environment surrounding reefs to assist with production of things like maps as well, as measuring how the environment can change. Parameters include measuring: depth, bathymetry and reef profiles; currents; temperature; water quality; visibility; and salinity.

Biological parameters measure the status and trends in the organisms on coral reefs. Biological parameters focus on the major resources and these parameters can be used to assess the extent of damage to coral reefs from natural and human disturbances. The most frequently used ecological parameters include: percentage cover of corals, sponges, algae and non-living material; species composition and size structure of coral communities; presence of newly settled corals and juveniles; numbers, species composition, size (biomass) and structure of fish populations; juvenile fishes, especially target species; populations of organisms of special interest such as giant clams, crown-of-thorns starfish, sea urchins etc.; extent and nature of coral bleaching; extent and type of coral disease (refer to Method 3, p 50).

Socio-economic monitoring: This aims to understand how people use, understand and interact with coral reefs. It is not possible to separate human activities and ecosystem health, especially when coral reefs are important to many local community livelihoods. Socio-economic monitoring can measure the motivations of resource users as well as the social, cultural, and economic conditions in communities near coral reefs. Socio-economic data can help mangers determine what stakeholder and community attributes can provide the basis for successful management. The most frequently used socio-economic parameters include: community populations, employment levels and incomes; proportion of fishers, and where and how they fish; catch and price statistics for reef fisheries; decision making structures in communities; community perceptions of reef management; tourist perceptions of the value of MPAs and willingness to pay for management etc. More details on these methods are in Method 4 on p 52.

How Monitoring Can Help

Monitoring can assist with the effective management of MPAs through the following tasks:

1. **Resource Assessment and Mapping –** what and where are the resources in the MPA that should be managed; **p 4**
2. **Resource Status and Long-Term Trends –** what is the status of these resources and how are they changing over time; **p 4**
3. **Status and Long-Term Trends of User Groups –** who are the major users and stakeholders in the MPA, what are their use patterns and attitudes towards management, and how they are changing; **p 5**
4. **Impacts of Large-Scale Disturbances** - how do impacts like coral bleaching, crown-of-thorns starfish outbreaks and tropical storms affect coral reefs in an MPA; **p 6**
5. **Impacts of Human Activities –** how do the activities of people affect the MPA and its resources. This includes fishing, land use practices, coastal developments, and tourism; **p 7**
6. **Performance Evaluation and Adaptive Management** - how monitoring can be used to measure success of MPA goals and assist in adaptive management; **p 9**
7. **Education and Awareness Raising –** how to provide support for MPA management through raising awareness and education of user communities, government, other stakeholders and MPA staff; **p 10**
8. **Building Resilience into MPAs** - how to design MPAs so they are more resilient to large-scale disturbances such as coral bleaching due to global climate change; **p 11**
9. **Contributing to Regional and Global Networks –** how to link up with and learn from other MPA managers around the world and assist others manage their coral reefs; **p 12**

How Monitoring Can Help - in More Detail

Here we provide a more detailed description of how monitoring can assist with these tasks, and the methods to use.

1. Resource Assessment and Mapping

How does it help? Monitoring can provide valuable information on the location and extent of major ecosystems within the MPA and adjacent areas. For example, it is important to know how much coral reef and other related habitats (e.g. mangroves, seagrasses) are protected within the MPA. Most of this information can be obtained during a baseline study when the MPA is established.

Typical Questions

- How much coral reef (and other key habitats) is protected in the MPA?
- Where are these resources located?
- Are there major catchments feeding into the MPA and what are the likely sources of pollution?
- What are the major currents that could carry pollution or larvae?

Methods

One of the first steps in managing an MPA is to assess the size and location of major habitats types within the protected area. Therefore it is be important to map the area of coral reefs and related habitat types (e.g. seagrass beds, mangroves etc). Mapping can be done with a range of techniques. If considerable scientific and financial resources are available, you can map the reefs with satellite imagery and/or aerial photographs and GIS technology (to prepare spatially referenced images showing the location and size of major habitat types). This process involves obtaining the images of the area, interpreting them to identify where major habitats appear to occur, and ground-truth these predictions using local knowledge and spot checks. The major habitat types can then be located on the images using GIS technology. If there is not enough funding for this or the expertise is not available, habitat maps can be made using maps of the area, local knowledge and spot checks to confirm the location of major habitat types.

2. Resource Status and Long-term Trends

How does it help? Monitoring is also important for managers to understand the natural variability and long-term trends in the ecosystems they are protecting. The first step is to conduct an initial baseline survey of the coral reef resources, which will include surveying key components of the coral reef community such as corals and fishes. Monitoring long-term trends in coral reef status will require repeating these surveys on a regular basis (every 1 to 3 years). This information will assist managers in understanding the status of their resources, and interpreting the impact of large-scale disturbances and/or human impacts on the reefs when they occur (see 5. Understanding Impacts of Human Activities). Trend information is also essential to determine whether management changes are actually working (see 6 Performance Evaluation and Adaptive Management), and where reefs are recovering from these disturbances.

Typical Questions

- What are the patterns of natural variability and long-term trends in the resource?
- What is the status of the coral reef communities, and is their condition improving or declining?
- Are indicators of coral reef health (e.g. cover of corals and algae) increasing or decreasing?
- Are the fish populations stable or increasing, especially breeding populations of the larger target species?

Methods

Coral reef status can be assessed by surveying the condition of major components of the ecosystem such as coral communities (cover, species richness, and colony size) and fish communities (species richness, abundance and size structure). Where possible, surveys should be designed to assess multiple examples (3-5 replicates) of the full range of coral reef types in the MPA (e.g. barrier reefs, fringing reefs, atolls etc).

Patterns of natural variability and long-term trends can be assessed by repeating the monitoring on a regular basis (every 1 to 3 years depending on available people and money). There are several standard monitoring protocols available to monitor the status and long-term trends of coral reef communities. The protocol to be used should depend on the objectives and available resources (costs and expertise). Options include:

- **Community monitoring** programs by local communities, industries and volunteers. The most commonly used program is Reef Check, which provides for the rapid and cheap collection of data by people without extensive training or experience. Reef Check provides a low level of detail, but useful information on reef status and the causes of reef degradation. Reef Check is recommended for people with the lowest level of expertise and funding, and is particularly useful for monitoring programs aimed at community education and awareness-raising. Further information is on www.reefcheck.org

- **Management monitoring** programs are mostly conducted by tertiary trained people in Government environment or fisheries departments, and universities. Since these programs are used to help make management decisions, they require more detailed information than community monitoring programs. The Global Coral Reef Monitoring Network (GCRMN) was specifically developed to assist MPA managers gather useful data and requires a low to moderate level of funding and expertise. Further information is on www.gcrmn.org
- **Scientific monitoring** is usually conducted by scientists to provide detailed information at the highest level of resolution. These programs tend to be the most expensive and require high levels of scientific expertise. The Australian Institute of Marine Science Long-term Monitoring Program provides a good example of a scientific monitoring program on the Great Barrier Reef (information is available on www.aims.gov.au/). A similar program is operated for the Florida Keys National Marine Sanctuary (www.floridakeys.noaa.gov/research_monitoring). Scientific monitoring programs are only recommended where managers have a high degree of technical expertise and financial resources.

Case Studies

- Monitoring tracks the status of coral reefs for improved management of the Great Barrier Reef (GBR) - Case Study 9 AIMS Monitoring, Australia p 30
- Broad-scale monitoring to assess coral reef degradation and allow Colombia to develop national reef management planning - Case Study 16, Colombia Monitoring Program p 44
- Community monitoring by coastal fishers to reverse the damage to their reefs - Case Study 6, Gilutongan, Philippines p 24
- Monitoring assessed effects of massive coral bleaching to develop integrated management plan to promote recovery - Case Study 2, Seychelles p 16

summary

3. Status and Long-term Trends of User Groups

How does it help? Socio-economic assessments provide information about the people who use coral reef MPAs and other relevant stakeholders. The methods can monitor the status and long-term trends of social, economic, cultural and political parameters associated with coral reefs. This can provide valuable information on the resources and how they are being used. Socio-economic monitoring also ranges over the same levels with the same range of skills as ecological monitoring **(community, management and research)**.

Monitoring provides information on who the users are, their patterns of use, and the social and economic benefits they get from the MPA. Effective monitoring can determine whether the major reef users are from a local community or travel into the area from outside, which has implications for management. Monitoring can also tell the manager what the community understands about the resources and whether they consider that there is a need for effective management.

One important group of reef users to monitor is tourists and tourist operators, since this industry can provide positive benefits for MPAs if managed properly. Monitoring of tourism operators and tourists also provides useful information for MPA management to demonstrate the costs and benefits of tourism and recreation activities. Monitoring can identify how much money is spent on tourism, how satisfied the tourists are with their experience, what they liked and disliked, and whether they or their friends will return for another visit. This information is important to the management of tourism in the long-term. Some key tourism monitoring parameters are: visitor numbers and origin; visitor use patterns (time and location of visit); perceptions of reef experiences (overall satisfaction levels, happiness with the tourism operation- were they environmental stewards?); perceptions of the MPA as a whole (reef health, presence of management staff); and willingness to contribute funds to MPA management for a healthy environment.

Typical Questions

- How much do local communities depend on the reefs and support management actions?
- How do people use the reefs, and where do they go?
- How many people fish and glean from the coral reefs in the area?
- How much time is spent fishing, and how much does it contribute to the local economy?;
- How important is tourism to the local economy?

Methods

Until recently, the only coral reef socio-economic monitoring programs were long-term studies that involved social scientists and economists spending months in coral reef user communities to get a detailed picture of all aspects of community life and associated coral reef relations. It is now necessary to develop rapid socio-economic monitoring to parallel ecological monitoring, which can assess a coral reef in much shorter period of time (e.g. a few days). To address these new monitoring needs, the GCRMN published the 'Socioeconomic Manual for Coral Reef Management' in 2000; and the GCRMN, Reef Check, NOAA (USA), WorldFish Center and other partners developed rapid socio-economic assessment protocols based on work carried out in Southeast Asia (SocMon SEA). The manual (Bunce et al., 2000) and protocols (Bunce et al. 2002.) are available on at www.ipo.nos.noaa.gov/coralgrantsdocs/SocMonSEAsia.doc). See the Method 4 on p 52.

Case Studies

- Long-term monitoring has demonstrated success of the MPA to raise awareness in Apo Island communities - Case Study 5, Apo Island, Philippines p 22
- Socio-economic monitoring has measured local community awareness and concerns to develop better conservation strategies - Case Study 8, Kimbe Bay, Papua New Guinea p 28
- Tourist questionnaires on interests and complaints determined their understanding of coral bleaching to develop alternative attractions - Case Study 3, Indian Ocean Countries p 18
- Monitoring of fishers showed dissatisfaction with Florida Keys management plans and economic changes - Case Study 17 Florida Keys p 46

4. Understanding the Impacts of Large-scale Disturbances

How does it help? Ecological monitoring can assist MPA managers in understanding the impacts of large-scale disturbances on reefs including:

- **Tropical storms,** especially tropical cyclones, hurricanes and typhoons, can cause severe damage to coral reefs. Corals can be smashed and reduced to piles of rubble by large waves (see Case Study 9, p 30), and freshwater from heavy rainfall can kill corals by bathing them in freshwater or delivering land based pollutants to the reefs;
- **Geological activities** can also cause severe damage to reefs, particularly from earthquakes and volcanoes. Damage caused includes physical damage to corals from earthquakes, and covering the reefs in sediment dislodged during earthquakes or from erupting volcanoes.
- **Coral bleaching** is a stress response in corals, which results in a loss of symbiotic algae that can lead to coral death. When this happens over a wide area, it is usually due to the combined effects of high water temperature and light intensity. It is widely recognised that coral bleaching events are increasing in frequency and severity due to global warming (an increase of greenhouse gases in the atmosphere that is warming the atmosphere and oceans). Coral bleaching now represents one of the greatest threats to coral reefs in the medium to long-term (next 50 years). Other predicted impacts of global warming on reefs include increased incidence and severity of storms, and increases in increases in concentrations of CO_2 in seawater, which will result in decreased rates of coral calcification and make colonies more fragile (see Case Studies 2, p 16; 7 p 26; and 10, p 32).
- **Coral and other diseases** appear to be natural phenomena, but their frequency and severity seem to be increasing. Diseases have caused major losses of key coral species in the Caribbean and there have been increasing reports of disease in the Indo-Pacific.
- **Predators** like the crown-of-thorns starfish (*Acanthaster planci*) and the coral eating snail (*Drupella*) are natural coral predators, which are prone to population outbreaks. These outbreaks have caused massive damage to coral reefs of the Indo-Pacific region in recent years. There is a strong suspicion that the major increases in coral predators and diseases may be due to human disturbances to coral reef ecosystems, as the current level of damage appears to be unprecedented. (see Case Studie 9, p 30 and Case Study 7, p 26).

Most reefs should recover naturally after these disturbances, although it may take 10 to 30 years for reasonable recovery. Monitoring can provide an assessment of the extent and severity of the damage, and the rate and degree of coral reef recovery. It can also help identify if reefs do not appear to be recovering from these impacts, and the likely causes (for targeted management action where appropriate).

Typical Questions

- What is the extent and severity of the impacts of a large-scale disturbance?
- Are the reefs recovering from these impacts, or are there other factors impeding recovery?
- Are there healthy populations of corals nearby to provide new recruits to repair reefs damaged by coral bleaching?

Methods

The impacts of large-scale disturbances can be assessed by comparing the status of the resource (see 2. Resource Status and Long-term Trends) before and after the disturbance. Provided there were no other major impacts during that time, it is reasonable to assume that changes in the coral reef communities were a result of these disturbances. **Broad Scale Surveys** (see Method 3 p 50) are particularly useful for rapidly assessing the extent and severity of the damage over large areas, such as damage from cyclonic storms, earthquakes, coral bleaching, and crown-of-thorns starfish (including counting their numbers). While **Benthic Surveys** are more appropriate for detailed assessments at smaller scales.

However, some modifications to these techniques are required for some specific disturbances:

- **Coral Bleaching:** Some modifications have been required to standard monitoring protocols to monitor the extent, severity and recovery from coral bleaching. Standard monitoring methods can detect the eventual impacts of coral bleaching (if the corals live or die), but they are insufficient to assess coral status during bleaching and recovery. ReefBase, World Wildlife Fund, and the Great Barrier Reef Marine Park Authority are currently developing a protocol for monitoring and reporting bleaching events. This protocol will be used in conjunction with GCRMN methods, and will provide a range of useful tools for varying situations depending on the time and resources available. These methods will be used to monitor the extent and severity of coral bleaching during bleaching events (usually 1 to 3 months after the start of bleaching), and to monitor recovery (6 to 8 months after the event to determine coral survival rates). This new protocol will be available in late 2003 on ReefBase at www.reefbase.org. The AGRRA methods (see Appendix 3, p 62) have also been developed to assess bleaching impacts. However, these methods require specific training and a high level of expertise (www.coral.noaa.gov/agra/).
- **Coral and other diseases** are another special case, which require specialised monitoring methods. The AGGRA methods specifically include disease assessment and identification, however identifying diseases requires specialised knowledge and expertise: www.coral.noaa.gov/coral_disease/cdhc.shtml
- Monitoring populations of **predators** like the crown-of-thorns starfish (*Acanthaster planci*) and the coral-eating snail (*Drupella*) require different monitoring methods. Broad scale surveys are a good method to use to monitor crown-of-thorns starfish outbreaks and their impacts on coral communities (see above). In contrast, *Drupella* and their impacts are best surveyed by slowly searching belt transects or quadrats (see Case Study 9, p 30).

Case Studies

- Socio-economic monitoring has helped managers determine alternative tourism attractions following a large bleaching event - Case Study 3, Indian Ocean Countries p 18
- Monitoring of the 1998 and 2002 mass coral bleaching events in the Great Barrier Reef was used by management to involve the public - Case Study 10, Great Barrier Reef Bleaching p 32)
- Monitoring provided advice to management on COTS outbreaks and bleaching and this has stimulated public involvement and management support - Case Study 7, Sekisei Lagoon, Japan p 26
- Monitoring helped develop the Integrated Marine Protected Area System Plan after massive coral bleaching event - Case Study 2, Seychelles p 16;
- Potential stresses from rising ocean temperatures have been monitored to develop plan for tourist diving capacity and consider reef rehabilitation - Case Study 1, St. Lucia, South Africa p 14;
- Long-term monitoring has tracked COTS outbreaks and tropical storm damage and recovery on the Great Barrier Reef - Case Study 9, AIMS Monitoring, Australia p 30.

5. Understanding Impacts of Human Activities (fishing, water quality, coastal development, tourism)

How does it help? There are many human activities that can have damaging impacts on coral reefs, and monitoring can help understand and manage these impacts. The major disturbances include:

- **Fishing** can result in major impacts on reefs from over-fishing and the use of destructive fishing methods. Many key fisheries species (fish and invertebrates) are important components of coral reef ecosystems, and their removal can cause serious problems for reefs. In particular, removal of grazing species that feed on algae (e.g. parrotfish, rabbitfish and surgeonfish) can lead to ecosystem level changes where coral communities are replaced by algae. Destructive fishing practices are of particular concern, because they not only remove the fisheries species, but also cause substantial damage to coral reef habitats. Damage is caused by the use of anchors, nets, traps, explosives and poisons (e.g. cyanide, bleach and derris roots). Over-fishing and the use of destructive fishing practices are two of the most serious threats to reefs worldwide. Monitoring can play an important role in understanding the status of the fisheries, and their impacts on coral reef communities;
- **Water quality** problems are usually caused by land-based activities that result in increased loads of sediments, nutrients and other pollutants flowing into the oceans. These can cause major damage to coral reefs around the world. The major sources of increased loads of sediment are from poor land use, particularly deforestation, agriculture and urban development. Sediments reduce water clarity and block light for coral and algal photosynthesis. Corals can either be buried in sediments or become stressed because of the extra energy required to clear the sediments. Sediments can also carry large concentrations of nutrients and other pollutants. Major sources of nutrients include untreated or partially treated sewage, industry waste, agriculture runoff (e.g. herbicides), and aquaculture effluent. Increased nutrients cause serious problems for reefs, because nitrogen and phosphorous stimulate algal growth, sometimes at the expense of corals. Nutrients also encourage the growth of algae in the plankton, which reduces available light

for coral communities. Other pollutants from agriculture and industry, including pesticides, herbicides, and heavy metals, can kill corals and other organisms. Monitoring can play an important role in understanding these threats and their impacts on coral reef communities.

- **Coastal development** has caused serious damage to many reefs, and totally destroyed others by dredging and filling operations. Reefs are often dredged or corals are harvested for limestone to make roads, cement or for use in chewing beetlenut, while filling is usually for gaining land for industry and urban developments. Reefs are also damaged by changes to currents caused by building sea walls and groynes, and by the release of sediments and other pollutants associated with construction. Monitoring can play an important role in monitoring and minimising impacts of coastal development on coral reef communities (see Case Study 11, p 34)
- **Tourism** if carefully managed, can cause minimal threats to coral reefs and provide a good source of livelihood for local communities as an alternative to fishing and other more destructive activities. However, uncontrolled tourism can cause major threats to reefs from anchor damage, the building of structures (on land and in the water), and as a source of pollutants (such as sewage and fuel spills). Monitoring can play an important role in demonstrating the costs and benefits of tourism activities on reefs.

Typical Questions

- Is fishing having a significant impact on key fisheries species?
- Are destructive fishing practices causing serious damage to reefs?
- Are land use practices a threat to coral reef health?
- Is coastal development affecting adjacent coral reef health?
- Are tourism activities affecting coral reef health?

Methods

These different types of human activities can have very different impacts on coral reefs, therefore, different monitoring protocols are required for each type of activity.

- **Fisheries monitoring methods** can involve monitoring both the fisheries and their impacts on populations of target and non-target species. **Fisheries monitoring** usually focuses on monitoring catch, effort, catch per unit effort, and biological characteristics of the key fisheries species. This information can be used to monitor trends in the fishery, and expected yield under different types of fishing pressure. Visual census methods can be used to monitor **fishing impacts on target species,** however the methods used should depend on the target species. For example, smaller fish like surgeonfishes, small parrotfish, small groupers and key invertebrates like holothurians can be monitored using 50 x 5m transects. However, different methods are required to monitor large species that are uncommon and particularly vulnerable to over-fishing (e.g. sharks, large wrasses, parrotfishes and groupers: see Method 5, p 54). Specialised methods are also required to monitor large reef fishes when they aggregate to spawn. The Nature Conservancy is developing a practitioners manual for monitoring grouper spawning aggregations in the Indo Pacific. The **impact of fishing** (particularly destructive fishing practices) on **non-target species** can be monitored using standard monitoring protocols (see 2. Resource Status and Long-term Trends) to monitor impacts on benthic communities (particularly coral and algal cover) and other fish species (e.g. small prey species). These protocols can be easily modified to record damage caused by destructive fishing practices (bomb blasts). Further information on monitoring the effects and yields of coral reef fisheries in MPAs is available in Russ (1991) and Samoilys (1997).
- **Water quality** assessment is included in some standard monitoring protocols recommended by the GCRMN and CARICOMP that characterise the conditions at the site where ecological data are collected. They include monitoring temperature, salinity, turbidity and light penetration. These parameters are important to reef health, and do not require expensive, sophisticated equipment and expertise. For example, traps to measure the amount of sediment in the water are cheap and easy to construct. In contrast, monitoring the impacts of pollution on coral reefs require dedicated monitoring programs with specialist techniques (see Method 6, p 56). This may include monitoring the source of the pollutant, how much of the pollutant reaches the reef, and the impacts on the reefs themselves. Scientific advice and expertise is usually required to design and implement these programs because they are more technical.
- **Coastal development** monitoring methods depend on the type of threat. For example, monitoring the impacts of dredging and filling operations may involve monitoring the areas before development to demonstrate the habitat that may be damaged as a result of these operations. This may involve mapping (see 1. Resource Assessment and Mapping) and describing the coral reef resources that could be destroyed near the development site (see 2. Resource Status and Long-term Trends). Reactive monitoring programs can also be used to minimise impacts on areas adjacent to the development. For example, monitoring programs can be developed to monitor the release of sediments and other pollutants into the water and their impact on adjacent coral reef communities (using a combination of methods described for monitoring Water Quality and Resource Status

and Long-term Trends of coral reef communities described above). If monitoring is continuous during development, the results can form the basis of a reactive monitoring program to minimise the impacts of the development on adjacent reefs. This requires having predetermined levels of pollutants and/or impacts on the reefs, which trigger specific management actions when they are reached (e.g. stop dredging when sediment levels reach a threshold level or corals start to show signs of stress). This sort of program requires intensive monitoring and is expensive, but it can be very useful for minimising impacts of coastal construction on coral reefs.

- **Tourism** monitoring will depend on the different types of tourism impacts. Damage to corals by anchor damage or divers can be monitoring using standard protocols described for monitoring Resource Status and Long-term Trends (see above), while noting the proportion of corals that show evidence of anchor damage (e.g. broken or overturned coral colonies). The impact of land-based infrastructure can be monitored using methods described for coastal development above, while the impact of pollutants (sewage and fuel spills) can be monitored using water quality monitoring methods (see above). There are also special socio-economic monitoring procedures to assess the impacts that tourists have on economies and local cultures (see 3. Status and Long-term Trends of User Groups p 5).

Case Studies

- Fisheries monitoring demonstrated the value of the marine reserve to the people of Apo Island and stimulated local community ventures into tourism Case Study 5, Apo Island, Philippines p 22;
- Long-term monitoring of the fishery and fish populations was used to ban a destructive scuba fishery - Case Study 13, Scuba fishing American Samoa p 38;
- Monitoring has assisted MPA managers control of blast fishing and with management of legal resource uses (fishery, tourism) - Case Study 4, Komodo National Park, Indonesia p 20;
- Water quality monitoring stimulated management to control pollution and demonstrated that the protected the coral reefs improved - Case Study 12, Pago Pago Harbor, American Samoa p 36;
- Reactive environmental monitoring closely followed marine construction activities to prevent damage to fringing coral reefs - Case Study 11, Nelly Bay Harbour, Australia p 34;
- Long-term monitoring supported MPA management to control coastal resource and tourism development and involve communities in monitoring - Case Study 15, Bonaire, Netherlands Antilles p 42;
- Community monitoring was the catalyst to stop damaging fishing and build a thriving tourism industry run by the coastal fishers - Case Study 6, Gilutongan, Central Philippines p 24;
- Monitoring followed damage to an atoll from a shipwreck and suggested more clean-up (see Case Study 14, Rose Atoll Wreck, p 40.)

6. Performance Evaluation and Adaptive Management

How does it help? Monitoring is important to determine if management activities have been successful in achieving their stated goals. For example, if the goal of an MPA is to protect corals and increase fish stocks on depleted coral reefs, then monitoring the status of the coral and fish communities will determine if the management actions have been successful. Similarly, socio-economic monitoring of local communities can inform managers whether their goals of maintaining and improving living standards for local communities have been successful. This information is essential to inform stakeholders of the success (or otherwise) of the management actions, and to modify management practices (adaptive management) where they have not been successful in achieving their goals. The aim of adaptive management is to modify management practices to be more successful, based on lessons learned from previous management actions. Where management actions have achieved their stated objectives, adaptive management may not be required, but if not, then there may need to be changes to the management plans or enforcement programs or education to increase compliance. Further monitoring will be required to determine if the adaptive management has been successful. A comprehensive guidebook on evaluating effectiveness of Marine Protected Areas using biophysical, socio-economic and governance indicators is available online at www.effectiveMPA.noaa.gov

Typical Questions

- Has the management activity been successful in achieving its stated goals?
- Has the MPA been successful in maintaining coral reef biodiversity and populations of key fisheries species?
- Has the MPA been successful in maximising benefits and minimising costs to local communities?
- Are local communities supporting and assisting MPA management?

Methods

The first step in measuring management effectiveness is to clearly identify the management objectives and then develop measures to identify success in achieving the stated goals. Measuring success will require monitoring similar sites both inside and outside the MPA, and (if possible) monitoring before and after the management action. For example, if the main objective of the MPA is to maintain biodiversity, then measures of success should include monitoring the diversity (or species richness) of key components of the ecosystem (e.g. corals and fishes). Standard coral reef monitoring protocols (see 2. Resource Status and Long-term Trends) can be used for this purpose. Similarly, if the objective of the MPA is to maintain populations of key fisheries species, then fisheries monitoring methods (which measure size and structure of reef fish populations) will be required to measure success (see Methods 3 and 5, p 50 and p 54). If the objectives are to minimise the impacts of the MPA on local communities, then socio-economic monitoring will be required (see 3. Status and Long-term Trends of User Groups p 5)

Case Studies

- Monitoring was used assist MPA managers with the control of blast fishing and with management of legal resource uses (fishery, tourism) - Case Study 4, Komodo National Park, Indonesia p 20;
- Performance monitoring helped control a major water quality problem and catalyse management action for secondary problems - Case Study 12, Pago Pago Harbor, American Samoa p 36;
- Long-term monitoring of fish populations was used to adjust management actions to ban a destructive scuba fishery - Case Study 13, Scuba fishing, American Samoa p 38;
- Monitoring has shown that fishers may be losing economically and do not want restrictions (see Case Study 17, Florida Keys, p 46.)

7. Education and Awareness Raising at All Levels

How does it help? Monitoring is a powerful tool to raise awareness of the problems facing coral reefs and the need for management among **local communities**, **local to national government officials**, **tourists** and **MPA staff**. To ensure that **MPA staff** understand the resources they are managing, it is important that all managers and staff (as well as the monitoring teams) participate in some monitoring, whenever possible. This does not mean that they have to join the monitoring teams, but they should go out at least once a year and assist with monitoring on the coral reefs and visit user communities during socio-economic monitoring. Therefore, we recommend that all coral reef management staff undertake basic training in monitoring e.g. Reef Check, which usually takes only 1 day. This ensures that managers understand monitoring methods and the data they produce, and keeps them in touch with user communities to hear their concerns.

Involving **community volunteers and tourists** in monitoring not only provides basic scientific data over a wider area, but also ensures that the wider community understands the need for coral reef management. It also creates a sense of awareness and stewardship for the resource amongst user groups. This is particularly true for repeat visitors who are usually more interested in learning about the reef as well as in participating in its management. Volunteer monitoring programs are usually low cost, more frequent and cover a larger scale, and the data may complement scientific programs. It can also provide comparison data from other areas the volunteers and tourists have visited.

If the wider community, especially **decision makers from government** can be involved in monitoring, it can be an important awareness raising tool. Nothing alerts a senior official more than showing them first hand the condition of the reefs and involving them in discussions with user communities, other stakeholders and tourists.

When user **community groups** are provided with basic training in monitoring and encouraged to assess their resources regularly, they also improve their understanding and develop a greater sense of stewardship over the resources. This will improve their support for management actions to protect and conserve their reefs. Asking fishers to assess the status of corals and fishes on their reefs, and compare the conditions that existed several generations ago (where they fished, average catches, size of fish etc.) has proved a powerful management tool.

It is important that all monitoring results are shared with **all stakeholders** to demonstrate that management is a cooperative process. The results should be presented at the appropriate level for the audience using methods of communication used by communities. The actual monitoring data and analyses are more appropriate for scientific audiences, but open meetings may be more appropriate for community groups who may communicate more by talking than reading. It is also essential to involve the community leaders, as they are the ones that most people listen to (e.g. chiefs, religious leaders), and who may be the best people to carry the results of monitoring and explain the value of management actions to the broader community.

Typical Questions

- What condition are our reefs in?
- What is the status of our key fisheries resources?
- Have our reefs improved or declined in recent times, and why?
- What are the threats to our coral reefs and livelihood?
- Does the community understand why management has introduced restrictions in the MPA?

Methods

The best methods to use for education and awareness raising at all levels are probably community monitoring programs such as Reef Check. These require a low level of skills and expertise, and provide useful information on reef status and key issues. Reef Check does not require a lot of funding and expertise, and has been proved useful around the world. Other protocols for communities and volunteers include tourism monitoring programs, such as the 'Eye on the Reef' on the Great Barrier Reef (www.gbrmpa.gov.au), and the RECON (Reef Condition Monitoring Program) of the Ocean Conservancy (www.oceanconservancy.org/dynamic/getInvolved/events/coral/coral.htm). For additional information on volunteer-based monitor programs the CRC Reef website at www.reef.crc.org.au/publications/techreport/TechRep24.html, the REEF fish monitoring program www.reef.org, the Caribbean Natural Resource Institute www.canari.org/, and REEFWATCH www.reefwatch.asn.au.

Case Studies

- Monitoring of local community awareness is developing better conservation strategies - Case Study 8, Kimbe Bay, Papua New Guinea p 28
- Environmental monitoring of marine construction informed the developers, managers and public of attempts to conserve fringing coral reefs - Case Study 11, Nelly Bay Harbour, Australia p 34;
- Monitoring has persuaded tourism operators to strengthen environmental awareness in tourists to make the industry sustainable - Case Study 15, Bonaire, Netherlands Antilles p 42.

8. Building Resilience into MPAs

How does it help? Monitoring can be very important in designing and implementing MPAs to help coral reefs survive climate change. One of the biggest threats to coral reefs in the next few decades will be the increased frequency and severity of coral bleaching events as a result of global change (see Coral Bleaching under Large -scale Disturbances?). If coral reef MPAs are to be effective in the long-term, they will need to be as resilient as possible to the effects of climate change. This will require designing and implementing large-scale networks of marine protected areas by:

- Spreading the risks by protecting representative and replicated areas of major habitat types;
- Safeguarding key sources of larvae by protecting areas that are naturally more resistant and/or resilient to coral bleaching as well as fish spawning aggregation sites. In this context, resistant reefs are those that appear to be more naturally resistant to coral bleaching (possibly due to local environmental factors), while resilient reefs are those that bleach but recover quickly.
- Maintaining ecological connectivity among coral reefs due to ocean currents, larval dispersal, and movement of adults to allow animals and plants to continue to move from one area to replenish others; and
- Continuing to effectively manage other threats, such as water quality and over-fishing, to ensure that reefs are as healthy and naturally resilient as possible.

This initiative is the subject of a CD-ROM toolkit by The Nature Conservancy released at the World Parks Congress in Durban 2003 entitled 'R2 Reef Resilience – building resilience into coral reef conservation, a toolkit for MPA managers'.

Typical Questions

- What areas appear more naturally resistant or resilient to coral bleaching?
- Have these areas been successfully protected?
- Are there areas near the MPA with healthy corals that should be protected?

Methods

Monitoring can be used to identify coral reefs that appear to be more resilient or resistant to global change so that management emphasis can be directed to protect these areas. These methods, and measures of success, are described in detail in the R2 reef resilience toolkit.

Case Studies

- Monitoring of massive coral bleaching damage has found more resilient coral populations that warrant management to provide future larvae - Case Study 2, Bleaching Seychelles p 16;
- Monitoring and research on climate change and coral bleaching being used to plan for sustainable MPA system to support diving tourism industry Case Study 1, St. Lucia, South Africa p 14;
- Monitoring of mass coral bleaching events in the Great Barrier Reef are used to plan expansion of World Heritage Site protection - Case Study 10, Bleaching, Great Barrier Reef p 32;
- Monitoring provided advice to management on COTS outbreaks and bleaching and this has stimulated public involvement and management support - Case Study 7, Sekisei Lagoon, Japan p 26;

9. Contributing to Regional and Global Networks

How does it help? There are major international efforts underway to conserve the coral reefs of the world against a range of damaging threats (listed above). These efforts include providing funds and expertise aimed at improving monitoring for all types of coral reefs. The International Coral Reef Initiative (ICRI) started in 1994 and formed the Global Coral Reef Monitoring Network (GCRMN) to improve and implement coral reef monitoring in all parts of the coral reef world. One task of the GCRMN is to assist developing countries implement monitoring of reefs, especially in MPAs. In the mid 1990s, Reef Check was formed to facilitate volunteer and community monitoring. Another ICRI network is ICRAN (International Coral Reef Action Network) which is stimulating coral reef management, again with a focus on MPAs. They are focusing of key demonstration sites where there is already effective management and monitoring aimed at assisting nearby regions. There are also regional monitoring programs (CORDIO, AGRRA, CARICOMP), which have a particular interest in coral bleaching.

Data from all monitoring programs can be lodged in the global database, ReefBase, which contains data and considerable information from reefs all over the world. This information can be reported by the GCRMN in '*Status of Coral Reefs of the World*' reports every 2 years. The use of either Reef Check or GCRMN methodology provides an added advantage in obtaining assistance from these global coral reef monitoring programs, as well as better recognition as part of a global program. Thus it is possible for all MPA managers to link into global and regional networks and gain the benefit of the experience in monitoring methods, protocols, database analyses and reporting in these programs. In turn your data and experience can contribute to the global effort to conserve coral reefs.

Typical Questions

- Where can a MPA manager obtain advice and assistance in developing a monitoring program and in receiving training in recommended methods?
- Are the problems faced in my MPA similar to other MPAs elsewhere in the world?
- How can my efforts in monitoring and management assist in solving the problems of declining coral reefs in the world?
- Are there sources of funds to assist in implementing monitoring in MPAs or for the reporting of results?

Methods

A brief summary of, and the contacts for, each of these monitoring programs and networks is summarised in Appendix 3, along with some of the networks and agencies assisting in coral reef conservation. Many of the methods are available on the Internet and advice from the GCRMN, ReefBase and Reef Check can be obtained from the network of coordinating centres (Nodes) and the Internet contacts listed in the Appendices.

Case Studies

- Gilutongam case study illustrates how a global program such as Reef Check can assist develop a local monitoring program - Case Study 6, Gilutongan, Central Philippines p 24;
- Membership of regional and global monitoring networks have assisted Colombia set up broad-scale monitoring and management - Case Study 16, Colombia Monitoring Program p 44.

Good Examples: Case Studies from Around the World

Case studies are an effective way to bridge the gap between theory and practice. These following case studies were chosen to illustrate successes of coral reef monitoring programs is assisting and sometimes changing management of MPAs around the world. These studies report examples: from different geographical areas; as responses to different situations and impacts; of the use of different methods and strategies; and with differing budgets and levels of expertise. These illustrate that coral reef monitoring programs can and should play a role in all MPA management plans, regardless of their size, budget or specific biological or socio-economic concern.

Coral Reef Monitoring in the Greater St Lucia Wetland Park

Michael H. Schleyer and Louis Celliers

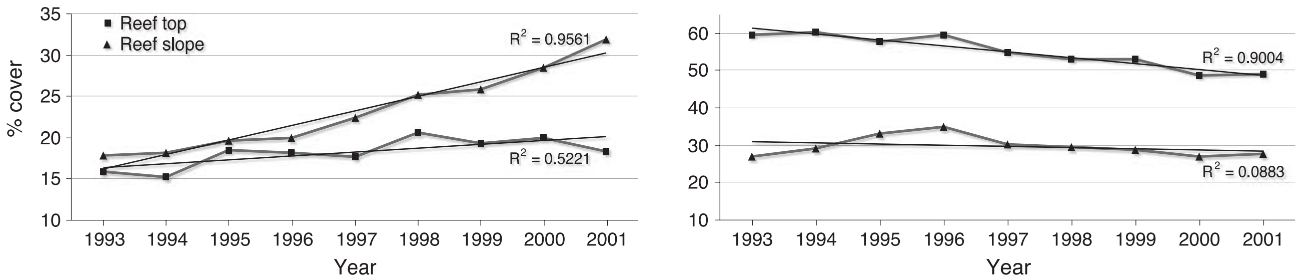
The challenge

South African coral reefs and communities are some of the southernmost in the world and near the limits for coral growth. There has been a steady rise in sea surface temperatures in the region and coral bleaching became evident in 2000. The reefs are also a major draw card for tourists, thus it was imperative that a coral reef monitoring programme be implemented to assess stresses from rising temperatures (caused by global climate change) and increases in tourist diving operations. Managers needed this information to develop management plans for the Greater St Lucia Wetland Park (GSLWP), a World Heritage Site, to protect its high biodiversity and ensure sustainable ecotourism.

The reefs are marginal coral communities growing as a thin veneer on a rocky base off KwaZulu-Natal. They are small but are important as a model for the study of corals at the latitudinal limits for coral growth. They are also starting to show many of the stresses that other systems experience. Soft coral cover, of relatively few species, exceeds that of the more diverse hard corals. There is a growing demand for access to the reefs for ecotourism, and monitoring was needed to assess their condition and sustainable diving limits, while recognising that they face pending threats from climate change.

What was done?

A long-term monitoring plan was established in 1993 comprising 80 fixed, 0.25m^2 quadrats that have been photographed annually and are being subjected to image analysis. Hourly temperatures have also been logged on the study reef since 1994 and monitoring has included measurements of any observed coral bleaching. Reef damage was assessed in 1994 and 1995 in additional 2m belt transects with a total length of 4.7km. This focused on the reefs that are more accessible to divers in order to establish the sustainable diving capacity of the reefs. A crown-of-thorns starfish (COTS) spot outbreak commenced on one reef in 1993 and, while initially monitored, became the subject of a PhD study in 1998. Finally, coral larval settlement on experimental plates was studied between 1999-2002 to determine larval dispersal and recruitment on the reefs and their capacity to recover from disturbance. This is being interpreted together with currents and swell height oceanographic data.



The left figure shows an increase in hard coral cover since 1994 on both the reef slope and top. The right figure shows a gradual decline in soft coral cover at the study site, which is roughly twice that of the hard corals.

How successful has it been?

The baseline monitoring program has revealed small, yet significant, changes in community structure on the reefs and water temperatures. A relatively large increase in mean temperature of 0.27˚C per year has been measured over the last decade, indicating local warming above the global increase caused by climate change. There was insignificant bleaching during the 1998 El Niño event, unlike further north in East Africa, but there was measurable coral bleaching during extended warming and high irradiation in 2000. The reefs now appear to be reaching a local temperature threshold for coral bleaching of ~29˚C. Published projections on the long-term effects of climate change indicate that these reefs will become more marginal as a result of global warming and the monitoring is being expanded to understand the future of more typical reefs. This will include more temperature monitoring, regular analysis of the conditions needed by corals to form skeletons (aragonite saturation state), and the measurement of subsurface irradiation. Our studies have shown that some corals are more resistant to bleaching than others. These are being evaluated for propagation in case reef rehabilitation is needed after a major loss of corals due to bleaching.

The spot outbreak of COTS has caused longer-term changes in isolated areas, causing a shift from a mixed community of hard and soft corals to one dominated by soft corals at much lower cover. This has management implications as the ecotourism value of the reefs will clearly be reduced by excessive COTS predation. An expert system was developed to model the reefs and assist managers to decide whether to regulate COTS in future outbreaks. The assessment of reef damage caused by ecotourism yielded recommendations that an annual precautionary limit of 7000 SCUBA dives per dive site be implemented to avoid reef damage. The analysis of the coral larval dispersal and recruitment data and associated oceanographic data has commenced and will provide information for managers on reef recovery in the event of future damage from COTS and coral bleaching.

Lessons learned and recommendations

- While the reef monitoring was initiated to study the effects of global warming, it now has wider applications in understanding local reef ecology and establishing the critical levels for management intervention in the event of reef stress;
- Monitoring has yielded information on coral resilience to bleaching and stress, permitting pilot studies on coral propagation for reef rehabilitation in the event of mass coral mortality;
- These studies show the value of long-term monitoring in determining what is happening to reefs now and what may happen in the future;
- The conservation authority has gained management-related information on reef damage by recreational users and COTS for inclusion in their planning; all research in the GSLWP is developed in consultation with the management authority.

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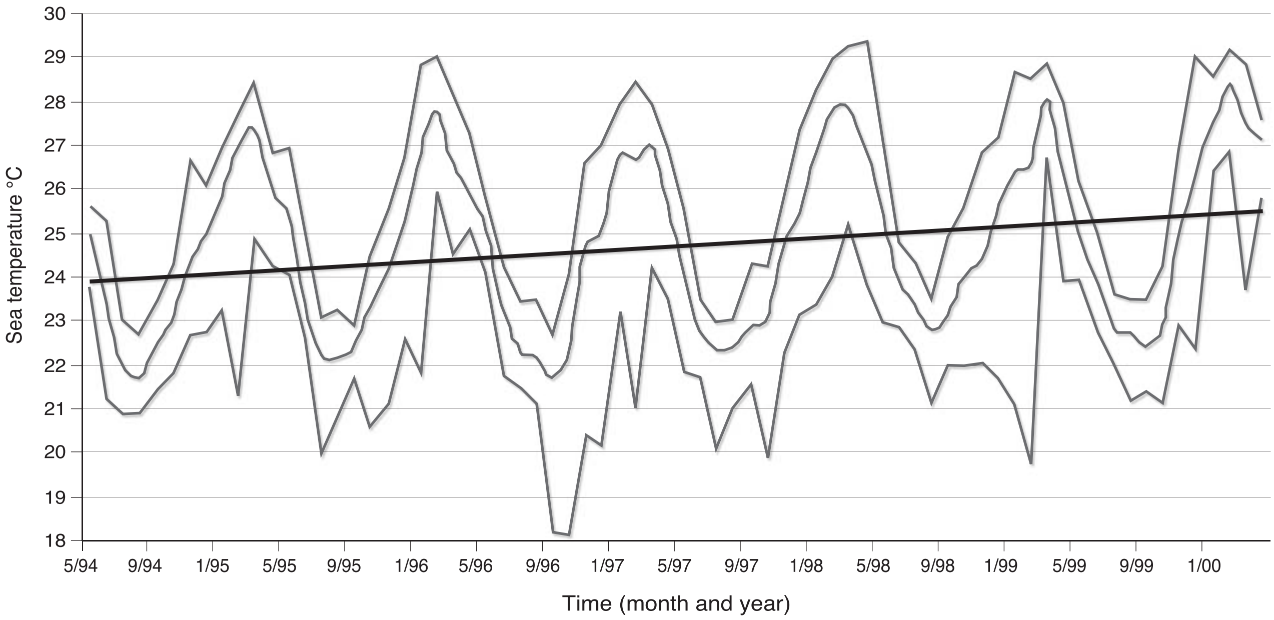


There is a clear trend of increasing seawater temperatures between 1994-2001 amounting to an increase of 2.7°C over a 10 year period. The figure shows the minimum, mean and maximum temperatures with a line indicating the trend.

Case study 1

Case Study 2

How Monitoring Helped Develop the Integrated Marine Protected Area System Plan after Massive Coral Bleaching in Seychelles

Udo Engelhardt, Bertrand Wendling, David Rowat, John Nevill and Jude Bijoux

The challenge

The 1998 mass coral bleaching event posed a major challenge for the coral reef managers in the Seychelles. About 80 to 95% of hard corals died on the coral reefs of the inner granitic islands when seawater temperatures exceeded 30ºC for several months. Management focus shifted immediately from maintaining a diverse and healthy reef ecosystem to facilitating and promoting its recovery. The need was also created to select sites for future coral reef conservation and recovery.

What was done?

The Seychelles Government, started a major GEF-funded (Global Environment Facility) monitoring program with a local NGO (Marine Conservation Society, Seychelles - MCSS), under the Seychelles Marine Ecosystem Management Project (SEYMEMP) and the Regional Coral Reef Monitoring Programme with the Seychelles National Coral Reef Network (SNCRN). The aims were to:

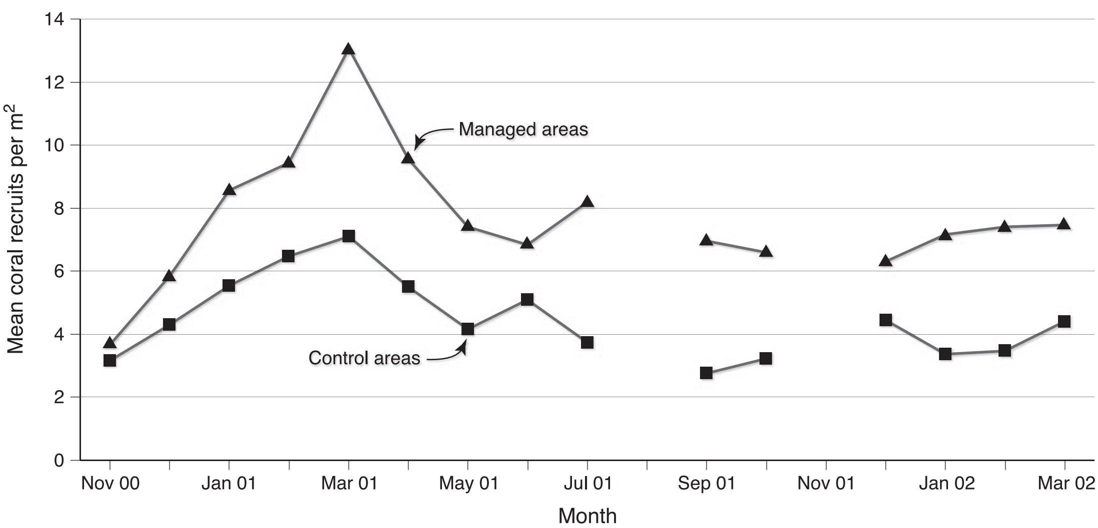
1. Quantitatively assess the damage to corals and associated fish communities;
2. Investigate which key environmental factors could interfere with coral reef recovery;
3. Identify trends in and develop tools to promote the recovery of degraded reefs;
4. Build capacity by developing of a Marine Unit within the Ministry of Environment and train staff from this unit, MCSS, Marine Parks Authority and SNCRN in specific and targeted reef monitoring techniques;
5. Assess the possible socio-economic impacts of the bleaching;
6. Sensitise the local population on best use practices for coral reefs.

The goals of these programs were to improve the recovery of coral reefs in general, guide the management of MPAs and develop strategies for coping with any future damaging impacts. These strategies are the basis of an **Integrated Marine Protected Area System Plan** for Seychelles.

How successful has it been?

Large-scale and high resolution scientific monitoring has proven invaluable, not only to determine the effects of coral bleaching, but also to follow emerging trends in reef recovery. The monitoring teams determined the following significant results:

High diversity reef sites: SEYMEMP transect monitoring identified recovering reef sites with a high diversity of coral species representing a significant proportion of the species known in this region. Some high diversity reefs are outside the boundaries of existing MPAs and the surveys will provide useful baseline data for their possible future inclusion into the MPA network. There are now reliable indications that coral



When populations of the black spined sea urchin were controlled by the MPA managers, there was a major increase in the numbers of juvenile recruits of Acropora and Pocillopora corals in the managed areas compared to the control areas where there was no reduction in the urchins.

diversity in the Seychelles is improving with consistent increases in the number of hard coral families and genera being found over the past 3 years.

Threats to viability of coral recruits: Benthic surveys and fish counts by SEYMEMP found large populations of invertebrate reef grazers (e.g. black-spined sea urchins *Diadema* spp. and *Echinometra* spp.), that were possibly due to reduced numbers of invertebrate-feeding predatory fishes. Hard coral recovery was reduced by the urchins' intensive grazing of newly recruited corals. Small-scale experimental management of sea urchin density by the Marine Unit increased levels of hard coral recruitment. Sea urchin populations were reduced to a specified density for 16 months, and after 12 months, branching coral recruitment doubled (*Acropora* and *Pocillopora* species) compared to areas where sea urchins were not controlled. Control of sea urchin populations is being recommended to accelerate recovery in MPAs and particularly in areas near resilient coral populations.

Identification of bleaching tolerant corals: Reef monitoring by SEYMEMP on the inner granitic islands has identified remnant mono-specific populations of hard corals that survived the 1998 mass-bleaching event. These resilient corals were mostly from very shallow reef habitats indicating that they were tolerant to high water temperatures and high levels of ultraviolet radiation. Their resilience makes them potentially useful for active reef restoration measures (e.g. possible coral transplantation) on degraded reef sites.

Corals growing in cold water up-welling areas: SEYMEMP monitoring has also identified some highly diverse hard coral populations growing in areas where there may be some localised cold-water up-welling. These remnant coral assemblages contain a diverse mix of coral species that generally did not survive elsewhere and will likely function as important seed sources for the replenishment of coral communities. These refugia thus merit special management measures.

Reduced damage to coral structures by installing moorings: One of these coral refugia, Anse Petit Cour, is within an MPA but is also a favourite anchorage for visiting yachts. The corals showed recent anchor-related damage, therefore a series of 8 environmental moorings were installed by MCSS. The Marine Parks Authority ensures correct use of moorings and their routine maintenance. Ongoing SEYMEMP monitoring has now shown that coral damage has been reduced significantly.

Lessons learned and recommendations

- Coral reef monitoring that addresses specific, locally important reef management issues can help MPA managers make decisions for the future e.g. ways to facilitate recovery;
- Long-term regular monitoring in MPAs and other critical sites is essential for scientific and adaptive management;
- Monitoring programs have to be designed, evaluated and refined to provide high resolution, reliable data to enable adaptive reef management;
- The ultimate goal for a small country is to develop and maintain sustainable, locally-driven monitoring and management capacity;
- Communities of high diversity or those resilient to environmental stress should be given specific protection to ensure the existence of healthy and diverse coral reefs;
- Involvement of stakeholders and local communities is essential for effective reef management.

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Case Study 3

Coral Bleaching in Indian Ocean States in 1998: Socio-economic Assessment of Reef Based Tourism

Herman Cesar

The challenge

Following the massive 1998 coral bleaching event in the Indian Ocean, MPA managers, the tourist industry and policy makers were keen to predict possible impacts on tourism and corresponding losses in revenues. If socio-economic assessments were applied, it would allow managers to take measures to mitigate impacts, such as developing alternative attractions for tourists, assessing new dive sites, attempting coral rehabilitation etc. Socio-economic monitoring and assessments were therefore started immediately following the bleaching event in 1998.

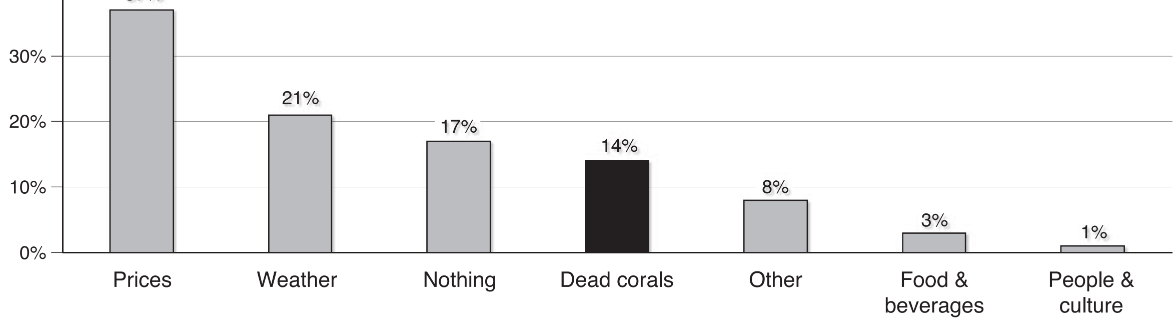
The strongest El Niño - La Niña climate change event ever recorded occurred in 1997 and 1998. This resulted in increased ocean water temperatures and excessive coral bleaching around the world. Coral mortality in the Indian Ocean was the most severe, with between 50 and 95% mortality in large areas. Many countries in the Indian Ocean depend to a considerable extent on their coral reefs for subsistence and income through fisheries and tourism. For example, in the Maldives about 56% of the national economy is based on travel and tourism and in the Seychelles it is about 21%. Hence, major economic impacts from the 1998 bleaching episode were expected in the national economies. Therefore, studies were undertaken in selected countries in the Indian Ocean to analyse the potential fisheries and tourist impacts. The socio-economic assessment of tourism impacts is the focus of this case study.

What was done?

Socio-economic assessments relating to tourism were undertaken in Kenya, Zanzibar, the Seychelles, the Maldives and Sri Lanka. The aims of the assessments were to:

- establish the level of awareness that tourists visiting these countries have about coral bleaching and associated mortality;
- evaluate tourist perceptions of the threat of coral bleaching; and
- determine the willingness to pay for improvements in reef quality.

In order to gauge tourist reactions to coral bleaching and reef degradation, questionnaire surveys were carried out in 1999, 2000 and 2001, administered to departing tourists in airports of the given countries and in selected dive shops and tourist establishments. These questionnaires contained 24 questions and took approximately 15 minutes to complete. Tourist attitudes were gauged by asking them what they liked most and least about their holiday. With regard to the most disappointing part of the holiday, 'the prices' category was selected most frequently (37%) in the Seychelles, followed by 'the weather' (21%). Only 14% of tourists surveyed found 'dead corals' to be the most disappointing part of their holiday. Similar results were obtained in the Maldives, where the price of beer (around US$5 per bottle) and other beverages were a major disappointing factor in people's vacations. The surveys also found that only a limited number of tourists (28 – 48%) were even aware of coral bleaching. Yet, of those aware of bleaching, 80% said this knowledge would actually affect their decision to visit and dive in an area. These studies were part of the Coral Reef Degradation in the Indian Ocean (CORDIO) program with funds from the Netherlands Consultant Trust fund of the World Bank. Several social scientists assisted with the questionnaires (Lida Pet-Soede, Susie Westmacott, Stephen Mangi, Annabelle Aish and Zeinab Ngazi).



These are the aspect that tourists liked least about their holiday in the Seychelles. Coral death ranked 4th in this list (the price of the beer may be more important).

Case study 3

In addition to financial losses to the local economy, coral bleaching can also affect tourist holiday satisfaction and thereby create a loss in their welfare or amenity. To calculate these welfare losses, tourists were also asked to indicate how much extra money they would be prepared to pay to enjoy better reefs (assuming that the fish abundance at those reefs would be the same). According to the contingent valuation method (CVM) respondents were willing to pay US$ 99 extra per holiday in the Seychelles, US$ 87 extra in Zanzibar and US$ 59 extra in Kenya to experience healthier reefs. Thus, it was determined that potential losses to 'welfare' incurred by tourists are relatively significant; they give weight to the notion that healthy reefs are an important factor for successful tourism in many Indian Ocean countries.

Country	Average	Deviation	High	Low
Seychelles	98.7	267.9	2000	0
Kenya	59	201.3	1500	0
Zanzibar	87.7	100	500	0

The willingness to pay extra in US$ by tourists visiting 3 countries to experience better reefs. These data can directly support management efforts.

Case study 3

How successful has it been?

The socio-economic monitoring program was successful because managers often operate in the dark on human welfare and economic issues. These results indicated that the coral reef health was a major factor in tourist satisfaction of their vacation, especially in the dive industry. The surveys also provided new findings that were helpful for MPA managers and policy makers in reef-based economies in the Indian Ocean. For example, should bleaching adversely affect the reefs, tourist may still visit the area if alternative activities (marine or land-based) are supplied. The willingness to pay by tourists for a healthier reef can be used when establishing more MPAs, promoting coral reef conservation and generating revenue through user fees.

The assessment results provided more confidence to governments in the region that major damage to the coral reefs, their major tourist attraction, would not cause a collapse in tourist numbers, provided that other attractions could be provided. It also meant that managers should concentrate on those aspects of the tourism experience that are under the direct influence of MPA managers. These include clean, unpolluted water, healthy fish populations, prices paid for drinks etc.

Lessons learned and recommendations

- Socio-economic monitoring helps managers take measures to mitigate impacts according to possible social and economic impacts of a natural occurrence, such as bleaching;
- Most tourists were found to be unaware of coral bleaching and mortality. For those who said they were affected, unhealthy coral reportedly affected their activities. This was especially true for divers;
- Many divers feel affected by the state of the reef and are willing to pay considerable amounts for good quality reefs and reef improvements. This means that conservation efforts must be visible to the public in order for people to be willing to pay for them.

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Case Study 4

How Monitoring Demonstrated Effective Control of Blast Fishing in Komodo National Park

Peter Mous, Jos Pet, Gede Raka, Yohannes Subijanto,
Andreas Muljadi and Rili Djohani

The challenge

The challenge was to design and implement a monitoring program that could assist MPA managers with the control of blast fishing and with management of legal resource uses (fishery, tourism) in Komodo National Park (KNP), Indonesia. The coral reef communities of KNP have been seriously threatened by blast fishing, cyanide fishing, reef gleaning and over-fishing, putting the Park's function as a replenishment source for surrounding fishing grounds at risk. The Park was established in 1981 to encompass areas where blast fishing has occurred at varying levels since the early 1950s. In 1996, The Nature Conservancy (TNC) and the Park authority implemented a detailed marine conservation program that included a plan for self-financing of Park management, stakeholder involvement in management, awareness raising, outreach, alternative livelihood development, surveillance and monitoring. Monitoring has been a vital component of the program, which has helped identify situations where management has been successful as well as identifying areas that require further protection.

What was done?

Various monitoring programs have been implemented over recent years, focusing on vulnerable species and ecosystems (including coral reefs), as well as resource use by humans. The coral reef monitoring program started in 1996 to gather spatial and temporal information on coral reef health and reef recovery, both inside and outside the Park. It was designed to assess management effectiveness, with more emphasis placed on covering a wide area, than fine-scale biological monitoring.

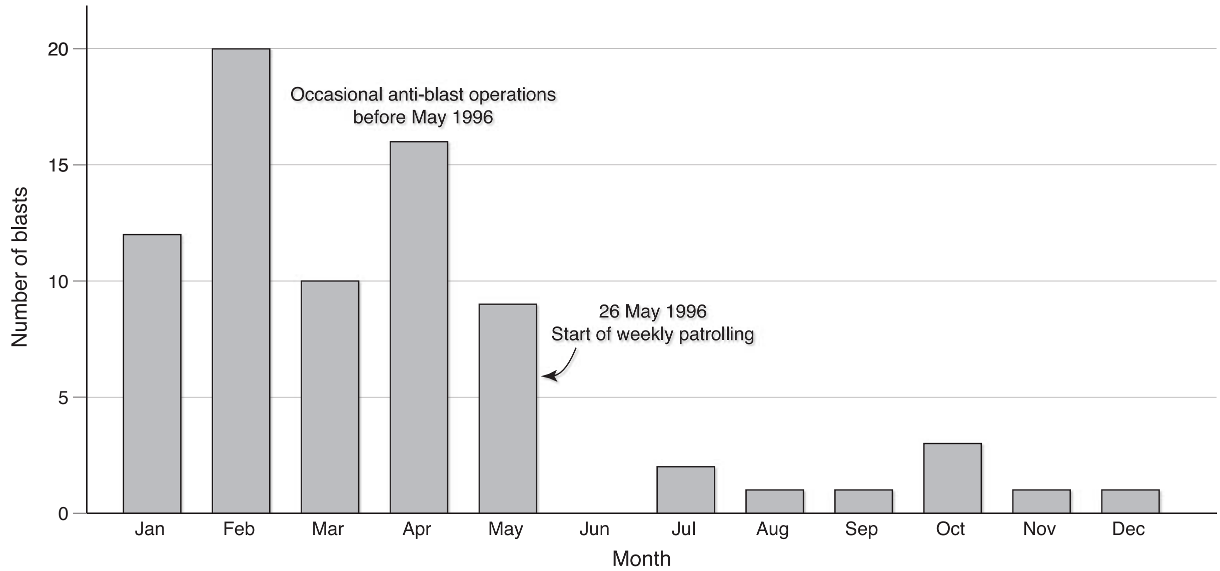
The simple monitoring program required minimum training. Observers made 5 repeated swims of 4 minutes each at 4m, 8m and 12m. After each swim, the observer stopped and recorded cover estimates of live hard coral, dead hard coral, soft coral and other (rock, sand, sponges, tunicates, algae, weeds, anemones, clams, etc.) on underwater paper. They surveyed 185 sites inside and around the Park and repeated them every 2nd year. Before each monitoring period the team of TNC field staff and Park rangers had 2 weeks to practice the observation techniques together with experienced 'veterans'. The fixed sites were re-located using a GPS receiver and the areas covered were relatively large with long swims to ensure that the results were robust with low deviations due to variations in the survey sites. The team prepared a survey report after each monitoring with the cover of live hard coral as the most important statistic. In addition to the monitoring program, the Park rangers kept records of the number of blasts they heard from the ranger posts inside the Park. These data are only available for 1996.

How successful has it been?

The observations by the Park rangers demonstrated that management was successful in decreasing the incidence of blast fishing in the Park, with fewer blasts after routine patrols were introduced in 1996. The decrease in blast fishing resulted in good coral reefs recovery. The monitoring program showed that average live hard coral cover gradually increased from 15% in 1996 to 24% in 2004 inside the park. The result was statistically significant, because outside the Park hard coral cover dropped from 25% to 17% between 2000-2002 after initial increases between 1996 and 2000. It is possible that a crown-of-thorns starfish outbreak in the Northeast of the Park and continued blast fishing around an island in the Northwest caused this decline, but more analysis is needed to confirm this hypothesis.

The data from the Park rangers and the monitoring program strongly suggest that the conservation program successfully reduced a key threat to the coral reefs in and around Komodo National Park. The results also show that coral recovery is fastest near the centre of protection and enforcement coming from the town of Labuan Bajo. Recovery is slower on average in remote areas, where enforcement is more difficult.

In addition to the straightforward benefits from monitoring the reef, there are several secondary benefits. For example, the monitoring teams function as the 'eyes and ears' of management as they are out in Park waters on a daily basis, and contribute considerably to the prevention and detection of illegal activities. Hence, the monitoring teams reduce the need for costly patrols by surveillance vessels! The full-time presence of a monitoring team in the Park also helps to detect biological events that are not strictly the focus of this particular monitoring program, such as coral bleaching and crown-of-thorns starfish outbreaks. Finally,



There was a clear drop in the number of blasts heard by the Park rangers after regular monitoring and enforcement patrols were introduced in May 1996.

sharing of monitoring results helps to maintain a close working relationship with Park rangers, patrol and enforcement teams and local communities. The site is used by ICRAN as a demonstration site for the region.

Lessons learned and recommendations

- Monitoring is a critical component of the management plan, and provides important information on where management is working and where additional attention is required;
- This program shows the value of long-term monitoring and managers can now state confidently that most of the damage to the reefs was due to blast fishing and that the reefs recover rapidly when the damaging practices are stopped;
- The monitoring method selected could cover large areas at relatively low cost in equipment and time, and still provide useful data for management;
- Local Park rangers were trained to do the monitoring as they know the area very well and this provides more support for management activities;
- Results from biological monitoring are much more meaningful if they can be combined with data on resource use by humans;
- Monitoring can be an effective tool to not only inform managers about the status of resources, but also provides secondary benefits including community outreach and prevention of illegal activities.

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Case Study 5

The Role of Monitoring in The Effective Management of Apo Island Marine Reserve, Philippines

Garry Russ and Angel Alcala

The challenge

Apo Island is a small (70 ha) high island surrounded by coral reef in the Central Visayas, Philippines. In 1982, a small no-take marine reserve (11 ha, 10% of coral reef area) was established on the island. The legal framework for marine resources management at Apo Island, including protection of Apo Reserve, was implemented in 1986. The main objectives of the reserve were to:

- prevent non-residents from fishing the reefs;
- prevent the use of destructive fishing techniques;
- protect habitats and breeding fish;
- increase fish numbers in the no-take area;
- help sustain local catch by export of fish into fished areas; and
- encourage tourism.

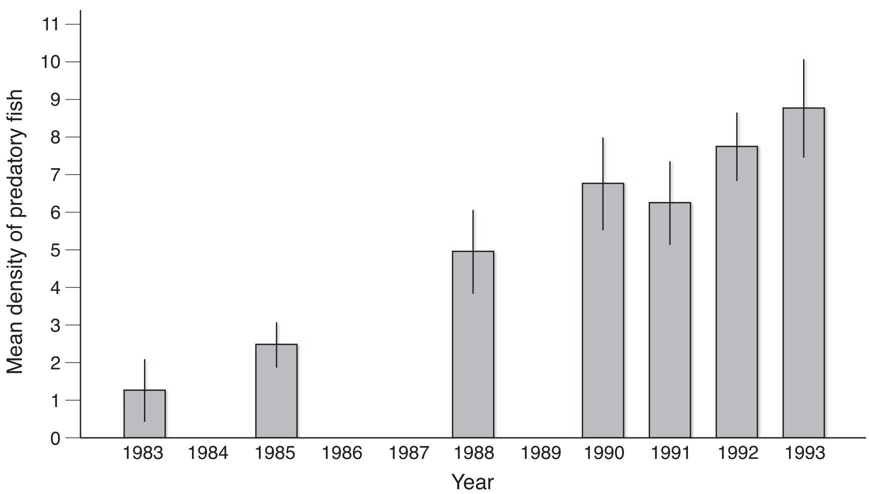
The marine reserve was protected and co-managed by the local community and government, with assistance from scientists from Silliman University, until 1993. It is now managed by the Apo Island Protected Area Management Board (PAMB), in which both local communities and the national government still participate. Apo Island is well known for its strict enforcement and good compliance. The monitoring challenge was to demonstrate to the people of Apo Island that the reserve had been successful in achieving its goals, and had benefited the local communities.

What was done?

Ecological and socio-economic monitoring programs have played an important role in managing the marine reserve since 1980, and have demonstrated that the reserve has been successful in achieving its goals. Fishing is almost entirely confined to local people, and destructive fishing practices have ceased. This has led to the protection of coral reef habitats and populations of breeding fishes.

A coral reef monitoring program started at the time the reserve was established and has demonstrated that the fish and coral communities inside and outside the reserve have improved since destructive fishing methods ceased. This has lead to an increase in tourism, which is now a major source of income for the local communities.

Since the reserve has been protected from destructive fishing practices and over-fishing, populations of key fisheries species have steadily increased within the reserve. For example, populations of predatory fishes inside the reserve increased by more than 7 times in the first 10 years of protection. More recent studies



Fisheries monitoring has demonstrated that the high fish yields of Apo Island have been maintained since the reserve was established 20 years ago. This figure shows that the mean density of predatory fish (groupers, snappers, and emporers) per 1000m² (+ /- SE) have increased in the 10 years from 1983 to 1993 (estimated by visual census).

have shown that the density of these large predatory fish has increased by more than 12 times over 18 years of protection in the reserve. This has lead to a spillover effect and an increase in fish numbers outside the reserve. In fact, catch and catch rates of target fish families is now higher, and fishing effort lower, than before the reserve was established. Catch rates of some fish groups are also significantly higher just outside the boundary of the reserve than in other areas, demonstrating fisheries benefits outside the reserve.

Socio-economic studies have demonstrated economic benefits of the reserve to the local community (from fishing, tourism and reserve income). It has also demonstrated good support for the reserve from local communities, including fishers, some of whom claim that their catches have doubled since the area was protected.

The results of these monitoring programs have been shared with the local communities through the marine conservation and education program run by Silliman University and the Marine Conservation and Development Program (MCDP). Sharing these results with local communities has contributed to the ongoing support of the community for the reserve.

How successful has it been?

Apo Island marine reserve is a good example of a successful marine reserve, which has become a model for community-managed marine reserves in both the Philippines and overseas. Its success is largely due to creating opportunities and benefits for the local community, good compliance and enforcement, and technical support from the Silliman University and the MCDP. Monitoring has played an important role in demonstrating the success of the reserve, and the fisheries and economic benefits to the local communities. The establishment and maintenance of a marine education and community centre has also provided a focus for management and maintained enthusiasm in the area, since it has provided an 'immediate and tangible benefit' for the community. The success of the reserve is largely due to an effective partnership between local communities, governments and scientists.

Lessons learned and recommendations

- Well-protected and managed no-take reserves can be successful in protecting biodiversity and key fisheries species within the reserve;
- Marine reserves can also provide fisheries benefits outside the reserve, due to spillover of fishes from the reserve;
- Well-protected MPAs can lead to economic benefits for local communities;
- Co-management of marine resources by local communities and government, with advice from scientists, can be an effective management strategy;
- Monitoring can play an important role in the effective management of MPAs, particularly if the results are shared with the local stakeholders.

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Using Reef Check to Stimulate Community Management of Gilutongan, Central Philippines

Gregor Hodgson and Mike Ross

The challenge

The rate of illegal blast, poison and scuba fishing, as well as general over-fishing, meant that there were few mature reef fish and most edible and aquarium species were particularly rare. The challenge was to involve the large population of poor coastal fishers in monitoring and management to reverse the damage to their reefs. Gilutongan is one of 7000 islands in the Philippines where about 1000 people live and the population growth rate is almost 10%. Fishing pressure on the reefs is higher around Cebu than elsewhere in the country and it is culturally unacceptable for fishermen to take up employment in a non-marine occupation. There were two potential scenarios: either the status quo would continue and the reefs would decline and potentially collapse; or the marine sanctuary that was established on one small island in 1991 had to succeed. But this was a 'paper park' with no management or enforcement.

What was done?

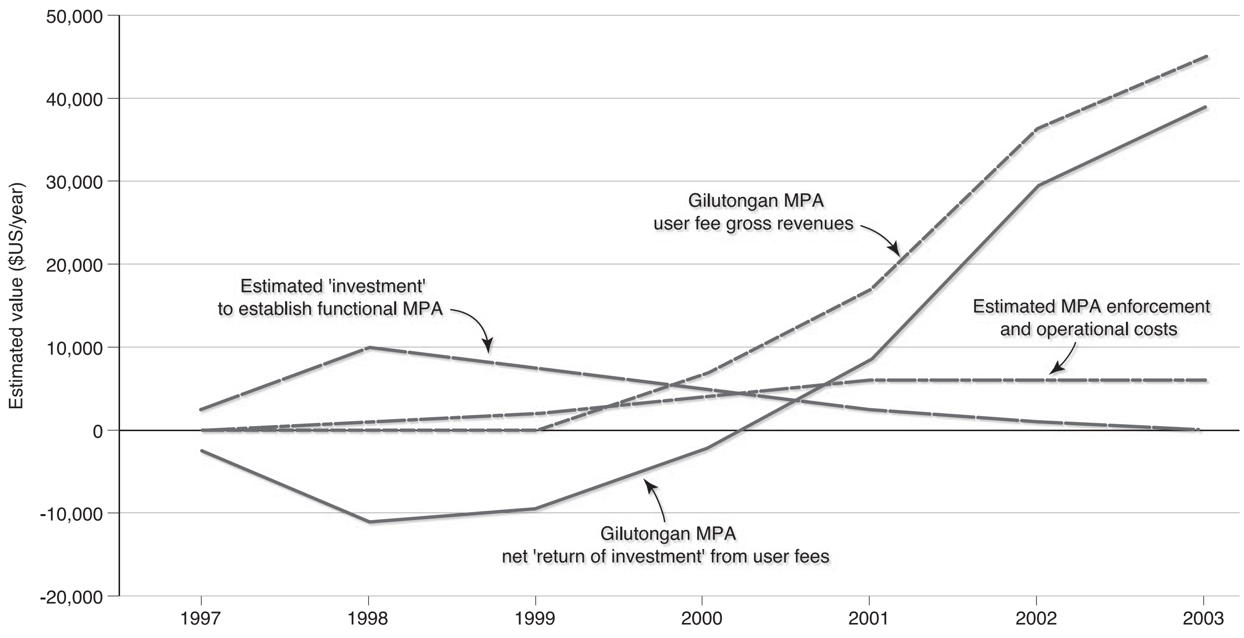
In 1998, teams of about 20 local divers were trained in scuba to carry out Reef Check surveys using a selected set of reef health indicators including fish, corals and invertebrates. Reef Check was chosen because it was designed to allow community members with no formal biological training to monitor their own coral reef resources and to produce reliable data for reef managers. The results of these surveys were presented to the community and the poor condition of the reef was widely discussed. The active participation of community-members in the surveys was considered to be an important factor in the community's decision to start active management in the marine sanctuary. In the past, monitoring was usually carried out by trained scientists who typically did not share data or information with local communities. A park manager was hired, and local resorts were asked to contribute to funding mooring buoys and a floating boundary marker line. Management training was provided by the Coastal Resource Management Project staff in Cebu, and a US$1fee was charged for all visiting divers. A description of Reef Check is in Appendix 3, p 62.

How successful has it been?

The Gilutongan Marine Sanctuary has been an outstanding success, both ecologically and economically. The ecological recovery of the reef corals and fish populations has been amazing. For example, the reef fish populations increased by 70% in the first two years, which was a dramatic surprise for the community. Importantly, these populations included both adults and juveniles of marine aquarium species, like butterfly fish, as well as traditional food fish species such as snapper and grouper. Reported fish catches outside the MPA have increased from 2 kg per **day** of small fish before 1998, to 2 kg per **hour** of high quality, larger fish now.

The economic success of the MPA has been even more stunning with over $30,000 in user fees collected in 2002. These funds cover the cost of constructing a visitor's center and other needed facilities. Socio-economic assessments of all economic benefits of the Gilutongan MPA were estimated at $200,000 per year, including resort and dive operator income. Enforcement is actively supported by a collective of 200 vendors representing nearly every family on the island, who now have significantly increased incomes. They function as 'life guards' and snorkeling tour guides. All boats use the mooring buoys instead of anchoring and damaging the corals, and the use of jet skis and all fishing has been successfully banned inside the MPA.

Gilutongan is now an important demonstration site for successful coral reef management in the region as it shows that dramatic improvements in reef health can occur within two years, if conditions are right. Two more MPAs have been established in nearby coastal communities and 4 more are planned. It demonstrates that a 'paper park' can be converted into a 'real park' with successful coral reef management, provided that there is a local and national government legal framework that gives residents the authority over their reefs, in particular the power to control access and use of the coral reef. Local tourism companies were involved at an early stage and were asked to assist by helping fund management activities. In turn they were allowed to take credit for some of the success. Participation of local environmental groups was also important because they established the necessary long-term support in the surrounding communities for the management, which reduced the need for and cost of enforcement. Where tourism is not a major industry, other private enterprises such as the marine aquarium trade may provide useful incentives for reef conservation.



This analysis clearly shows the economic benefits for the community since the Gilutongan MPA was established. These analyses are only based on the user fees, and do not include the other community benefits from more fish and as tour guides.

Lessons learned and recommendations

- Involve local communities early in monitoring and management to get them on side.
- Reef Check was the appropriate monitoring tool to start the process of community-based management of coral reefs because it was targeted at their level.
- The Reef Check protocols were modified to include coral reef health indicators and target fish species that were important to the local community, especially the fishermen. Thus the community could see the improvements in the corals and fishes that resulted from their management.
- Communities must be given authority to manage their reefs by local and national governments, especially given the power to determine who can and cannot use coral reef resources.
- The tourist industry is a valuable partner in MPA management as they can provide alternative livelihoods based on healthy coral reefs. If tourism is not an option, then a well managed marine aquarium trade may provide alternative livelihoods.

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www.ReefCheck.org; www.cebudive.com; www.oneocean.org; www.coast.ph

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Case Study 7

Long-term Coral Monitoring in Sekisei Lagoon, Iriomote National Park, Japan

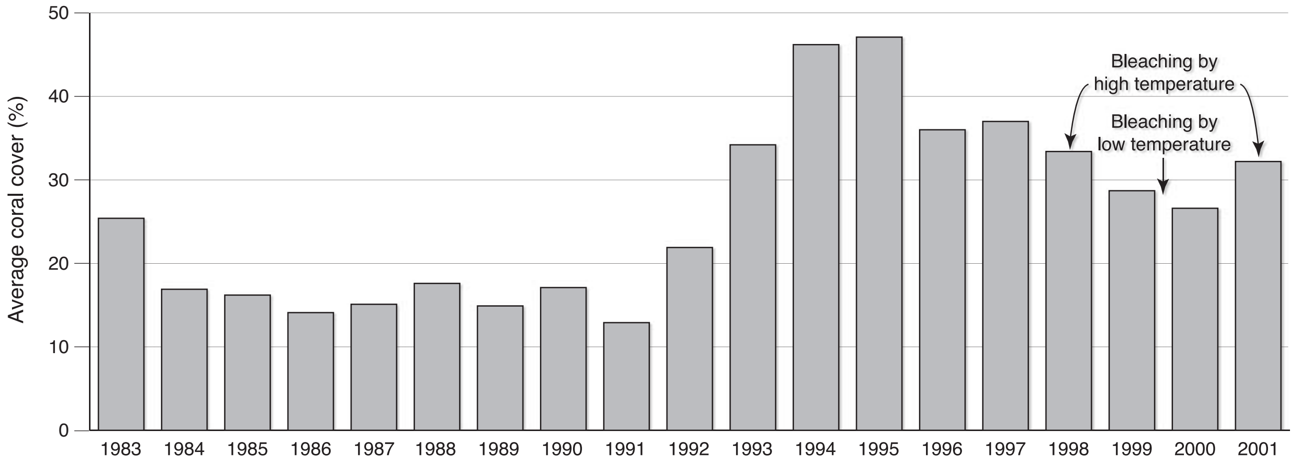
Tadashi Kimura

The challenge

In the late 1970s to 1980s, crown-of-thorns starfish outbreaks caused extensive damage to coral reefs of the southern Ryukyu Islands of Japan. The national and local governments tried to eradicate the starfish to protect coral reefs in Sekisei Lagoon, which was a part of Iriomote National Park in the Ryukyu Islands. The attempts were largely unsuccessful as most of the coral communities were destroyed during the outbreak, with only a small area partially protected by the collecting program. This catastrophe was a lesson for the local and national governments and a monitoring program was urgently required to provide advice for management in case of another outbreak or to seek ways of making these reefs more resilient.

What was done?

The Yaeyama Marine Park Research Station started an annual monitoring program to observe coral health and count the number of crown-of-thorns starfish in 1983. This monitoring was focused on the large Sekisei Lagoon which is 32,100 ha and generally shallow. There are 6 small islands and many patch reefs in the lagoon. This program continued until 2001 with the research station supporting the monitoring by raising funds from various sources, until it was taken over by the Ministry of the Environment in 2002. They chose a spot check method for the monitoring, which is a quick survey using 15 minutes snorkelling swims to assess coral cover, coral community components and the number of crown-of-thorns starfish. This monitoring was in place when major coral bleaching events struck the region. Results of the monitoring showed 8% mortality from bleaching in 1998 and 5% mortality in 2001. It has also shown increasing numbers of starfish since 2001that are in potential outbreak populations. The Government started research on the distribution of these starfish to find their major aggregation centres in 2002.



The coral cover at many sites in Sekisei Lagoon has fluctuated from less than 15% on average to almost 50% cover in the 20 years that monitoring has followed these reefs. The early declines were due to persistent populations of the coral predator, the crown-of-thorns starfish, and recent declines have been due to coral bleaching and damage from red soil sediments to reefs near the larger islands.

The regular monitoring has stimulated related research and conservation activities by the government and local communities. The Ministry of the Environment had several research and management programs of coral reefs in the area. A local committee has been established for coral reef conservation in the region initiated by the scientists of the Yaeyama research station, which conducted the long-term monitoring. The committee started its own monitoring program to support the annual monitoring program by the research station. This has catalysed the current grass-roots movement on environmental conservation in this region. Civilian monitoring of red-soil sediment pollution is conducted every year around Ishigaki Island, and another group based on marine environment conservation has been established among local NGOs, individuals and the government.

The monitoring has also stimulated the national government to formulate an integrated management strategy for Japanese coral reefs. The Ministry of the Environment started a project of integrated management in Sekisei Lagoon in 2002, because of the alarms over the damage to corals in the area by bleaching in 1998, 1999 and 2001, stress from red-soil erosion from adjacent islands, and potential damage by crown-of-thorns starfish outbreaks.

How successful has it been?

The monitoring data now provides the MPA managers with sufficient information to determine the direction of conservation efforts for these coral reefs as well as informing them of the impact of the bleaching events. The Government realized the importance of coral reef protection and established the International Coral Reef Research and Monitoring Centre, a core coral research and monitoring institute which opened in 2000. Regular coral reef monitoring will now be extended to a national scale with the establishment of a network of coral research institutions. The Ishigaki centre also functions as a resources centre for the nearby countries of East and Southeast Asia for assistance in coral reef monitoring and reporting for the GCRMN. The Ministry of the Environment also started an integrated management project for the area in 2002.

Additional coral reef conservation activities have been initiated through the enthusiasm of the scientists at the research centre, while maintaining a strong interest in annual coral reef monitoring. These activities have had a positive effect on local communities which are now more aware of the environment.

Lessons learned and recommendations

- Long-term monitoring is essential to determine the fate of coral reefs subject to occasional, but severe stresses such as coral bleaching and crown-of-thorns starfish attack;
- Rapid survey and low technology methods are suitable for monitoring large areas such as the Sekisei Lagoon;
- Regular monitoring, however needs the support of core institutions and scientists to develop and run programs as well as contribute to the conservation activities of the local people;
- The Government support is also required to fund and facilitate a monitoring program;
- The long-term monitoring program cannot stand alone without the understanding and initiatives of coral conservation by local communities.

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Case Study 8

How Socio-economic Assessments Can Assist Marine Reserve Management: Kimbe Bay, Papua New Guinea

Joshua Cinner, Michael Marnane and John Ben

The challenge

A no-take Locally Managed Marine Area (LMMA) was established in 1997 adjacent to the Kilu community in Kimbe Bay (West New Britain province), Papua New Guinea (PNG). The Kilu LMMA project has involved a wide range of stakeholders, including community leaders, local and international NGOs, dive operators and university researchers. The Kilu LMMA is particularly important because it is one of the first community-based marine reserves in PNG and is a focal point for significant scientific research and marine conservation efforts. The Kilu LMMA will also form the cornerstone of an effort between NGOs and interested communities to develop a network of LMMAs in the wider Kimbe Bay and New Guinea Islands region. Since the project's inception, managers have used ecosystem monitoring to assess the ecological effectiveness of the LMMA, identify major threats, and characterise reef health. However, managers were also interested in socio-economic monitoring so they could customise conservation strategies to reflect the specific needs and concerns of the local community.

What was done?

In April 2002, a socio-economic assessment of the Kilu community was conducted. Information was gathered using several techniques, including: household surveys; key informant interviews (including resource users and community leaders); focus groups; oral histories; and participation in fishing trips. Information from the assessment was used to:

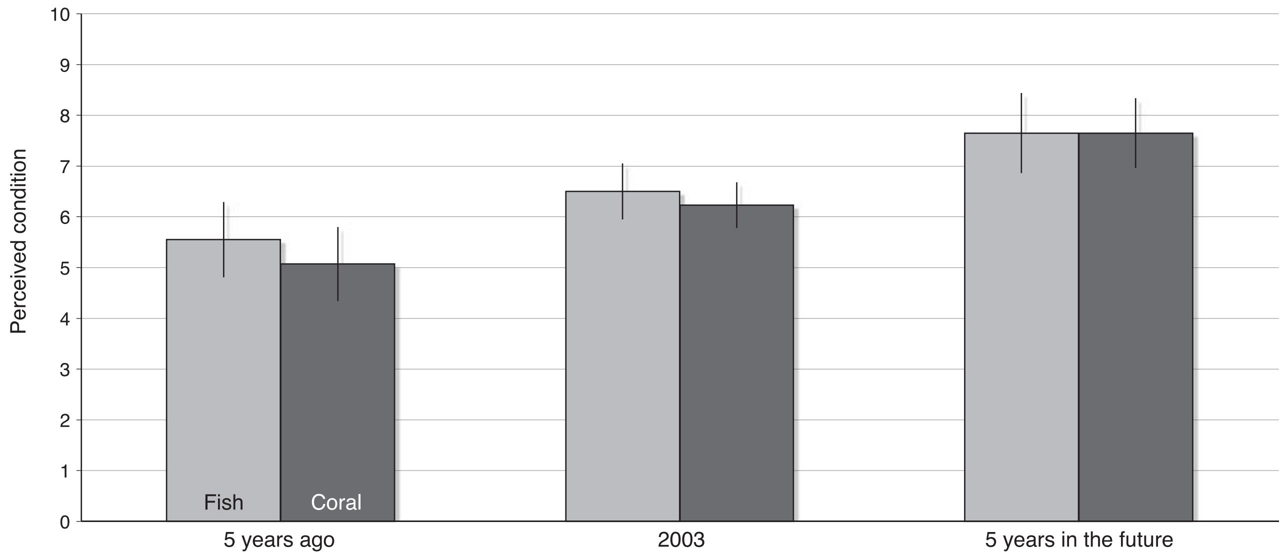
1. quantify fishing pressure and other resource use patterns;
2. examine awareness of and compliance with reserve rules;
3. assess whether the community understood the rationale behind the reserve;
4. evaluate the perceived success of the project;
5. examine social and cultural factors that may be influencing the project; and
6. provide recommendations to address any problems identified.

How successful has it been?

Results from the socio-economic assessment revealed that, despite relatively low direct pressure on the marine resources in the local area, the Kilu LMMA faced significant challenges. The compliance was reported as low and prevailing perceptions about the goals of the reserve were of particular concern. The socio-economic study found that the following factors were likely to influence how the reserve was perceived and may contribute to low compliance.

- The community had difficulty understanding the rationale behind the no-take reserve because it did not fit their customary model for reef closures. For generations, the community had closed their reefs to fishing when an important person in the community died. After 3-12 months, the reefs were usually opened to harvest fish for a feast to mark the end of the mourning period. Thus, the community believed the goal of a reef closure was to build up fish stocks, which could then be exploited when needed.
- Important information about the LMMA was not effectively trickling down from community leaders to the wider community.
- There was confusion amongst the community about whether other divers, in particular researchers, who were seen entering the protected areas were extracting resources e.g. fishing.
- There was significant confusion about the respective responsibilities of the local NGO and the community in managing the LMMA.

Despite these issues, Kilu residents believed that the condition of coral reefs and the fishery were improving. The perceived improvements were attributed largely to the presence of Mahonia Na Dari (a local NGO) and the LMMA. These perceptions suggest that residents in Kilu had confidence in Mahonia Na Dari and the other conservation partners and were willing to continue working with them.



This figure shows that community perceptions about the condition of coral reefs and reef fisheries are gradually improving from 5 years ago, to the present, and 5 years in the future (based on a Likert scale of 0 = worst condition to 10 = best condition; N = 40).

Lessons learned and recommendations

Based on the socio-economic assessment, the following recommendations were presented to Mahonia Na Dari and other stakeholders:

- Because the community's traditional experience is that reef closures are temporary regimes and are established for useful purposes, there is a need to increase awareness about the benefits to be gained from permanent closures, such as spill-over and increased fish and coral recruitment to surrounding reefs;
- Because information about the closures was not effectively trickling down from leaders to the wider community, awareness programs should seek to involve the whole community and take advantage of informal information exchange mechanisms;
- Establishing a scientific liaison officer could help to clarify to the community: the types of research being conducted; the reasons behind it; the benefits of the data being gathered; and the locations where scientific extraction is occurring;
- There was a need to clarify the respective roles of Mahonia Na Dari and the community in protecting the reef resources and enforcing regulations.

Other lessons from the Kilu LMMA include

- The partnership of a local NGO (Mahonia Na Dari) with other conservation partners in Kimbe Bay is a critical example for marine conservation in PNG. Lessons learned from the Kilu LMMA will be used to expand conservation activities in the area;
- The understandings from socio-economic monitoring of the Kilu LMMA have been useful in preparing stakeholders for the considerable challenges of developing a network of LMMAs in the region; and
- Socio-economic monitoring has helped project managers identify important social and cultural processes affecting the LMMA, refine the program to fit in with the local context, and develop a framework for local action that will incorporate socio-economic issues early in the LMMA process.

Contacts

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Case Study 9

A Long-term Monitoring Program for the Great Barrier Reef and its Value for Managers – the 'Aims' Reef Monitoring Program

Hugh Sweatman and David Wachenfeld

The challenge

The challenge was to design a program to monitor the largest series of coral reefs in the world to provide valuable information for coral reef managers, without being excessively expensive. The Long-term Monitoring Program (LTMP) of the Australian Institute of Marine Science (AIMS) was developed to track the status of and trends in shallow coral reef communities across much of the Great Barrier Reef (GBR). This aimed to give the management agency, the Great Barrier Reef Marine Park Authority (GBRMPA), a context to assess localised changes and develop effective management strategies. The monitoring has an added value as the GBR is an icon in Australia and its condition is of critical interest and political significance to Australians.

What was done?

The program differs from many monitoring programs because it is not focussed on particular threats or areas, but aims to assess the general status, trends and historical variability of the whole reef system. This allows resource managers to place local and short-term changes into a large-scale, long-term context. This is particularly important for understanding and developing management responses to large-scale ecological threats such as crown-of-thorns starfish and coral bleaching. The LTMP also assists in identifying emerging issues, such as coral disease. Finally, the program provides resource managers with informed assessments on the condition of the environment that they are managing.

The program employs full-time trained marine biologists, statisticians and information technologists who employ verified and documented methods with extensive quality control on data collection and database management. There are intensive surveys of permanent sites on 48 reefs every year, with broader scale surveys of about another 50 reefs. The intensive study reefs were chosen to represent the major gradients in reef communities on the GBR: between the ocean and the coast (range 2 km to 200 km); and north to south (over 1,100 km).

The intensive sampling is focussed on marked 50 m long transects that follow depth contours at 6-9 m on the Northeast side of the study reefs. Groups of 5 transects make a 'site', with 3 sites per study reef. The program samples benthic assemblages along the marked transects using an underwater video camera. Benthic organisms are identified to about 70 categories because the restricted resolution of the video images means that corals are generally identified to family, although some can be identified to species. Small reef fishes (~200 spp.) are censused visually along the same transects, and observers also search for juvenile crown-of-thorns starfish (COTS), *Drupella* spp. and diseased and damaged (or broken) coral colonies. These reefs and those for the broader scale surveys are also surveyed for COTS and coral cover (using a categorical scale) using a series of 2 minute Manta tows around the whole perimeter (see method 3 p 50).

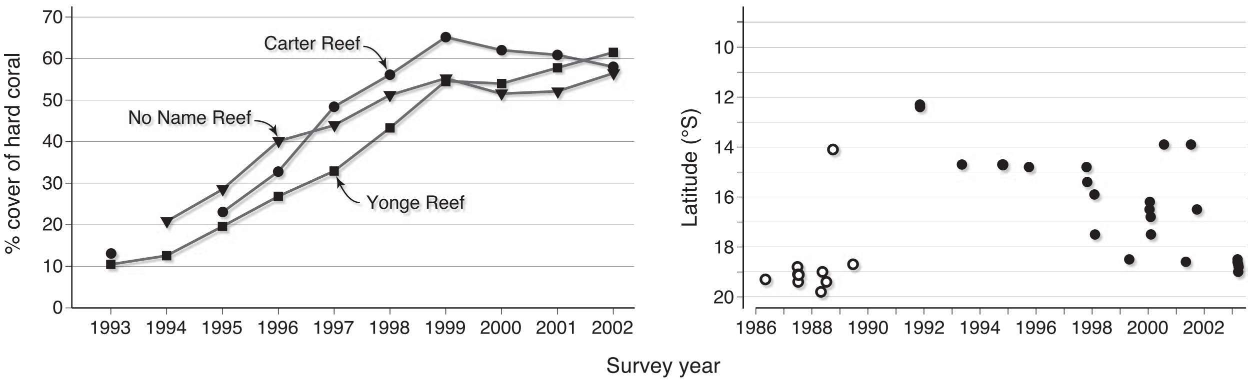
It is very important that any changes detected reflect actual changes in the reef communities rather than changes in the observers. The program places strong emphasis on ensuring data quality through a program of regular re-training, through data checking and use of data entry programs that trap likely errors and check for statistically unlikely values based on past surveys and through Standard Operating Procedures that are regularly updated. The program concentrates on the Internet to provide rapid reporting in multiple formats for managers and other users (www.aims.gov.au/reef-monitoring). This interactive database system was developed in collaboration with the MPA managers. The rapid web-based reporting keeps the local information up to date, and a summary picture of the health of the whole GBR is reviewed approximately annually.

How successful has it been?

This 12 year program of data collection now provides a broad picture of the status and trends of coral reef communities over a huge area of reef. For example, the program has clearly documented:

- Large-scale disturbances such as Tropical Cyclones Justin and Rona;
- Recovery of hard coral cover following Tropical Cyclones Ivor and Harry;
- Changes in density and distribution of populations of crown-of-thorns starfish.

The Program provides systematic observations to identify emerging issues; a current example is that of coral diseases. Awareness of coral diseases has been increasing worldwide and the AIMS program has incorporated



***Left:* Coral reef recovery is clearly shown for 3 northern reefs of the GBR after Tropical Cyclone Ivor destroyed large areas of corals in 1990 (each point is the mean of 15 x 50m transects at the same sites on the Northeast faces).**

***Right:* This figure shows the value of long-term monitoring with two different outbreaks of the crown-of-thorns starfish, each of which started in the northern part of the GBR. The hollow circles show the end of the wave that started in the early 1980s and the solid circles show the outbreak that started in the early 1990s, which is following the same southward drift on the East Australia Current as earlier outbreaks.**

some simple observations on the occurrence of disease, providing the first systematic surveys on the GBR. While diseases are widespread on the GBR, they currently affect very few coral colonies.

The program is valuable to GBRMPA because it allows an informed assessment of any emerging issues, and identifies the likely causes of any impacts. The program also provides detailed baseline data on coral reef community status and trends in study sites where there is ongoing scientific research.

Lessons and recommendations

- An important emphasis is on rapid analysis and reporting with appropriate allocation of resources to data management, statistical analysis and programming;
- It was particularly important that the managers were involved in the design of the program and data reporting format;
- Frequent communication between monitors and managers is essential to discuss relevance and reporting of monitoring information;
- Efficient handling of data is essential; all data should be downloaded and analysed as soon after collection as possible (i.e. immediately);
- Extensive quality control procedures are essential to reduce differences in data collection by different observers. All monitoring plans should have documented operational procedures;
- Video methods were developed to reduce time underwater and provide a permanent record, but these are only valuable if there is a developed analysis system to record the data quickly;
- Long-term commitment of people and funds are essential to implement such a successful monitoring project. The true value of such a program does not manifest itself until a long-term data set (at least 10 years) has been collected.

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Details of the AIMS Long-term Monitoring Program and the Standard Operational Procedures are on www.aims.gov.au/pages/research/reef-monitoring/reef-monitoring-index.html

Contacts

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Case Study 10

Monitoring and Management of Mass Coral Bleaching in the Great Barrier Reef Marine Park

David Wachenfeld and Paul Marshall

The challenge

Major coral bleaching events were recorded on the Great Barrier Reef (GBR) in 1980, 1982, 1987, 1992, 1994, 1998 and 2002 as a result of unusually warm seawater. These bleaching events represented a significant challenge for the Great Barrier Reef Marine Park Authority (GBRMPA) because:

- the Great Barrier Reef Marine Park (GBRMP) is the world's largest marine park at just under 350,000 square kilometres (126,000 square miles) and contains about 2900 individual coral reefs, spread throughout this area. This means that understanding the extent and severity of a coral bleaching event is extremely challenging; and
- the source of the problem, unusually warm sea water, is outside the direct control of a management agency such as the GBRMPA.

What was done?

GBRMPA developed and implemented a Coral Bleaching Response Plan, which was designed to answer:

1. **What is the extent of any area of unusually warm water and how much warmer than the long-term average is it?** Two methods were used to answer this question. The National Oceanic and Atmospheric Administration (NOAA) of the USA provided a variety of sea temperature maps, generated from satellite sea surface temperature (SST) data. These maps helped us understand the level of temperature stress over the entire GBRMP. In order to get more accurate local information, GBRMPA, the Co-operative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef) and the Australian Institute of Marine Science (AIMS) established a network of temperature loggers throughout the GBRMP. Most of these are downloaded about once per year and provide a historical picture of sea temperatures. In addition, near-real-time temperature and other meteorological data were obtained from 6 Automatic Weather Stations on the GBR, which transmit real time weather data (including sea temperature) back to AIMS.
2. **What is the extent of coral bleaching?** With 2,900 coral reefs spread over 350,000 km^2, this is a challenging question. The only effective way to cover such an area is by aerial surveys, because medium to large areas of relatively severe coral bleaching on remote reefs can be seen from the air. This technique was used two times during bleaching events and about 640 of the 2900 reefs in the GBRMP were surveyed on each occasion. The drawback with aerial surveys is that they have a tendency to underestimate the amount of coral bleaching on a reef, particularly if only a small area is bleached or if the bleaching is only mild. In order to compensate for this, we also carried out underwater surveys that do not underestimate bleaching, but are much more expensive (per reef), labour intensive and time consuming than aerial surveys. Therefore, the number of reefs that can be surveyed underwater is much smaller.

   During the 2002 bleaching event, GBRMPA completed detailed underwater surveys of 27 reefs selected to estimate the extent of bleaching over as much of the surface area of the Great Barrier Reef as possible. While this was relatively successful in covering the width of the continental shelf, the selected reefs only represented about 1/3 of the 2,000km length of the GBR. Therefore it was recognised that combined, aerial and underwater survey data provided the most cost-effective estimate of the extent and severity of coral bleaching within such a large area.
3. **What is the average severity of coral bleaching across the 2900 coral reefs?** As discussed above, the aerial surveys were able to cover many reefs over a large area, but they tend to underestimate the severity of coral bleaching, especially if the bleaching is relatively mild. Thus, to estimate the average severity of bleaching, we had to rely on underwater surveys. This means that the estimate of average severity is based on a relatively small number of reefs. Therefore to get the best estimate of average severity, it was essential that the surveyed reefs had to be selected randomly within a spatially structured design (attempting to capture as much of the GBRMP area as possible). It was critically important that these reefs were not selected with any reference to known patterns of warm water, but were representative of all of the reefs of the GBR.
4. **What is the maximum severity of coral bleaching and associated mortality among the 2900 coral reefs?** It was not possible to answer this question from aerial surveys, therefore, the answer relied on data collected using underwater surveys. Unlike the reefs surveyed to answer

Question 3, the reefs surveyed to answer this question had to be selected from areas where records showed the warmest water and where the greatest bleaching was anticipated.

How successful has it been?

The GBRMPA Coral Bleaching Response Plan has been successful in many ways. It provided answers to these 4 questions and allowed GBRMPA to inform all members of the Australian public with an interest in the GBR and global climate change. The information was used to brief Ministers, inform the media, educate students, inform tourism operators, and collaborate with scientists. This enabled an informed debate about the effects of climate change on the health of the GBR and the information empowered GBRMPA to lead discussions on management responses to climate change in tropical marine environments. GBRMPA has focussed on the message that resilience is critical to the survival of tropical marine ecosystems in a warming world. Although a marine management agency cannot influence global climate change, it can maximise the resilience of a tropical marine ecosystem by protecting biodiversity, improving water quality and promoting sustainable fisheries.

Lessons learned and recommendations

- Even if a management agency cannot control the cause of coral bleaching (unusually warm water), it is still essential to have good information on coral bleaching events;
- With a good understanding of the patterns of impacts, and of the ecological implications of coral bleaching events, local management agencies can do much to improve the capacity of reefs to cope with the threat of climate change;
- A wide cross-section of people are interested in what is happening in their marine environment, therefore management agencies should ensure that they effectively communicate all the information they have;
- Co-operation is critical: only with strong co-operation between management and research agencies can the necessary information be collected;
- The management agency should establish a coral bleaching response program that includes sea temperature monitoring, ecological impact monitoring, and a communication plan;
- The management agency should maintain ongoing communication with all stakeholders about coral bleaching and other impacts of climate change; and
- The development of strong partnerships with other interested people and organisations, especially in research institutions, provides distinct benefits for all partners.

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Consult the Great Barrier Reef Marine Park Authority's coral bleaching program at: http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/01-02/final_report/introduction.html

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Case Study 11

Reactive Monitoring at Nelly Bay Harbour

Using Environmental Monitoring to Manage Marine Construction Activities

Andrew Chin and Paul Marshall

The challenge

The Great Barrier Reef Marine Park Authority (GBRMPA) was tasked with designing and implementing an environmental management and monitoring system for Nelly Bay Harbour, which would allow construction works to proceed and ensure that the adjacent fringing coral reef suffered minimal damage. Nelly Bay lies within the Great Barrier Reef Marine Park and is on Magnetic Island, about 10km northeast of Townsville, Queensland, Australia. The Nelly Bay fringing reef is highly valued by residents and tourists for recreation such as diving, fishing and snorkelling. Construction plans for Nelly Bay raised concern among citizens and managers that it had the potential to damage the health of the Nelly Bay fringing coral reef growing only meters from the (previously built) harbour breakwaters.

What was done?

The development within Nelly Bay lasted from October 2000 to January 2003. It involved the construction of a commercial ferry terminal, barge ramp, a canal/harbour estate with residential and tourism developments, a public boat ramp and public areas. Works included dredging of the entrance channel, shaping the harbour basin and stabilising the harbour shoreline.

The developer was granted a permit by GBRMPA that required the implementation of an Impact Monitoring Program (IMP) to manage and monitor the environmental risks posed by various construction activities. One condition of the permit was to appoint a full-time site Environmental Site Supervisor by GBRMPA to watch over construction activities and to ensure that development complied with the Environmental Impact Management Plan.

Identifying environmental risks: The first step in the monitoring program was to identify the likely sources of environmental risk, in this case, sediment plumes. Sediment would come from two sources:

1. **Harbour dewatering**: water from the harbour basin would be pumped out to allow for construction. This water was likely to be very muddy;
2. **Dredging**: the entrance channel to the harbour had to be dredged which would stir up lots of sediment.

Excessive sediment levels can harm corals through direct smothering and decreased light availability due to increased turbidity. To manage these risks, GBRMPA employed the principles of 'reactive monitoring' and designed the monitoring program so that managers would be alerted when sediment levels reached 'unsafe' levels. This allowed managers to take action before excessive sediment levels could cause widespread damage to the Nelly Bay coral reef. **Trigger levels** were developed to help managers identify what 'unsafe' levels of sediment were, or when coral health had been affected.

Trigger levels: GBRMPA developed both water quality and coral health trigger levels with help from independent scientific experts in coral reef biology and ecology, and marine sedimentology:

- Water quality trigger levels - these were based on the natural turbidity levels associated with Nelly Bay coral reefs;
- Coral condition trigger levels - these used the amount of coral bleaching and coral mortality as indicators of coral reef health.

When monitoring showed that a trigger level had been reached, GBRMPA responded by either implementing further monitoring to assess the likely risk to corals, or by shutting down the activity causing the problem. Because the developer pays for the monitoring activities and because works could be shut down if sediment levels reached critical trigger levels, they were given an incentive to use methods that did not stir up too much sediment. This was also beneficial to the reef, as sediment levels should have remained at 'safe' levels.

How successful has it been?

The monitoring program was very successful in alerting managers to rising levels of environmental risk and allowed GBRMPA to initiate actions before the Nelly Bay reef suffered significant damage.

Dewatering: The harbour was pumped dry for 10 months with 297 pumping days, however, trigger levels were reached 144 times resulting in pump shut down on 103 occasions. Receiving water quality monitoring (i.e. at coral reef sites) showed that by stopping pumping down, suspended sediment levels in receiving waters at the reef slope remained comparable to natural levels on all but two occasions during the 10 months.

Dredging: Technical difficulties and the developers' decision to change the dredging method 10 times resulted in dredging operations extending over 19 months. This created constant challenges for the monitoring program. Fortunately, the reactive monitoring design provided flexibility and allowed for a unique water quality and coral monitoring program to be designed for each of the 10 dredging methods. As dredging was a high risk activity, monitoring of receiving waters (at the coral reef sites) was carried out on 167 occasions and dredging operations shut down 32 times.

Coral health: Surveys of corals at control and impact sites showed that corals were more affected by natural events than by construction activities. Two of the four coral species monitored at the impact sites close to the harbour were in better condition than corals at the control sites further away. Another positive sign was that, while both the impact and control site corals were significantly affected by the 2002 Great Barrier Reef mass bleaching event, recovery of impact site corals was similar to that of control site corals. In summary, construction activities did not cause significant mortality of corals on the Nelly Bay fringing reef.

Lessons learned and recommendations

- It is important that the developers be aware of the potential costs of using machinery or methods that have high levels of environmental risk (e.g. generate lots of sediment) *before* the start of construction;
- Reactive monitoring allows managers to detect rising levels of environmental risk and respond *before* environmental damage occurs;
- Trigger levels help managers identify what are 'unsafe' levels, help the developer understand what the environmental limits are and clearly lay out the management responses and consequences to the developer;
- Reactive monitoring programs of this scale needs considerable scientific expertise, full time monitoring by an independent monitoring team, on-site environmental managers and funding from the developer;
- While major marine construction activities can be managed to preserve coral reefs, such programs will require a long-term commitment from management agencies and may be expensive.

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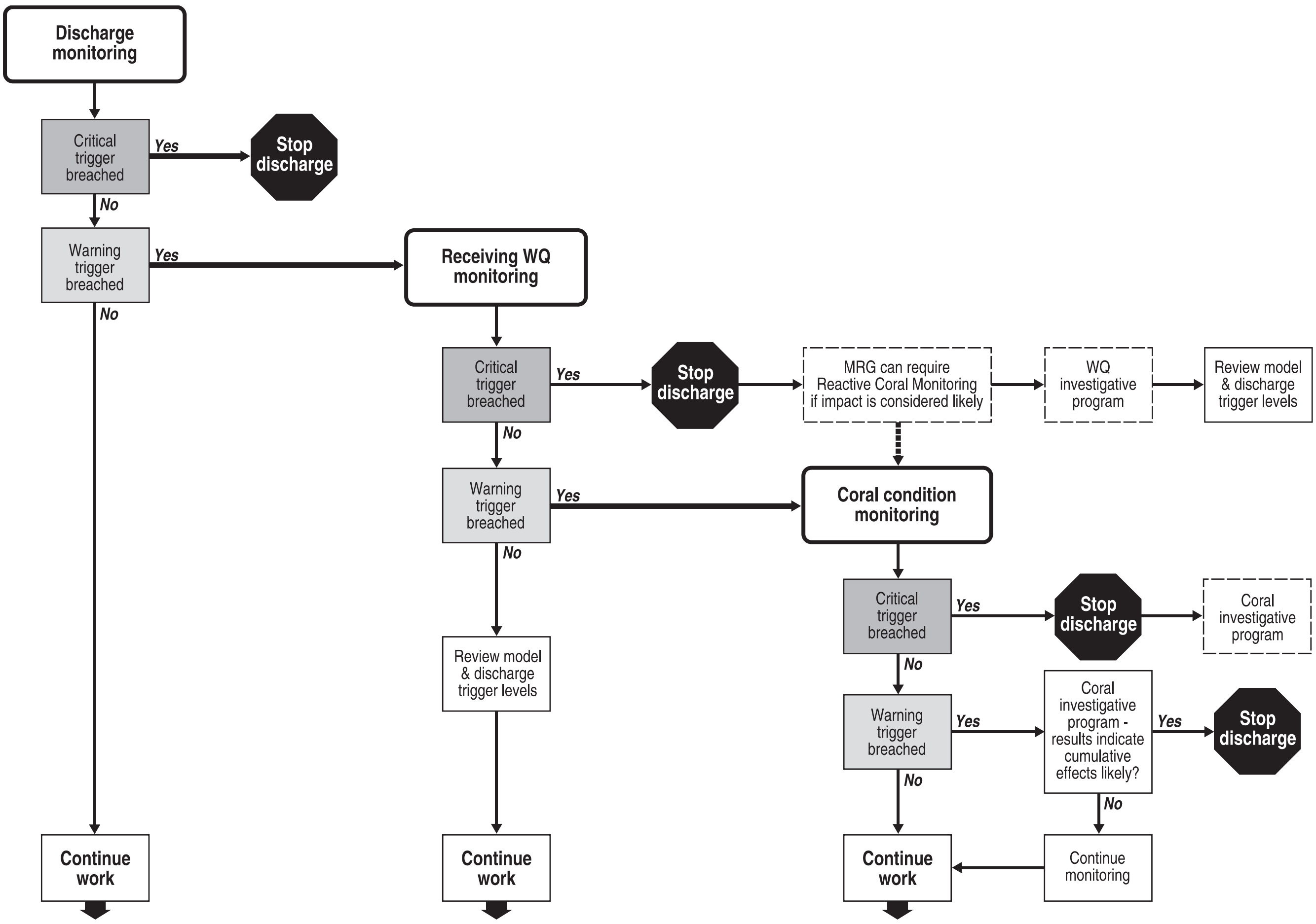


The 'risk-responsive' monitoring cascade used in the Nelly Bay Harbour Impact Monitoring Program

Case Study 12

Monitoring Demonstrates Management Success to Improve Water Quality in Pago Pago Harbor, American Samoa

Peter J. Peshut

The challenge

Early last century, Pago Pago Harbor was characterized by lush coral cover and minimal human impacts. Since then, increased human activity within the watershed has resulted in degraded natural resources within the harbor. Major changes in land use, especially unplanned and uncontrolled urban development for most of the century resulted in declining water quality. Moreover, two tuna canneries began operations in the 1950s and discharged untreated and uncontrolled volumes of process wastes into the inner harbor for several decades. This waste overloaded the inner harbor with nutrients and severely depressed dissolved oxygen levels, resulting in eutrophication. The wastes were also carried to the middle and outer harbor by currents.

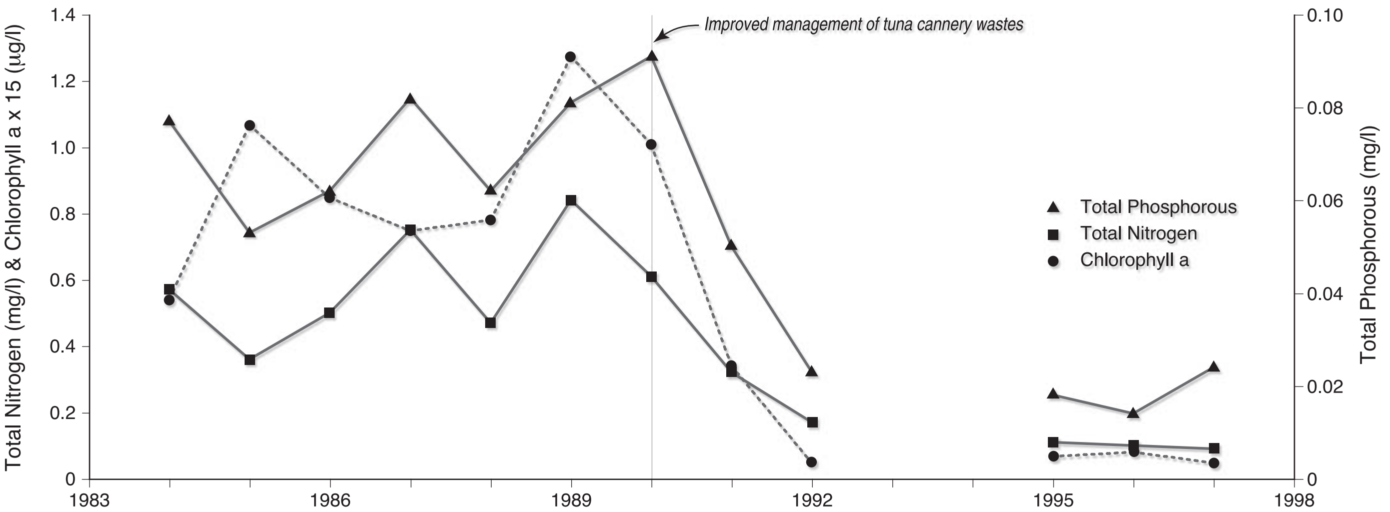
This rapidly declining water quality in Pago Pago Harbor posed a major challenge for local managers. There was a need to monitor the current water quality conditions in the harbor and evaluate whether management actions could be effective in improving water quality and protecting the coral reefs in the harbor.

What was done?

Two ecological monitoring programs have played an important role in managing Pago Pago Harbor, and demonstrating that management has been successful in achieving its goals to date. Overall water quality has improved in the harbor and impacted coral reefs have begun to show signs of recovery.

The United States Environmental Protection Agency (USEPA) started water quality monitoring in the late 1980s in an attempt to characterise water quality in the harbor and the American Samoa Environmental Protection Agency (ASEPA) began its monitoring efforts soon after. The two tuna canneries were targeted first for management actions and both agencies worked to guide the canneries towards improved waste management, which included installation of a waste treatment system, extending the canneries outfall pipes to the outer harbor, and the segregation of high nutrient wastes for off-shore disposal. The success of the corrective action for Pago Pago Harbor was dramatic with a major drop in the level of nutrients (nitrogen and phosphorus; N - P) concentrations in harbor waters as a result of this action. The N - P concentrations plummeted after the canneries were required to dispose of wastes beyond the inner harbor and there was a corresponding decrease in chlorophyll and turbidity, and an increase in dissolved oxygen and light penetration.

A coral reef monitoring program started a long time before major changes in human activities. Monitoring of coral communities along the 'Aua Transect' on the east side of the harbor started in 1917 and has continued at irregular intervals since. Past records combined with local community reports indicate the lush coral cover that was historically present in the harbor began to decline around the 1950s. This decline in coral correlated



Continued water quality monitoring has demonstrated a rapid improvement in water quality in the inner harbor after the tuna canneries improved waste treatment in 1990 and pumped the wastes into a deep ocean outfall (source ASEPA 2001).

with a decrease in water quality in the harbor, which was associated with an increase in poorly managed human activities, particularly the tuna canneries. Recent monitoring of coral reef communities in the harbor suggests, however, that some coral reefs have started to improve during the past 10 years in response to improved water quality. Thus, coral monitoring has provided managers with a valuable perspective on changes in the coral reefs in the harbor over time, particularly in relation to other factors such as water quality.

The results from weekly monitoring activities in catchment streams and harbor beach sites have also been shared with the local communities through regular newspaper postings, in English and Samoan, resulting in increased community awareness.

How successful has it been?

Pago Pago Harbor is a good example of how monitoring can assist in reversing the negative environmental impacts from human activities. Monitoring highlighted changes in water quality and coral reef health and demonstrated the success of the management actions. While the inner harbor still has problems with solid waste and there is heavy sedimentation after major rain storms, the days of algal blooms, floating mats and objectionable odours, are past. The middle and outer harbors, which suffered less degradation than the inner harbor, now have blue water, white surf, and coral cover is starting to recover. There are many spots throughout the harbor that have 30m visibility and coral monitoring has shown a rapid recent increase in coral cover. Harbor water quality and coral reef cover are still regularly monitored and data show consistent trends towards improvement.

These results show that management has been successful in addressing a major water quality issue in the harbor, but there are other issues that still need to be addressed. For many years, cannery wastes masked the other contributors to harbor degradation. With these wastes greatly reduced and under control, data from monitoring activities suggested that non-point source pollution, stemming from land use practices, lifestyles, and human behaviour within the watershed, was resulting in harbor degradation. Once this was recognized, monitoring efforts were expanded into non-point source efforts, which continue to support management actions.

Lessons learned and recommendations

Continual monitoring has demonstrated that:

- Water quality monitoring played a key role in implementing and demonstrating the successful management of tuna cannery operations;
- Continued water quality monitoring also highlighted additional problem sources which can now be managed;
- Coral reef monitoring has demonstrated improved coral reef health as a direct result of water quality issues;
- Monitoring has played a key role in informing stakeholders of the water quality issues; and
- Public awareness raising and information sharing is critical in making the community aware of the current impact of water quality stemming from their activities.

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CaseStudy 13

American Samoa Bans Destructive Scuba Fishery: The Role of Monitoring in Management

Alison Green

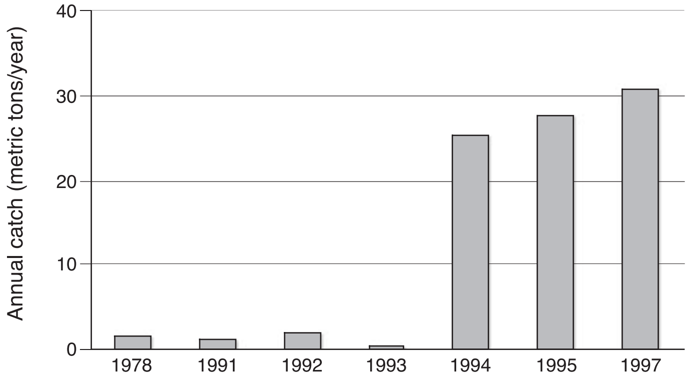
The challenge

It was important to act decisively when a new, high technology commercial fishery became established (the night-time scuba fishery) in the mid 1990s on the main island of Tutuila, American Samoa. This island is heavily populated and fished by artisanal and subsistence fishermen. The new fishery, which dramatically increased the catch of reef fishes on the island, posed a new threat to both fish populations and local fisheries. Urgent action was required to stop this fishery, but there was not enough time for a detailed assessment to be done. Local managers and scientists acted with the best available information, based on long-term monitoring of the fishery and fish populations.

What was done?

American Samoa has three long-term monitoring programs: two programs in Pago Pago Harbor and Fagatele Bay National Marine Sanctuary (since 1917 and 1985 respectively); and broad-scale surveys of the reefs throughout the Territory since 1996. These surveys have been conducted by visiting scientists (C. Birkeland and A. Green) since 1985 and 1994 respectively.

The government Department of Marine and Wildlife Resources has also monitored the coral reef fisheries intermittently for many years, and was the first to show that there was a problem with the scuba fishery.



There has been a dramatic (15 times) increase in catch of reef fish, especially parrotfishes, since the scuba fishery started operating. Parrotfishes are heavily targeted by this fishery.

This information led local managers to hold public meetings to discuss banning this fishery, and they invited the visiting scientists to present their survey results. The scientists observed that there was an alarming decline in the reef fish populations on Tutuila since the scuba fishery had commenced. The scientists, however, reported that it would be more than a year before quantitative data would be available to support their observations. They agreed that the situation was too severe to wait for more information, and supported banning the scuba fishery immediately. The local community also reported that subsistence fishing had become more difficult in recent years since the scuba fishery commenced. The perception was that teams of night-time scuba fishermen were working their way around the island, systematically wiping out reef fish populations.

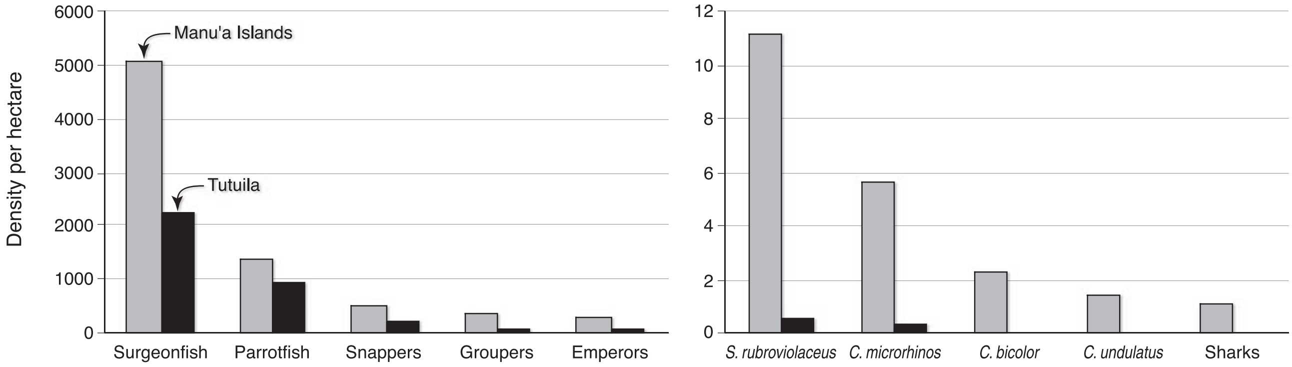
The scuba fishery was banned by Executive Order by the Governor of American Samoa in April 2001 (and subsequently banned by regulation in January 2002) due to concerns that this greatly increased catch rate would lead to overfishing of the reef fish populations. A recent survey confirmed that the reef fish populations on Tutuila are more heavily affected by fishing than those on the adjacent Manu'a Islands (where this fishery did not become established, and fishing pressure is lower), and that the local government did the right thing in banning this highly efficient fishery.

For example:

- Densities of the five major fisheries families (including parrotfishes) are lower on Tutuila than in the Manu'a Islands; and
- Large reef fishes that are particularly vulnerable to overfishing, such as large parrotfish (*Cetoscarus bicolor, Chlorurus microrhinus*, and *Scarus rubroviolaceus*), maori wrasse (*Cheilinus undulatus*) and sharks are now absent or rare on Tutuila, but are still present in Manu'a.

How successful has it been?

The coral reef and fisheries monitoring programs have been very successful in assisting the local government in banning this destructive fishery. Recent monitoring data show that local managers did the right thing in banning this highly efficient fishery before fish stocks were seriously overfished on Tutuila. If they had waited another 18 months for more rigorous scientific evidence before they acted, the fishery would have continued and probably resulted in more serious impacts on the fish populations.



Left:* *This shows that the density of the five major fisheries families are very different on Manu'a Islands compared to Tutuila where fishing pressure is higher (see Green 2002).

Right:* *The density of large reef fish species is also lower on Tutuila than in the Manu'a Islands (see Green 2002).

Local enforcement officers report that there has been little or no scuba fishing around Tutuila since the ban. However, this fishery has not stopped it merely displaced to neighbouring Samoa, which has subsequently banned the fishery (through traditional bans and new fisheries legislation). It is likely that this fishery will move to other Pacific countries.

Lessons learned and recommendations

- The night-time scuba fishery is highly efficient, and poses a major threat to coral reef fishes (particularly parrotfishes). This fishery should not be allowed to operate in an uncontrolled manner, because scuba fishing will quickly overfish local fisheries resources, and recovery may take decades (if at all);
- Monitoring can play an important role in fisheries management. On Tutuila, two types of monitoring programs contributed to banning a destructive fishery: monitoring both the fisheries catches; and the reef fish populations;
- Scientists and managers should not wait until more information is available, but should take the precautionary approach and act decisively to protect their resources if there is reasonable justification;
- Management actions can be most effective when supported by relevant stakeholders, including managers, scientists and the local community.

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Case Study 14

Monitoring and Partial Cleanup at Rose Atoll National Wildlife Refuge (NWR) After a Shipwreck

Jim Maragos and Jeff Burgett

The challenge

The 250mT (metric ton) Taiwanese fishing vessel *Jin Shiang Fa, g*rounded on Rose Atoll refuge in 1993. The U.S. Fish and Wildlife Service (FWS) and the American Samoa Division of Marine and Wildlife Resources initiated immediate damage assessment and long-term monitoring of major fuel and chemical spill impacts on the reefs, especially to crustose coralline algae on the reef flat, slope and lagoon. A salvage tug could only remove the bow section from the reef and the remaining two-thirds of the ship disintegrated into thousands of pieces, with lighter parts washing into the lagoon. An invasive blue green algal mat (*Lyngbya, Schizothrix*) quickly established on dead reef surfaces and spread along the entire length of the SW reef, threatening the coralline algae. Dissolved iron from the metallic debris was thought to be stimulating the blue greens; this was confirmed in 1997 and 2002 by chemical analyses.

What was done?

After the grounding, FWS organised partial removal of metallic debris from the SW reef flats and fore reef during 3 cleanup efforts in 1999-2000, and 105mT of metallic debris and 2mT of non-metallic debris were removed. However there is still 40mT of large metal on the fore reef and another 10mT of other debris in the lagoon. Surveys of fish, giant clams, benthic algae, and dissolved iron have been made between 1994 and 2002 to assess coral reef response to the damage. FWS also sponsored general coral surveys at 7 ocean and lagoon sites in 1994 and installed 7 permanent transects on lagoon patch reefs in 1999-2000.

In February 2002, FWS and NOAA scientists completed fish, benthic algae, dissolved iron, invertebrate, and coral surveys including:

- 7 rapid ecological assessments and 2 new permanent 50m transects on ocean reefs;
- coral surveys at 4 existing and a new 50m permanent transect on lagoon patch reefs;
- collection and removal of marine debris from near Rose Island;
- algal quadrat re-surveys along reef flat and surf zone transects ; and
- collection of 35 water samples for dissolved iron analysis.

The water samples showed a slight decline in dissolved iron concentrations compared to pre cleanup levels. The 2002 visit allowed FWS scientists to complete the first re-survey of all sides of the atoll since the 1993 shipwreck and coral bleaching in 1994.

How successful has it been?

Coral surveys in 1994 showed that coral populations were only locally stressed by the ship grounding, but an unrelated coral bleaching event in 1994 damaged many large table, rose, lobe, and brain corals to depths of 20-30m but their final fate could not be determined. However, 5 genera (*Acanthastrea, Barabattoia, Favites, Scapophyllia,* and *Stylophora*) and 20 species including 8 *Acropora* reported in 1994 were not seen in 2002 and may have died in the bleaching event.

The 2002 coral surveys revealed that corals were in the early stages of recovery from a massive kill, presumably from the combined effects of the 1994 bleaching and the 1993 grounding. Coral diversity is still high; 29 to 51 species per site on ocean reefs and 13 to 15 species on lagoon reefs, with 72 species reported in 2002 (compared to 49 in 1994). Coral cover in 2002 was lower on windward fore reefs, averaging 15-20% compared to 30-67% on more sheltered reefs. The 1994 estimates for coral cover averaged 60-70% on fore reefs, indicating that coral recovery has a long way to go. Coral cover on lagoon patch reefs varied from 25-33%. Lagoon back reefs near the grounding site have many small brain corals and several species of small table *Acropora.* Reef flats in the surf zone near the grounding site now have more rose coral *Pocillopora*, however bits of the blue green alga *Lyngbya* are breaking off and drifting into the lagoon and smothering young corals, and large drifts of other blue green algae still accumulate in the lagoon, suggesting that algal growth rates are still high.

The pink coralline algae have recovered only slightly since the 1999-2000 cleanup. The zone of heavy growth of *Schizothrix* and other blue-greens had shrunk from a 700m to a 400m wide 'black' band by 2002, with a less severe 'brown' zone spreading out another 200m at each end. The 2002 studies confirm that the remaining 40mT of iron should be removed before the coralline algae can fully re-colonise reef habitats. There is still metallic debris on the fore reef slopes and a few small pieces have washed onto the reef flat. Most of the pieces are less than 5mT, but the large engine shaft and block remain embedded in the upper reef margin. Further debris removal will require much larger and more expensive equipment to eventually allow coralline algae to compete successfully against the blue-green algae and become established as the primary reef builders at the atoll.

Lessons learned and recommendations

- It is easier to mobilize scientists and resource managers to assess damage from a shipwreck in a valuable protected area;
- Initial monitoring results helped justify a partial emergency cleanup in 1999-2000;
- Repeated monitoring of algal and coral populations downstream indicated that problems continued due to remaining wreck material that was scattered across the reef flat and the lagoon;
- The long-term effects of the 1993 ship grounding was compounded by the 1994 coral bleaching event and close examination of the data was necessary to distinguish between the two stresses;
- Assessment and monitoring data helped convince the U.S. Coast Guard in 2003 to complete ship debris cleanup and sustain monitoring over the next decade.

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Case Study 15

Running Successful Monitoring Programs on a Small Island: Bonaire, Netherlands Antilles.

Kalli De Meyer

Case study 15

The challenge

The Bonaire National Marine Park (BNMP) in the Netherlands Antilles has achieved global prominence for innovative marine conservation. In 1992, they introduced fees for scuba divers to finance MPA management. Early monitoring of the reefs by visiting scientists was occasional, however, and it was not sustainable. Therefore the challenge for the BNMP was to support MPA management with an appropriate and effective long-term monitoring program that could be implemented with the few resources, limited personnel and low funds available in this isolated location.

MPA management has experimented with several different monitoring programs over the past 12 years to assess the effectiveness of management strategies and quantify the impacts of human and natural disturbances. These data have been repeatedly used in MPA decision making by allowing timely responses to threats, stimulating policy changes and driving the research agenda.

What was done?

MPA management has participated in a number of monitoring programs including Reef Check and regional ones like CARICOMP, AGRRA, REEF. They also designed their own using stratified, random photo quadrat sampling. The programs were run either by visiting scientists or by Marine Park staff and volunteers. The MPA staff routinely collect:

- data on physical parameters (temperature, salinity, visibility and meteorological data);
- data on the use made of the Park;
- detailed statistics on yacht visitation;
- sighting forms of whales, dolphins and turtles (together with the Sea Turtle Club Bonaire); and
- monthly statistics on dive site use from dive operators.

The Marine Park was lucky to have access to a monitoring program established in 1974 by Rolf Bak (NIOZ, Holland) with 4 permanent photo quadrats, which have been photographed annually.

How successful has it been?

All monitoring programs have yielded valuable data on the status of the Bonaire reefs and assisted management decision making. The data also convinced local decision makers of the need to protect the fragile fringing reefs by controlling development and improving waste water treatment. Between 1993-97, the monitoring data collected and analysed by students from UK universities indicated a need for more research into diver impact. A study commissioned in 1994 has lead to significant changes in BNMP policy and set new priorities on controlling threats to the reef. Unfortunately MPA staff had insufficient time to continue the program and it was abandoned.

The photo quadrat data from 1974 show a dramatic loss of coral cover at all depths, especially at 20m since about 1990. Reef loss is probably related to repeated bleaching events, coral disease, and overgrowth by algae and a colonial ascidian *(Trididemnum solidum)*. These losses are coincident with rapid increases in tourism and coastal zone development and the data were used to convince decision makers to implement coastal construction guidelines and install waste water treatment facilities in coastal resorts.

Participation in global and regional monitoring programs is beneficial for the MPA because it allows them to compare their reefs with different biogeographic areas. CARICOMP data collection from 1994-99 also showed a gradual but persistent decline in coral cover and increases in algal abundance. Physical data from this program were used successfully to predict bleaching events and implement timely campaigns to alert the local dive industry to exercise extreme care at dive sites. The CARICOMP methods are, however, labour intensive and data collection was primarily conducted by visiting scientists. This program stopped because of a lack of human resources and funding in the BNMP.

AGRRA training and monitoring in 1999 found that the Bonaire reefs were amongst the 'healthiest' in the Caribbean with high coral cover and diverse fish populations, including high grouper counts. However, the local volunteers who were trained are no longer working on Bonaire and the program stopped.

The MPA staff have encouraged local volunteers who were trained to identify fishes, invertebrates, seagrasses and corals. The volunteers have used Reef Check protocols at two sites annually since 1997, and REEF (Reef Environmental Education Foundation) has trained volunteers to 'expert fish spotter' level. Since 1995, the volunteers have recorded 391 fish species on Bonaire's reefs; the highest count at any location in the Caribbean. The volunteers have collected data on the spatial and temporal distribution of the colonial ascidian as part of a comprehensive benthos study in the largest seagrass bay. They are also studying coral larval recruitment on Bonaire reefs.

Bonaire has been recognised by the ICRAN project as a Demonstration Site for the Caribbean. The US National Fish and Wildlife Foundation has provided funds to develop standard monitoring protocols for the Netherlands Antilles to enable direct comparisons with other Marine Parks and improve the involvement of volunteer groups.

Lessons learned and recommendations

- Monitoring programs by visiting scientists, although yielding excellent data, were not sustainable, because the Bonaire MPA had insufficient trained staff and funds. Any plans for monitoring programs should be based on the available resources for continued data collection and analysis;
- Monitoring programs developed by Marine Park staff and volunteers are more reliable and sustainable, and these programs can respond quickly and effectively to management needs. Monitoring programs should be based on local personnel and equipment;
- Established regional monitoring programs are important in providing a regional dimension and assistance with materials, training and advice. They are unsustainable in the long-term without sufficient local capacity;
- It is easy to be over ambitious when designing monitoring programs: small-scale data collection with limited replication can also provide valuable information when monitoring change;
- The monitoring data have been used by the Marine Park to increase awareness in the local community of the fragility of the reefs and the need for conservation;
- For small island MPAs, local volunteer groups may provide an important alternative resource to implement basic monitoring programs such as Reef Check and REEF. Such programs require considerable training and organization, and the volunteers should be involved in planning and implementing projects. Special incentives, such as social events, souvenirs and recognition are needed to maintain interest and lead to more sustainable involvement;
- Volunteer programs lead to better understanding and increased stewardship and support for conservation of coral reefs and the Marine Park;
- The Marine Park monitoring programs failed to detect chronic over-fishing by local fishermen and massive declines in reef fish populations, particularly grouper, snapper and grunts. This was detected through chance observations by visiting scientists compared with historical data;
- Long-term historical data are invaluable in assessing the status of reefs and as support for long-term monitoring programs.

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Case Study 16

Broad-scale Monitoring of Coral Reef Protected Areas in Colombia

Jaime Garzón-Ferreira

The challenge

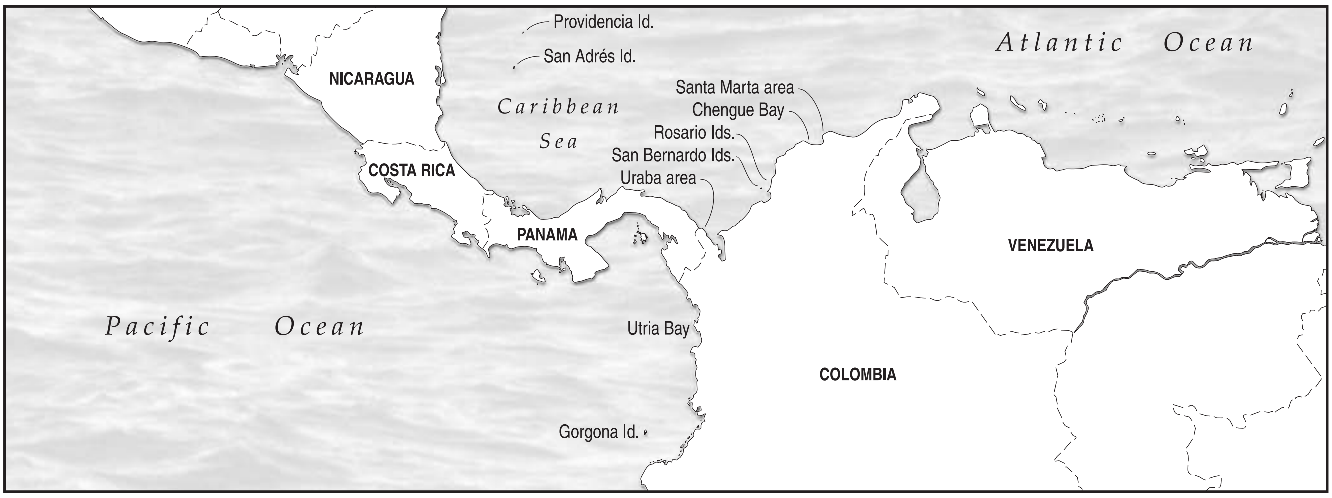
The Government and management agencies had only fragmented, incomplete or inadequate data on the status of Columbia's coral reefs until the early 1990s. This meant that effective management of these reefs was not possible. There were large areas of coral reefs scattered over a vast area, but the potential budget for monitoring was very small.

Colombia has coral reefs in the Caribbean and the Eastern Tropical Pacific, with about 1100 km^2 in the Caribbean, scattered over 21 discrete areas from reefs fringing the mainland or rocky shores, reefs on the continental shelf around offshore islands, out to oceanic reef complexes in the Western Caribbean (San Andrés Archipelago). These oceanic reefs are the best-developed and include atolls, banks, barrier reefs, fringing reefs and patch reefs, and contain more than 75% of Colombian reef area. The Pacific coast reefs cover less than 1 km^2, mainly on Gorgona Island and Utría. Most of the Colombian coral reefs are under some form of governmental protection, but only 21% are in the National MPA system, which is supported by legislation to restrict damaging activities.

There has been considerable coral reef decline since the 1980s, both inside and outside MPAs. Reefs in the Pacific suffered high levels of coral bleaching mortality in the 1983 ENSO event, and Caribbean reef areas have lost much live coral cover due to mass mortalities of corals and other invertebrates from disease and bleaching, overgrowth by algae and overfishing. The 'Instituto de Investigaciones Marinas y Costeras (INVEMAR)' spent the last 10 years designing, organising and implementing a coral reef monitoring system to address the causes, to determine the extent of degradation, and to provide the data to management agencies and international organizations.

What was done?

Reef monitoring in Colombia started in 1992 when INVEMAR joined the CARICOMP program with one permanent monitoring site in the Caribbean. The program expanded in 1998 as a nation-wide reef monitoring system (SIMAC) to include water quality measurements, a yearly estimation of benthic reef cover, coral disease incidence, gorgonian density, abundance of important mobile invertebrates, fish diversity and abundance of important fish species. We installed and evaluated monitoring stations in 3 areas in the Caribbean (San Andrés Island, Rosario Islands Natural Park and Santa Marta-Tayrona Natural Park) and at Gorgona Island Natural Park in the Pacific. We established 24 monitoring stations, each with 5 permanent transects in 1998. As resources became available, we added more monitoring stations such that in 2002 the SIMAC network now has 8 reef areas (6 in the Caribbean; 2 in the Pacific) with 58 stations and 246 permanent transects. The additional areas are Providencia Island (Caribbean), the San Bernardo archipelago (Caribbean, Natural Park), the Urabá area (Caribbean), and the Utría bay (Pacific, Natural Park).



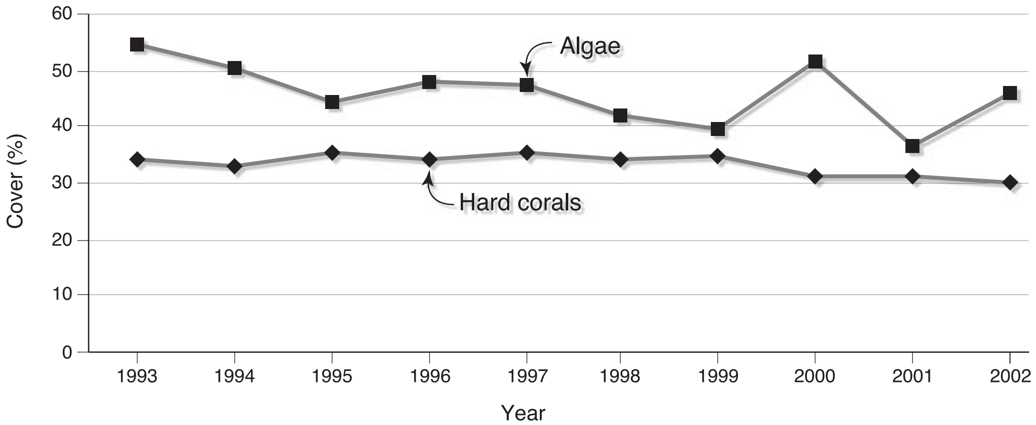
The coral reefs of Colombia are spread over 2 oceans and vary from those just off shore to mid-ocean atoll-like reefs in the Caribbean. This presents special logistic problems for monitoring with large distances and very different reef types.

The primary goal was to make SIMAC information useful and accessible to scientists and managers, so we developed a functional database with systems for data storage and access via the internet. A query system permits examination of raw data on-line, plus it provides some basic statistics (means, standard errors) and graphics.

How successful has it been?

The majority of the monitored areas (71%) and stations (52%) of the SIMAC program are located within MPAs and the managers are becoming more impressed with the quantity and quality of data available and are now seeking to expand monitoring into more areas within Columbia. The Natural Parks agency has signed an agreement with INVEMAR to help develop SIMAC within the MPAs, as well as CORALINA which is the resource management unit in the San Andrés archipelago. The monitoring data are being used to support the management of protected reefs, particularly because they have easy access to these data and were involved in the planning and operation of the program.

The SIMAC data were also used to prepare reports in 2000, 2001 and 2002 on the status of marine resources in Colombia for the Ministry of the Environment and other resource management agencies. A survey was conducted to determine the attitudes of managers towards the monitoring program, and most reported that the program provided useful information for reef management.



Monitoring over 10 years has shown that Chengue Bay has stable high live coral cover, unlike many other areas of the Caribbean therefore it was designated as a no-take reserve. Its value is accentuated because it is a reference site in the Caribbean because of the long-term environmental data set. There are less than 6 years data for most other areas, thus the data have not been used yet in resource management decisions.

Lessons learned and recommendations

- Close collaboration between scientists and resource managers in the design and implementation of a monitoring program promoted collaborative decision making and identified the information needs of MPA managers;
- Involving MPA management people in field monitoring stimulated more interest and support for the monitoring program, and improved the exchange of information and expertise between scientists and managers;
- Writing an annual report on the status and trends from the monitoring program built awareness among managers, scientists and the government. Keeping the database routinely updated has ensured that monitoring information is always available for reef managers.

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Case Study 17

Socioeconomic Monitoring in the Florida Keys National Marine Sanctuary

Manoj Shivlani, Vernon R. Leeworthy and Thomas J. Murray

The challenge

The Florida Keys National Marine Sanctuary (FKNMS) encompasses 9,950 km^2 in South Florida and the Florida Keys and was designated in 1990 to be one of the first sanctuaries to develop and implement no-take zones. The Sanctuary plan has 24 no-take zones, which aim to protect ecosystem function and vulnerable resources, avoid concentrations of uses, and reduce user conflicts. However, the zone plans have met opposition from stakeholders who argued that the zones will reduce their ability to use the marine resources and could force them out of business. The Sanctuary Research and Monitoring Action Plan set up long-term ecological and socioeconomic monitoring to better understand the impacts of FKNMS regulations on the Sanctuary and on the users, especially assessing the impacts of the no-take zones.

What was done?

The Socioeconomic Monitoring Program was set up in 1998 by the National Oceanic and Atmospheric Administration (NOAA) to assess the effects of FKNMS regulations on commercial fisheries and the local economy in the Florida Keys. The program has also tracked user attitudes, perceptions, and beliefs concerning FKNMS regulations and strategies from 1998-2002. The SMP integrates field surveys and existing fishery information and included 4 panels of users based on their **location**: Dry Tortugas Ecological Reserve; Western Sambo Ecological Reserve; or **fishery**; Marine Life Collectors; and General Fishery. The location panels represent fishers who used the Dry Tortugas and Western Sambo regions prior to their implementation as no-take zones. The marine life collectors consist of fishers from the Florida Keys who collect tropical fish and invertebrates in the smaller no-take zones (designated as Sanctuary Preservation Areas and Special-Use Areas). The general panel serves as a control, to determine whether effects may result from factors other than the FKNMS regulations.

Each panel contained 5-9 fishers, with a strong and long-standing interest in the fishery and who were identified from previous research and experience in the region. The members provided economic and social data on an annual basis.

Panel Costs and Returns from 1997 to 2001 in US Dollars

PANEL	COSTS/RETURNS	1997-98	1998-99	1999-2000	2000-01
Dry Tortugas	Harvest total	196,090	215,778	189,299	149,759
	Net earnings	61,909	38,118	47,139	29,064
	Vessel cost	163,333	218,333	235,000	190,000
	Gear cost	40,975	43,750	39,571	34,750
Western Sambo	Harvest total	97,725	129,666	133,149	81,464
	Net earnings	27,725	45,913	44,390	22,299
	Vessel cost	138,889	140,500	185,500	146,857
	Gear cost	69,899	79,766	98,718	76,000
Collectors	Harvest total	48,200	N/A	31,958	30,109
	Net earnings	N/A	N/A	19,330	12,022
	Vessel cost	40,750	N/A	56,000	44,167
	Gear cost	17,750	N/A	17,300	15,417
General	Harvest total	96,523	113,379	129,557	92,252
	Net earnings	30,806	37,577	39,778	20,970
	Vessel cost	70,000	70,000	77,167	52,143
	Gear cost	47,367	63,416	67,800	56,243

The table shows the panel costs and returns from 1997-2001 with harvest totals and net earnings increasing or remaining stable in the first 3 years but declining in the 4th year. The drop in production is reflected in lower capital investment in vessels and generally decreased gear costs for the 4th year, except for the General panel.

The information collected suggests that extra-Sanctuary factors may contribute strongly to inter-annual fishery harvests and production e.g. higher vessel and gear costs by Western Sambo fishers between the 1998-99 and 1999-2000 seasons were related to gear lost during Hurricane Georges in 1998, not the no-take zone. Similarly, 4th year reporting shows that all panels had lower earnings, and the Dry Tortugas, Western Sambo and general panels all had substantially lower harvest totals. This may be related to a decline in the major spiny lobster and stone crab fisheries in the region, rather than the no-take zones. This is reinforced when these data are compared to those from the general, or control, panel. All 3 panels had major decreases in earnings and harvests from previous years, and these may be due to local impacts of the no-take zones that lead to higher operating costs (i.e. displacement, crowding), but are not reflected in the inter-panel analysis. User attitudes, beliefs, and perceptions concern the opinions of all panel members on the FKNMS and its zoning strategy. The information collected was compared with a baseline attitudes, beliefs, and perception study from 1996 to determine whether fisher opinions have changed over time. Most panel members (94%) do not believe that the no-take zones have increased or replenished stocks in the region, and none believe that his group has been a primary beneficiary of the zoning strategy. Almost two-thirds of the panel members do not favor the current zoning plan, and 77% oppose further zones in the Sanctuary. Finally, 68% are against the establishment of the Sanctuary.

The monitoring program has also collected spatial data from panel members to determine if there are major differences in areas used, species caught, gear type, and home port. The data suggest that panel member fish in areas of the FKNMS that are close to their home ports, except for the Dry Tortugas fishers and those targeting stone crab and king mackerel, and occasionally spiny lobster. Fishing activity is very high around no-take zones, and large quantities of lobster, reef fish, and aquarium species are harvested near the boundaries of the no-take zones. An important finding was that a single-year data set is only a snapshot of spatial fishing effort and longer comparisons are needed. Fishers decide to expand or contract their fishing areas and activities due to many factors, including changes in regulations, financial solvency, and environmental conditions; often a complex combination of all 3 factors.

Lessons learned and recommendations

- This socio-economic monitoring program was a useful and cost-effective means of assessing commercial fishing (and other uses) in the MPA;
- The monitoring was particularly useful in identifying non-MPA sources of perturbation or fluctuation; however, abbreviated monitoring cannot replace more comprehensive analyses required to determined total socio-economic impacts;
- The monitoring works best when other data and information are collected. The FKNMS, the State of Florida and NOAA Fisheries all collected detailed fishery statistics and the FKNMS had established a baseline of fisher attitudes, perceptions, and beliefs;
- Monitoring programs can only succeed where there is strong fisher (stakeholder group) support for and involvement with the study. The program should collect data for several years, therefore there is a need for a long-term commitment by users, researchers, and funding bodies, otherwise there can be no effective monitoring in the MPA.

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Methods

Method 1

Select the Scale of Coral Reef Monitoring Programs

Before starting monitoring, it is essential to select the most appropriate scale for the program. This will depend on whether you are managing a small or large MPA, whether you are experiencing short-term or long-term impacts, as well you must consider what are the available resources in trained people, money, equipment and time. These will decide whether:

- to conduct monitoring over a large or small spatial scale (=area); and
- to commit to a long-term or a short-term monitoring program;
- the level will be **community**, **management** or **scientific** (see No. 2. Resource Status and Long-Term Trends, p 4), based on available financial resources and human expertise.

These decisions are important to ensure that the program is sustainable, able to answer the questions posed, and to ensure that the program is achievable with available resources

Large-scale Monitoring is used to assess major disturbances like tropical storms, crown-of-thorns starfish predation, coral bleaching, coral diseases and sediment pollution over large areas. Monitoring is important to understand the impacts of these disturbances on reefs and determining the nature and rates of recovery. Standard monitoring protocols are available to compare areas before and after the disturbances, or compare similar areas that have and have not been affected (see No. 2. Resource Status and Long-term Trends, p 4).

Small-scale Monitoring applies when a MPA is very small or it is predicted that a disturbance will only have local impacts, like those listed for short-term monitoring. Frequently changes in MPA status can be detected over a small-scale if the resources available to a manager are limited e.g. not enough people or no boats to survey distant reefs. Specific examples include damage from tourist divers around a resort or platform or ship groundings on a coral reef.

Long-term Monitoring is the most common form of monitoring to provide data and information on the status and long-term trends of the coral reefs and also the coral reef user communities. This information is essential for performance evaluation and adaptive management. The major monitoring parameters usually include:

- assessing corals and other benthic organisms for changes in bottom cover;
- determining whether there are changes in the major species or life forms;
- assessing total fish populations with an emphasis on the number and size of key target fisheries species;
- monitoring fish catches, prices, preferences and catch per unit effort;
- assessing income distribution amongst fisher communities.

Short-term Monitoring programs are less common, but can assist managers detect changes from industrial or tourism developments, sediment increases from deforestation, impacts of a ship wreck on a coral reef (see Case Study 14, p 40). A short-term study of 2 to 4 years would be important if a manager needs to monitor changes from a development, like building a tourist resort.

Data Storage, Analysis, Accessibility and Reporting

Monitoring without adequate and careful handling of the data and information obtained is a waste of time and money. Unfortunately, many monitoring programs have failed because the data have been lost or stay in filing cabinets in the same format as when collected. Diving to collect the data can be fun; but there is often less enthusiasm for processing the data.

MPA managers should seek advice on how to store, analyse, and report all data obtained from monitoring. The whole process should be planned in advance with a budget allocation to ensure that the data are correctly stored, analysed and made accessible.

The critical steps for data management are:

1. Plan the data system before collection. Develop a protocol for collecting and storing the data in the field, transferring into the computer and into the home base. Develop a data entry program that is compatible with the receiving database;
2. Take field notes at the time of sampling (who collected the data, methods used, problems encountered). Put these notes into the database for interpretation later. Taking a portable computer into the field is a good idea;
3. As soon as possible, the data collected should be entered into the database and backed up to ensure that there is a second set if the first is lost; if this is delayed, the data may be difficult to interpret;
4. After entry, it is essential to check the data point by point to avoid data transcription errors. This is best done with the help of a second person;
5. Soon after data entry and checking, preliminary analyses should be performed to verify that there are no serious errors and also to give feedback to the monitoring team and other stakeholders. This is best done through graphic presentation of the data using a data analysis package. AIMS in Australia produced ARMDES for this purpose and this is being updated by ReefBase for global distribution by the GCRMN;
6. Preliminary analysis may show that there is a need to change the sampling methods. This may be through more samples, more frequent samples, or it may show that observers are not identifying some categories or species correctly;
7. All data should be permanently archived into to another computer and a backup copy maintained elsewhere;
8. The global database, ReefBase based at the WorldFish Center in Penang Malaysia can provide permanent storage of primary and summary data. Permanent storage is strongly recommended.

ReefBase (www.ReefBase.org) is the accepted global information system for coral reef conservation and management and was developed by the WorldFish Center, Penang Malaysia. It offers a range of information, tools and resources for managers, students and scientists relevant to managing reefs for sustainable use and production. ReefBase stores all records of coral bleaching worldwide. It currently has over 6,000 records in its database, which can be accessed as reports, graphs and maps. All data from Reef Check and the GCRMN are stored here. The AIMS LTMP (see Case Study 9 p 30) shows how data can be reported with their results on the www.aims.gov.au/reef-monitoring.

Method 3

Ecological Monitoring Methods for Coral Reefs

These are commonly used methods for very basic coral reef ecological monitoring. The ecological methods have been developed over more than 30 years, whereas most of the socio-economic methods for coral reefs have only been developed during the last 10 years and are still under active development.

Ecological assessments are used to monitor the status and long-term trends of biological and physical parameters associated with coral reefs. Standard protocols for surveying tropical marine resources, including coral reefs are in English *et al.* (1997).

Physical parameters to measure

- Depth, bathymetry and reef profiles – these are critical in developing maps for management plans and selecting sites for monitoring;
- Currents – general measures of current directions and speeds are important for predicting the flows of pollution or new larvae;
- Temperature – measures of water temperature at different locations on coral reefs. These are important when monitoring for coral bleaching;
- Water quality - the amount of sediments, nutrients and pollutants in the water to assist in assessing pollution. Sediment can be measured in basic sediment traps;
- Visibility – how far one can see under water (i.e. penetration of light for photosynthesis);
- Salinity – this should only be measured when large flows of freshwater have occurred to determining the level of stress to corals.

Biological Parameters to Measure:

- Percentage cover of corals, sponges, algae and non-living material (i.e. dead coral, rock and sand) – this measures the area of living corals and also detects dead corals which may indicate stress;
- Species composition and size structure of coral communities – measure either the species or genera or life-form categories depending on available expertise;
- Presence of newly settled corals and juveniles – this measures coral recruitment and potential for recovery;
- Numbers, species composition, size and structure of fish populations (including measures of biomass) – particular emphasis is placed on target fish for fishers or aquarium collectors;
- Juvenile fishes, especially target species – this uses similar methods as above but at smaller scales;
- Populations of organisms of special interest such as giant clams, crown-of-thorns starfish, sea urchins etc.
- Extent of coral bleaching, species or genera of corals showing bleaching and the amount of bleaching in the coral colonies;
- Extent and type of coral disease – measured as above, and can include measures of broken or damaged corals.

Methods to measure parameters

Broad scale surveys: These are used to assess broad changes in coral reef communities over large areas looking for the general structure and health of the reefs as well as track large-scale disturbances (i.e. crown-of-thorns starfish or coral bleaching and disease)

- Manta tows – involves towing an observer behind a motor powered boat around the perimeter of a reef for timed interval (usually 2 minutes) and recording major reef components e.g. coral cover, anchor and blast damage, giant clams, crown-of-thorns starfish etc.
- Timed swims or random swims – involves swimming over the coral reef, usually within a selected depth range, and recording major categories as above. This is particularly useful in searching for the presence of large fish and doing biodiversity presence/absence surveys (a special example is Method 3 for large fish; p 54)

Benthic surveys: These are used to assess changes in individual coral reef community health (or prevalence of disease) over time at smaller scales and generally in more detail.

- Transect lines (tape measures, chains or ropes with knots) – involve monitoring indicators at intercept points or at set intervals along the transect line. The most appropriate lines are 50m fibre glass tapes similar to the ones used by builders. Assessments are usually done by recording data on underwater paper or slates;
- Belt transects (including video monitoring) – involve assessing populations along a belt either side of a transect line, and can be a 1m to 10m wide belt depending on the target (see note below);

- Quadrats (large and small) - involve monitoring indicators in specific sized quadrants, varying from small squares of 10 to 20cm to the most common 1m sides, up to 10m long sides. Assessments can be made of random smaller squares inside the quadrats or by photographing the quadrats and counting what is under fixed points;
- Settlement plates – usually unglazed tiles attached at 45^{o} near a coral reef and assessed microscopically for settled coral colonies.

Tools for recording data

- Plastic Slates or underwater paper – plastic material that is resistant to water. Slates are heavier but can be used many times after cleaning. Underwater paper is lighter and can be washed and stored as a permanent record of the data;
- Photo transects or quadrats – this requires the use of an underwater camera (or pairs of cameras) which can either be the standard film type or newer digital cameras. The photographs can become a permanent record of the site provided they are archived correctly. It is essential to extract the data within a few days of taking the photographs, or else the task can become too large and memory about the site can fade;
- Video cameras – these permit surveys over large areas when limiting time underwater is important. These should only be used for monitoring when there is an existing system of analysis already established and the monitoring is well trained to record the data within several days to weeks of survey. A video provides a permanent record (provided that they are well archived) of a site for later comparison if un-anticipated events occur.

Other Methods

There are many other measures one can take of coral reefs, but all monitoring is time consuming and MPA managers have to select parameters that they need to employ that will provide useful data that can be analysed to show the status and trends in the coral reef resources in the MPA. Where possible all monitoring should be conducted inside MPAs and outside at comparable sites as well to assess differences between managed and unmanaged situations. Methods are listed in **Appendix 2.**

Reference

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Method 4

Socio-economic Monitoring Methods for Coral Reefs

Socio-economic assessments are used to monitor the status and long-term trends of social, economic, cultural and political parameters associated with coral reefs. Standard protocols are available for coral reef socio-economic assessment and monitoring in Bunce et al., 2000 and Bunce et al. 2002.

Socio-economic monitoring aims to understand human behaviour and how people interact with coral reefs. It is not possible to separate human activities and ecosystem health, especially when coral reefs are very important in many peoples' livelihoods. Socio-economic monitoring can measure the motivations of resource users as well as the social, cultural, and economic conditions in dependent communities. Socio-economic data can help mangers determine what stakeholder and community attributes can play a vital role in successful management. The most frequently used socio-economic parameters include:

Social parameters to measure

- Household Demographics – includes the age, gender, education level, religion, literacy, etc.;
- Employment – measures how people earn money or gather food. A special emphasis is on assessing people directly using marine resources, especially fishers;
- Cultural / heritage impacts – measures what areas or reef resources are of special interest to communities for cultural or religious purposes;
- Traditional uses and activities – determines how communities used and managed reef resources in the past. This is used to compare with current practices;
- Social networks and interactions – this is important in determining who are the key decision makers and how decisions are made in the community;
- Community infrastructure – details how communities are governed and how they relate to higher levels of government;
- Local perception of reef management and management success – this is essential for managers to understand and target methods of influencing perceptions in favour of resource conservation;
- Level of understanding of human impacts to reefs – measures whether communities are aware of their damaging activities and concerned about sustainability;
- Level of understanding and cooperation of MPA regulations – managers need this information to develop education programs to increase support for MPA management.

Economic parameters to measure

- Individual and household income – this is essential if the goals are to improve people's livelihoods. A special measure is reef associated activities;
- Catch data – measures what is extracted, where caught and where consumed or sold;
- Use of all products (sustenance vs. economic) – this includes all aspects of harvesting from coral reefs including animals, plants, rock and sand, as well as cultural items;
- Number and type of markets – this follows the flow of fisheries products in and out of the community;
- Fishing effort and changes over time – measures how much effort is put into harvesting from coral reefs and how effort has changed with increases or decreases in resource stocks;
- Local perceptions on extractive vs. non-extractive value of reef – assesses how communities value coral reef for both products and for cultural and aesthetic values;
- Level of reef use by outsiders, including fishers, and a special measure is the value of tourism and the value that tourists place on a healthy coral reef.

Ecological parameters are closely linked to socio-economic ones, therefore both types of monitoring should be done in the same place at the same time. For example, monitoring of fish populations should be directly linked to surveys of fish markets, particularly if there are seasonal changes in what fishers catch. Similarly ecological parameters reflect the natural state of the MPA, which will have impacts on socio-economic factors such as income and employment.

Six basic steps to socio-Economic monitoring

1. Advance preparation, including identifying purposes of the socio-economic monitoring, selecting the relevant indicators, defining the process to conduct socio-economic monitoring, identifying and consulting with stakeholders, and identifying the monitoring team;
2. Data collection through secondary sources
   - National census data - relevant data for selected indicators such as population and employment statistics. These data can be confirmed through surveys in communities;
   - Local government and council records - relevant data for selected indicators such as recreation

patterns or tourism patterns (in some countries religious institutions keep these data);
- Historical sources – includes compiling and reviewing relevant data from previous reports, assessments, and surveys. Many government departments keep these data, often in easily accessible formats.

3. Data collection through key informants
- Interviews – involves interviewing people who have specialized knowledge about indicator due to their experiences or knowledge;

4. Data collection through household interviews

5. Data collection through observation
- Observations – includes qualitative descriptions of what a researcher sees or hears while visiting a community,

6. Data analysis and communication – the same rules for data management as outlined in Method 2 apply for socio-economic data gathering. Planning is essential before starting.

Additional tools for data gathering

- Surveys (mail, phone, person) – involves distributing a survey to a randomly selected group of possible respondents to gain information regarding their knowledge on a subject or to provide feedback or comments;
- Focus / Discussion Groups – involves a selected group of individuals, perhaps key stakeholders, meeting to discuss;
- Public meetings – includes presentations by relevant stakeholders regarding an issue of concern and provides opportunity for community members to provide feedback or comments;
- Cost-benefit analysis - assesses the potential costs and benefits of a resource or activity in monetary terms to determine the most efficient use of resources;
- Multiple criteria analysis – assesses the potential costs and benefits of a resource or activity using multiple data types;
- Citizen juries – involves representative members of the public, acting as concerned citizens, making a decision on behalf of society on a given charge;
- Modelling – used to run simulations, predict effects, or identify effects that may not be intuitive.

Further details on these steps and guidelines on how to conduct socio-economic assessments for coral reefs are in 1. below and online at http://www.aims.gov.au/pages/reflib/smcrm/mcrm-000.html. This contains information on costs, frequency, indicators and a wealth of other information. Practical guidelines on how to conduct socio-economic monitoring for Southeast Asia are in 2. below and online at http://ipo.nos.noaa.gov/coralgrantsdocs/SocMonSEAsia.doc. These guidelines may require some modification for application in other areas and cultures.

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Method 5

A Rapid, Quantitative Survey Method for Large, Vulnerable Reef Fishes

Howard Choat and Rachael Pears

Introduction

MPA managers are often faced with the task of collecting information on the abundance and population size structure of large fish species targeted by reef fisheries. Underwater visual surveys are the most effective way to collect this information, particularly in remote locations. Larger species are particularly vulnerable to over-exploitation, and are often the first to be reduced by fishing in an area. They include sharks, napoleon wrasse *(Cheilinus undulatus),* large parrotfish (particularly the humphead parrotfish *Bolbometapon muricatum* and Pacific Steephead parrotfish *Chlorurus microrhinos),* and large groupers.

These methods are about determining patterns of abundance of a number of larger reef fish species that are targeted by fisheries in many countries. The first step is to develop modified counting methods that account for the characteristics of key target species, including both large and mobile, or cryptic species. The methods used to count fishes need to be carefully chosen to suit the biology and behaviour of the species and the reef locality. Many reef fish species have some of the following attributes: large size; high mobility; relative rarity; patchy or clumped distributions; camouflage; and fairly cryptic behaviour. Therefore such fisheries species may be poorly counted by established visual survey protocols for reef fishes (e.g. small belt transects in Method 3, p 50).

Methods

Here we outline the modified counting methods for: 1. large, mobile reef fishes; and 2. medium and large groupers.

1. **Large, mobile reef fishes**

   When present, sharks, napoleon wrasse and humphead parrotfishes tend to be large and conspicuous in their behaviour, since they tend to swim above the bottom. They can be counted using a long-swim technique, aimed at covering a large area in a short time with minimal diver disturbance. This approach is necessary as these species are mobile, usually have clumped distributions, and may show diver negative or positive behaviour. The long-swim technique consists of 20 minute timed swims with a standardised swimming speed over a depth of approximately 5m along the reef front (just below the reef crest, so that you can see the reef crest, flat and slope where these species tend to occur). Record the size and number of all individuals of these species observed within 10m either side of the observer on underwater paper. For very large mobile species, the appropriate transect dimensions are 400m x 20m. Steephead parrotfish can be counted using the same methodology, although narrower transects (5m either side) are required for this smaller species.

2. **Groupers**

   Most species of groupers are cryptic in behaviour and tend to stay close to the bottom, or hide in caves or under overhangs and ledges. As groupers are often well camouflaged they are easily overlooked, therefore, counting these species requires a modification of the above technique to improve detection rates. These species can be surveyed using slower swimming speeds of approximately 6 metres per minute (to allow the observer to search the substratum more thoroughly) for 30 mins, counting and estimating the size of all individuals within a 5m wide band. The main observer actively searches for groupers within the band, and must be experienced in the underwater detection and identification of the local species. A second observer should swim slightly behind the main observer to record numbers and sizes of any larger mobile groupers that are within 10m either side. This collects information on species such as the brown-marbled grouper (*Epinephelus fuscoguttatus*) that do not usually allow close approach by divers. More visible roving grouper species (e.g. members of the genus *Plectropomus* or *Epinephelus*) can be counted using the methodology for sharks, wrasses, and parrotfishes.

   The information is of added value if raw count data are converted to density estimates to compare abundances over time and among places. First, you need to determine the area of each count by estimating the distance of the swim multiplied by the width of the count. The distance is estimated by measuring swimming speed over measured distances. The distance travelled can also be estimated from the surface if you have a GPS available. Divers can be trained to judge the fixed width by eye (fish within this distance from the swimmer are included in the count). Counts are then converted to a standard density (number, either per ha or 8,000m^2) for comparing densities among areas.

Prior to commencing a count program, divers should calibrate swimming speeds (usually the distance covered in 5 mins) and the accuracy of their width estimates (5-10m each side of the swim line) using tape measures. Observers must be well trained in the survey techniques, underwater identification of local species, and fish size estimation. The divers counting the fish should be the only people in or near the area to ensure that the fish are not attracted or chased away. The procedure for each count must be standardized to achieve consistency and dive safety considerations are paramount. Further useful information on visual survey methods is in the references.

Conclusions

The long-swim techniques have been tested in many countries including the Seychelles, and have proved to be suitable for counting many larger reef fishes. Advantages of these methods:

- long-swims enable larger areas to be covered in a limited dive time compared to small transects;
- disturbance of fish by divers is minimised as no tapes are used before counting;
- these techniques are better suited to fishes that are sensitive to diver activity;
- wider transects for conspicuous species is useful for counting larger fishes that do not allow close approach;
- slower swim speeds with increased search intensity within a 5m wide band produces higher counts than other methods for more cryptic groupers;
- long-swim methods are logistically simple and provide useful data in addition to the more established visual survey methods.

Long-swim techniques are an improvement over small and narrow transects for counting some large, vulnerable fishes. However, the choice of counting method should be matched to the main species of interest. Groups of species with similar attributes may be counted together, but attempts to count all species at once are unlikely to produce useful results. Fish counts focused on fisheries species can provide a rapid assessment of the status of coral reef fishes and valuable long-term monitoring data for MPA and fisheries management.

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Method 6

Water Quality Monitoring in Coral Reef Systems

Jon Brodie

Introduction

Damage to coral reef systems from land-based pollution is one of the world wide issues facing the continued existence of reefs. Well known examples of reefs damaged by water pollution include the Kaneohe Bay, Hawaii, where sewage discharge caused major losses on the coral reefs offshore, and Jakarta Bay, Indonesia where pollution from over 10 million people has been a major factor in the death of virtually all corals in the bay. Even very large reef systems such as the Florida Keys, USA and the Australian Great Barrier Reef have been damaged and continue to be threatened by land-based pollution.

To detect reef damage due to poor water quality, monitoring of reefs using standard 'reef health' methods may be used. However, it is often very difficult to separate the potential causes of reef damage and change e.g. coral reefs may be damaged by bleaching, destructive fishing, natural change, cyclones and coral disease. If it is suspected that water quality is an issue, then a monitoring program to measure ***sources*** of the pollutants, their ***transport*** to the reef areas and thus the ***exposure*** of the reefs to pollutants should be established. Such a monitoring program will complement the monitoring program set up to detect ***biological effects*** on the reef system.

Methods

Sources and loads

Generally land-based pollutants are delivered to the marine environment from a point source. The point source may consist of a pipe carrying sewage effluent or industrial wastewater or more commonly the source will be a river, stream or drain carrying pollutants from the catchment area. As samples can be taken from all of these at a single point, monitoring is relatively straightforward, in principle. The following important categories have to be considered in the design of the monitoring program:

1. **The pattern of flow**
   Effluent pipes often have fairly regular flows and so can be monitored at any time. In contrast, rivers and streams, especially in the tropics, have very variable flows and most pollutants are transported in the wet season. Therefore the sampling of rivers and streams must be concentrated at this time;
2. **Pollutants to be measured**
   There is usually a large range of possible pollutants from a catchment or wastewater discharge, thus it is essential to narrow the range of pollutants measured to include those most likely to be the cause of the problem. Pollutants which can stress coral reefs include suspended sediment, nutrients (nitrogen and phosphorus compounds), toxic metals (e.g. lead, cadmium and copper), petroleum hydrocarbons (lubrication oils and fuels), pesticides, organochlorine wastes and organic matter. It is very expensive to sample and analyse for all these materials, therefore it is essential to target for analysis those pollutants which may be causing the problem and have a known source in the catchment area;
3. **Estimate loads**
   The actual amount (mass) of pollutant being discharged is important to know as well as the concentration of the pollutant in the water. To measure loads it is necessary to know the volume of the discharge as well as the concentration of the pollutant at a number of times during the discharge event;
4. **Catchment source identification**
   To attempt to manage the pollutants, it will probably be necessary to identify the actual source areas or activities within the catchment, which result in the majority of the pollutants. This may involve monitoring 'up the catchment' as well as at the river or stream mouth. 'Proxy' data may also be of use such as the amount of pesticide sold in the catchment, fertiliser use data and sewage treatment plant discharges into the river.

Transport and exposure

As pollutants are discharged into the marine environment from an outfall or river, there are processes that occur to decrease the concentration of the pollutant. These processes include sedimentation, evaporation and biological and chemical transformations as well as simple dilution through mixing with seawater. It is often important to know whether there is sufficient pollutant (either load or concentration) reaching the reef systems to cause biological effects.

Monitoring pollutants in the marine environment, whether in the water column or in sediment or organisms is far more complex than monitoring point source discharges. The three-dimensional nature of the seawater body means that many samples are required to characterise what is happening. Therefore a rigorously designed sampling program is necessary to generate conclusive results. Hydrodynamic modelling may be of use in predicting transport, dilution, dispersion and sedimentation, but such models are also complex and need expert design.

Biological effects

The coral reef monitoring program must include indicators, which are relatively specific to show water quality impacts. Many traditional reef monitoring indicators such as coral cover and fish counts are not very useful in detecting water quality impacts. Indicators such as coral recruitment, recruit survivorship, algal abundance and dynamics, immunoassay methods and photosynthetic performance (PAM) may be more useful indicators for many pollutants.

Conclusions

Monitoring must not only focus on a change in the system, but also on the causes of the change. If pollution is to be managed then the sources of the pollutants must be identified and quantified. Thus an integrated water quality monitoring program should measure sources, transport and effects so that an assessment of management options can be made. The effectiveness of management activities to solve water quality problems can also be tested with such an integrated program of monitoring.

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Appendices

Appendix 1

Monitoring recommendations from the 2nd International Tropical Marine Ecosystems Management Symposia (2003)

The International Tropical Marine Ecosystems Management Symposia (ITMEMS) are specifically designed to provide a platform for coral reef managers to discuss management issues and to prepare recommendations for improved management. The symposia provide a forum for managers to make special requests of scientists to help in providing useful information for direct use in managing coral reefs. Among the many themes addressed at ITMEMS2 in Manila, March 2003, coral reef monitoring prevailed as one of the leading topics of discussion. The participants discussed many issues of coral reef management and recommended that 'Strategic Research and Monitoring Programs' be an integral part of the management of coral reefs and related ecosystems. The meeting stressed that, where possible, the most relevant scientific information should be used to make decisions for MPA management. Additionally, management should be adaptive and responsive to changes in resource trends and how resources are used by communities. Following are extracts from the ITMEMS2 Action Statement which can be found at the ITMEMS2 website at www.icriforum.org/itmems.html.

Several strong messages were reiterated throughout the course of the ITMEMS2 meeting by managers, including the need for continued monitoring and performance evaluation. Managers also emphasized the importance of the free exchange of data and information to user groups and outside stakeholders. Lastly, ITMEMS recognised the importance of coral reef monitoring as a tool for managers and recommended that approximately 10% (range 5 to 15%) of all MPA budgets be allocated for monitoring.

The following are specific recommendations from the ITMEMS2 meeting:

Research and monitoring programs

Well designed and targeted 'Research and Monitoring Programs' are essential components of tropical marine ecosystem management to maintain biological diversity, natural resources, ecosystem condition and services and the values of coral reefs and related ecosystems. ITMEMS2 made the following recommendations and action requests:

- Continued commitment to high quality research and monitoring for tropical marine ecosystem management;
- That research and monitoring programs be highly targeted towards supporting decision makers on key issues;
- That all elements of research and monitoring should incorporate the full involvement of, and respect for the range of knowledge and skills available from, the whole community including scientists, resource users, indigenous people and members of the general community;
- Global evaluation and adoption of existing protocols for management related research and monitoring and development of new protocols where needed;
- Long-term monitoring of environmental and social conditions. This information is essential to provide early indications of emerging issues, measures of background (natural) variation and long-term trends and impacts; and
- Encouraging multidisciplinary research in which socio-cultural-economic and ecological components are integrated and complementary.

Information coordination and dissemination

A major obstacle to effective management and conservation of tropical marine ecosystems is lack of awareness and access to existing information and the experiences of other managers. There is a wealth of information resources scattered among various organisations but much of it is inaccessible. ITMEMS2 made the following recommendations and action requests:

- Summary data and results including performance evaluation from all relevant projects should be made available on ReefBase, FishBase, and other widely accessible venues to promote information exchange, transparency and to stakeholders;
- A centrally coordinated certification and accreditation system should be established to ensure data quality standardisation and documentation. This should include guidelines for data storage safeguards, security, metadata, and the development of a core set of variables and formats;
- There should be a formal obligation (specified in permits, grant agreements etc.) for non-sensitive data to be made publicly available in a variety of formats as soon as possible;
- A code of conduct for data collectors and information managers be developed to ensure maximum free flow of data and proper regard to security for sensitive data;
- Information systems be client oriented, able to provide for demand-driven requests for information in both digital and hard copy formats. Websites storing data in digital formats must be recognised as key data storage access facilities requiring similar levels of support as traditional libraries; and
- As a matter of priority, a global inventory of tropical marine ecosystem databases/information systems should be created and made publicly available.
- There should be immediate action to develop and/or strengthen national, regional and international mechanisms for gathering and sharing information and expertise on the sustainable management of coral reefs and related ecosystems.

Review or performance evaluation

Maintaining and improving management depends upon good information on the implementation of management measures and their effectiveness in achieving the objectives of management. ITMEMS2 made the following recommendations and action requests:

- Management performance evaluation systems are based on clear performance targets and conform to the principles for management performance evaluation, including provision for stakeholder participation in establishment of performance targets and evaluation; and
- The quality of management performance evaluation systems be monitored to ensure acceptability, reliability, compatibility, and conformity to indicators, processes and other related evaluation protocols.

Resources and allocation

The ITMEMS2 participants recognised that the design of performance of any monitoring and evaluation systems should be done in the context of limited resources and competition with other elements of management. ITMEMS2 made the following recommendations and action requests:

- A specific financial resource (5-15%) of the total MPA budget be allocated for monitoring and management performance evaluation.

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Appendix 3

Coral reef monitoring programs, networks and sponsors

AGRRA – Atlantic and Gulf Rapid Reef Assessment
International scientists and managers collaborate via AGRRA to determine the regional condition of reefs in the Caribbean and Gulf of Mexico using a rapid assessment protocol. AGRRA seeks to provide baseline data on coral reef health by visual assessments of coral cover, coral mortality, coral recruitment, macroalgal index, sea urchin density, abundance and size of key fish families. Consistency between observers is ensured through training workshops. AGRRA assessments have been on 500 reefs throughout the Caribbean since 1998 and they have extensive regional databases on Caribbean coral reef condition. Contact: Robert Ginsburg or Phil Kramer, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Rickenbacker Cswy, Miami, USA; agrra@rsmas.miami.edu or rginsburg@rsmas.miami.edu; www.coral.noaa.gov/agra/

AIMS - Australian Institute of Marine Science
AIMS is one of Australia's key research agencies and particularly committed marine research in the tropics. AIMS undertakes research and development to generate new knowledge in marine science and technology, and to promote its application in industry, government and environmental management. The research program involves medium- to long-term research that is geared towards improved understanding of marine systems and the development of a capability to predict the behaviour of complex tropical marine systems. A major theme is developing and applying monitoring methods to assist in the sustainable management of tropical marine resources. AIMS supports a wide range of coral reef monitoring and studies for effective coral reef management. Contact: AIMS, Townsville Australia; www.aims.gov.au

CARICOMP – Caribbean Coastal Marine Productivity Program
This is a regional network of 25 marine laboratories, parks, and reserves established by IOC-UNESCO in 1986 that has been monitoring long-term variation in ecosystem structure and functioning in coral reefs, seagrasses, and mangroves using standard protocols in relatively undisturbed sites. The network also responds to regional events such as coral bleaching events and hurricanes. The Caribbean Coastal Data Centre at the University of the West Indies in Kingston, Jamaica archives the data and makes it available. The CARICOMP program networks institutions are in 18 countries: Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Colombia, Costa Rica, Cuba, Dominican Republic, Haiti, Jamaica, Mexico, Netherlands Antilles, Panama, Puerto Rico, Trinidad and Tobago, USA, and Venezuela. More details: www.uwimona.edu.jm/centres/cms/caricomp/; contacts John Ogden, jogden@seas.marine.usf.edu; Dulcie Linton, Caribbean Coastal Data Centre, Jamaica, dmlinton@uwimona.edu.jm

CI - Conservation International
CI is a global, field-based environmental organisation that promotes the protection of biological diversity. The Marine Rapid Assessment Program (RAP) of the Center for Applied Biodiversity Science at CI organizes scientific expeditions to document marine biodiversity as well as freshwater and terrestrial biodiversity hotspots, and tropical wilderness areas. Their conservation status and diversity are recorded using indicator groups (molluscs, corals and fish), and the results are combined with social, environmental and other ecosystem information to produce recommendations for protective measures to local communities and decision-makers. The main focus of Marine RAP surveys has been the 'coral triangle' in Southeast Asia, which contains the richest coastal and marine biodiversity in the world. Contact: Sheila McKenna, Conservation International, Washington, USA; www.biodiversityscience.org and www.conservation.org, s.mckenna@conservation.org

CORDIO – Coral Reef Degradation In The Indian Ocean
CORDIO is a regional, multi-disciplinary program developed to investigate the ecological and socio-economic consequences of the mass coral bleaching in 1998 and subsequent degradation of coral reefs in the Indian Ocean. CORDIO is an operational unit within ICRI. The objectives are to determine the: biophysical impacts of the bleaching and mortality of corals and long-term prospects for recovery; socio-economic impacts of the coral mortality and options for mitigating these through management and development of alternative livelihoods for peoples dependent on coral reefs; and prospects for restoration and rehabilitation of reefs to accelerate their ecological and economic recovery. CORDIO assists and coordinates with the GCRMN in the Indian Ocean with monitoring and running the Node in East Africa. The participating countries are: Kenya, Tanzania, Mozambique, Madagascar, Seychelles, India, Maldives, Sri Lanka, Reunion, Comores, Mauritius and Chagos. Program co-ordination contacts: Olof Lindén, olof@timmermon.se; in South Asia: Dan Wilhelmsson, dan.wilhelmsson@cordio.org; in East Africa: David Obura, dobura@africaonline.co.ke; in Island States: Jean Pascal Qoud, cloecoop@runtel.fr

GBRRF – Great Barrier Reef Research Foundation

The Foundation was established to encourage research to ensure the sustainability, conservation, protection and responsible use and management of the world's coral reefs. The GBRRF is a non-government, not-for-profit body that is independent of research providers and focussed on funding research that supports long-term practical solutions to the threats facing coral reefs. The GBRRF raises funds for monitoring and research to ensure that the information is disseminated widely to assist in policy formulation for environmental conservation and community benefit. The GBRRF is advised by an International Scientific Advisory Committee. Contact: David Windsor, GBRRF, Brisbane Australia, david.windsor@barrierreef.org, www.barrierreef.org;

GBRMPA – Great Barrier Reef Marine Park Authority

The Great Barrier Reef Marine Park Authority (GBRMPA) is the principal adviser to the Australian Government on the care and development of the Great Barrier Reef Marine Park (GBRMP). It is also the lead agency for Great Barrier Reef World Heritage Area issues. The goal of the GBRMPA is to 'provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park. GBRMPA is supported by scientific advisors who assist in designing monitoring programs, especially through the Australian Institute of Marine Science, and regularly publishes a report on the status of the GBR available on: www.gbrmpa.gov.au/ Contact: David Wachenfeld and Paul Marshall, Great Barrier Reef Marine Park Authority, Townsville, Australia; p.marshall@gbrmpa.gov.au

GCRMN - Global Coral Reef Monitoring Network

The GCRMN was formed in 1995 as an operational unit of ICRI. The GCRMN is in partnership with ReefBase and Reef Check, which constitute the central direction. The GCRMN is sponsored by IOC-UNESCO, UNEP, IUCN, CBD, the World Bank, AIMS, WorldFish Center and the ICRI Secretariat and central coordination is supported by the U.S. Department of State and the National Oceanic and Atmospheric Administration through contributions to IOC-UNESCO and UNEP. IUCN currently Chairs the Management Group of the GCRMN, and the Global Coordinator is hosted at AIMS. The GCRMN seeks to encourage and coordinate three overlapping levels of monitoring: Community - monitoring by communities, etc. using Reef Check methodology and approaches; Management - monitoring by Government environment or fisheries departments, and universities; and Research - high resolution scientific monitoring. Equal emphasises is placed on monitoring to gather ecological and socio-economic data, with manuals available for both. A major objective is to produce 2 yearly national, regional and global Status of Coral Reefs Report, such as those that form the basis for this report. The GCRMN functions as a network of independent Regional Nodes that coordinate training, monitoring and databases within participating countries and institutes in regions based on the UNEP Regional Seas Programme: Middle East with the Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) and the Regional Organisation for the Protection of the Marine Environment (ROPME); Eastern Africa –operating through the CORDIO network in Mombasa; South-west Indian Ocean Island States operating through the Global Environment Facility and Indian Ocean Commission; South Asia – assisted by CORDIO, IUCN and the South Asia Cooperative Environment Programme; South East Asia - with assistance from the WorldFish Center, Penang Malaysia; East and North Asia – assisted by the Ishigaki International Coral Reef Research and Monitoring Center in Japan; Southwest Pacific and Melanesia, coordinated through the Institute of Marine Resources, University of the South Pacific; Southeast and Central Pacific, the 'Polynesia Mana Node' coordinated in French Polynesia from the CRIOBE-EPHE Research Station on Moorea; Northwest Pacific and Micronesia, the 'MAREPAC Node' coordinated from the Palau International Coral Reef Center; Hawaiian Islands and U.S. Caribbean – coordinated by NOAA USA; Northern Caribbean and Atlantic region coordinated through the Caribbean Coastal Data Centre, Centre for Marine Sciences, Jamaica; Mesoamerican Barrier Reef System coordinated through MBRS Project office in Belize; Eastern Caribbean coordinated by CANARI; Southern Tropical America Node via the 'Instituto de Investigaciones Marinas y Costeras' (INVEMAR). Central Coordination contact: Clive Wilkinson in Townsville (c.wilkinson@aims.gov.au); or Jamie Oliver at in Penang Malaysia (j.oliver@cgiar.org); or Gregor Hodgson, in Los Angeles, rcheck@ucla.edu; home page: www.gcrmn.org

ICRAN - International Coral Reef Action Network

ICRAN is a public/private partnership response to the International Coral Reef Initiative's (ICRI) Call to Action to protect coral reefs worldwide. Initiated with generous support from the United Nations Foundation and the Goldman Fund, ICRAN's strategic alliance approach has been developed to ensure the future of coral reefs and related ecosystems and the future of the communities they sustain. This strategy includes alternative livelihoods, training, capacity-building, and the exchange and application of current scientific, economic and social information. The ICRAN partners are: CORAL, GCRMN, ICRI, MAC, Reef Check, SPREP, UNEP (Regional Seas), UNEP-WCMC, UNF, WorldFish Centre, WRI and WWF.
Contact: Kristian Teleki, Cambridge UK; kteleki@icran.org; www.icran.org

ICRI - International Coral Reef Initiative
ICRI was developed to reverse the declining status of the world's coral reefs. It is a partnership of countries, international organisations, NGOs and regional seas programmes created in 1994 following calls at the 1992 UNCED Rio Earth Summit and by the Small Island Developing States. ICRI was initiated by Australia, France, Jamaica, Japan, Philippines, Sweden, UK and USA, along with CORAL, IOC-UNESCO, IUCN, UNDP, UNEP, and the World Bank. ICRI seeks to mobilise global support for coral reefs and catalyse sustainable management through representation in diplomatic and international fora, such as UNEP and IOC governing councils and major environmental conventions through the ICRI Coordination and Planning Committee. ICRI developed the Call to Action and a Framework for Action at an international workshop in Dumaguete City, Philippines in 1995; and has refined these as the ICRI Renewed Call to Action at the International Tropical Marine Ecosystems Management Symposium (ITMEMS) in Townsville, Australia in 1998. Some recommendations of ITMEMS2 are in Appendix #1. The Secretariat is tasked with implementing the ICRI agenda, has been hosted in rotation since 1995 by the Governments of USA, Australia, France, Sweden and the Philippines and presently by the UK and the Seychelles. The GCRMN was the first operational unit of ICRI, followed by the establishment of ICRIN - the Information Network; and ICRAN - the Action Network. Contacts: Robert Canning, Robert.Canning@defra.gsi.gov.uk or Chris Thompkins, Chris.Tompkins@defra.gsi.gov.uk; Rolph Payet, rolph@seychelles.sc; www.icriforum.org

IMPAC – International Marine Project Activities Centre
IMPAC is a partnership of international agencies undertaking project activities in the Indo-Pacific marine tropics. This is new concept to further the sustainable development and conservation of critical habitats in tropical coastal areas - coral reefs, mangrove forests, seagrass beds and the associated fisheries by bringing together major UN agencies, and international NGOs, development banks and foundations under one roof to tap into the existing tropical marine expertise in Townsville, Queensland, Australia. IMPAC is an associate of the CRC Reef Research Centre. Contact: clive.Wilkinson@impac.org.au; www.impac.org.au

IUCN - The World Conservation Union
IUCN combines States, government agencies and NGOs as a Union of 980 members across 140 countries to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. The IUCN has a Marine Programme that is assisting in conserving through sustainable development, the worlds tropical coastal resources. IUCN is a founding member of GCRMN and currently chairs the Management Group. Contact for the Global Marine Program: Carl Gustaf Lundin, Gland Switzerland, Marine@iucn.org

ReefBase
ReefBase (www.ReefBase.org) is a global information system for coral reef conservation and management developed by the WorldFish Center, Penang Malaysia. It provides managers with monitoring data and advice on coral reefs, especially MPAs. ReefBase stores all records from the GCRMN and Reef Check as well as records of coral bleaching worldwide, photographs and maps. ReefBase, WWF and GBRMPA are developing a protocol for the reporting and monitoring of bleaching events. Contact: Jamie Oliver, The WorldFish Center J.Oliver@cgiar.org; www.reefbase.org

Reef Check
Reef Check is a university-based environmental organisation established to facilitate community monitoring and management of coral reefs. Reef Check is active in over 60 countries and territories throughout the tropics where it seeks to: *educate* the public about the coral reef crisis and how to stop it; *create* a global network of volunteer teams which regularly monitor and report on reef health under the supervision of scientists; scientifically *investigate* coral reef processes; *facilitate* collaboration among academia, NGOs, governments and the private sector to solve coral reef problems; and *stimulate* community action to protect remaining pristine reefs and rehabilitate damaged reefs worldwide using ecologically sound and economically sustainable solutions. Under the ICRI framework, Reef Check is a GCRMN partner and coordinates training for the GCRMN throughout the world. Contact: Kelly McGee; rcheck@ucla.edu, www.ReefCheck.org

TNC - The Nature Conservancy
TNC is a science-driven, business-oriented, non-confrontational NGO that collaborates with international, regional and local partners to support conservation around the world. The Nature Conservancy is promoting a worldwide effort to conserve coral reefs and their rich biodiversity by creating networks of ecologically connected protected areas that are resilient to local and global stresses. TNC is committed to working with a wide range of partner organizations to protect tropical marine biodiversity. Key components of our efforts are to help: expand the area of coral reefs and associated habitats under protection; eliminate threats to their biological integrity from unsustainable fishing, pollution, coastal development etc.; and improve the management effectiveness of MPAs. Contact: Alison Green; agreen@tnc.org

UNEP - (United Nations Environment Programme)
The mission of UNEP is to provide leadership and encourage partnerships in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations. UNEP emphasises partnerships and participation of civil society - the private sector, scientific community and NGOs - in the sustainable utilization of natural resources. A UNEP priority is to support and implement the Plan of Action from the World Summit on Sustainable Development. UNEP has concentrated resources and expertise on MPAs and coral reefs at the UNEP - World Conservation Monitoring Centre, Cambridge, UK, which also hosts the ICRAN Coordinating Unit, the administration of the ICRI Secretariat and the UNEP Coral Reef Unit (CRU). The CRU co-ordinates UNEP coral reef activities, represents UNEP in international frameworks and conventions, and works with UNEP's partners towards reversing coral reef degradation by increasing the global, regional, national and local support and awareness for coral reef conservation and sustainable use. Contact: Stefan Hain, stefan.hain@unep-wcmc.org

Appendix 4

Brief History of Coral Reef Monitoring and the GCRMN

Ecological monitoring of coral reefs has a 30 year history, with extensive refinement of methods and protocols so that they are accepted by coral reef managers. However, the necessary socio-economic monitoring has only been developed since the late 1990s to perform broad-scale rapid assessments.
Here is a selected history of coral reef monitoring from the GCRMN perspective:

2003 ITMEMS 2 (Second International Tropical Marine Ecosystems Management Symposium) Manila, March 2003. This renewed the call for more and improved monitoring, including allocating approximately 10% of all MPA management budgets to monitoring and performance evaluation. ITMEMS 2 had 195 participants from 35 countries;

2003 NOAA and the GCRMN released SocMon in 2003 at ITMEMS 2 as socio-economic monitoring protocols to assist managers with rapid assessments of user community interactions with coral reefs;

2002 The 'Status of Coral Reefs of the World: 2002' was published by the GCRMN (www.gcrmn.org) and AIMS (www.aims.gov.au) and reported that the best recovery on reefs damaged during 1998 was either in well managed coral reefs or those remote from human disturbance. The report had151 authors from over 80 countries and these are lodged on ReefBase, (www.reefbase.org) ;
Wilkinson, C. (2002). Status of Coral Reefs of the World: 2003. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, p. 393

2000 The GCRMN and AIMS 'Status of Coral Reefs of the World: 2000' report was released at the 9th International Coral Reef Symposium in Bali, 2000 and reported that 16% of the world's reefs were massively damaged during the 1997-98 climate change related bleaching event. Most damage was in the Indian Ocean where about 46% of all reefs were damaged beyond recognition in 1998. This report had 116 authors with details from 99 countries or states.
Wilkinson, C. (2000). Status of Coral Reefs of the World: 2000. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, p. 363

2000 GCRMN, in association with NOAA - USA, published 'Socio-economic Manual for Coral Reef Management' by Leah Bunce, Phil Townsley, Bob Pomeroy and Richard Pollnac to provide reef managers with rapid assessment tools to understand human use in parallel with ecological monitoring.
Bunce, L., Townsley, P., Pomeroy R. and Pollnac, R. (2000). Socio-economic Manual for Coral Reef Management. Australian Institute of Marine Science and GCRMN, Townsville 183 pp.

1998 ITMEMS 1 was held in Townsville, Australia, November 1998 and featured over 300 people, mostly resource managers, from 49 countries. The participants repeated the call from 1995 for improved research and monitoring to assist resource managers (see below);

1998 The first 'Status of Coral Reefs of the World: 1998' report by GCRMN and AIMS was released at ITMEMS 1. This assembled reef status reports by experienced scientists presented at the 8th International Coral Reef Symposium in Panama City, 1996. There were 41 authors and 11 regional chapters. It also contained the first compiled report of global-scale coral bleaching during the 1997-98 El Niño/La Niña global climate shift.
Wilkinson, C. (1998). Status of Coral Reefs of the World: 1998. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, p. 184

1997 The Atlantic and Gulf Rapid Reef Assessment (AGRRA) program and methods were developed in response to reports of disease, coral bleaching and human disturbance damage in the wider Caribbean region. This is a science based program designed to provide managers with rapid assessments of reef health and indicate causal relationships (www.coral.noaa.gov/agra/)

1997 Reef Check started as a volunteer monitoring network and has since expanded to 60 countries with thousands of people assisting with rapid monitoring by people with minimal training and skills. Reef Check is now the community and volunteer arm of the GCRMN and their methods are recommended for initial training for all reef monitors. Reef Check is assisting with the development of methods to assess the aquarium trade and socio-economic parameters (www.ReefCheck.org).

1997 The GCRMN recommended and improved survey manual was updated and printed for coral reef (and other coastal resource study).
English, S., Wilkinson, C., Baker, V. (1997). Survey Manual for Tropical Marine Resources, 2nd Edition. Australian Institute of Marine Science, Townsville, p. 390

1996 A session in the 8th International Coral Reef Symposium in Panama on the 'Status of Coral Reefs Around the World' (Chairs Clive Wilkinson and Bernard Salvat) had 14 invited papers from 41 authors (the basis for the 'Status of Coral Reefs of the World: 1998').

1995 The International Coral Reef Initiative was formed in Dumaguete City, the Philippines where the 'Call to Action' and the 'Framework for Action' was eventually endorsed by over 80 countries. This meeting called for the Global Coral Reef Monitoring Network, with the USA providing seed funding.

1994 Australian Institute of Marine Science published the 'Survey Manual for Tropical Marine Resources' folowing a 10 year Australian aid project that assisted 5 countries of Southeast Asia develop capacity and methods to assess coastal resources.
English, S., Wilkinson, C., Baker, V. (1994). Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science, Townsville, p. 368

1994 The Global Task Team on the Implications of Global Climate Change on Coral Reefs (UNEP, IOC-UNESCO, ASPEI, IUCN) developed monitoring guidelines for a global program and published:
Wilkinson, C.R. and Buddemeier, R.W. (1994). Global Climate Change and Coral Reefs: Implications for People and Reefs. Report of the UNEP-IOC-ASPEI-IUCN Global Task Team on Coral Reefs. IUCN, Gland Switzerland, pp. 124

1993 A meeting at the University of Miami assessed the status of the world's coral reefs, and reported a major gap in reef monitoring capacity. Urgent action was to improve coral reef monitoring.
Ginsburg, R.N. (Ed.) (1993). Global Aspects of Coral Reefs: Health Hazards and History. 7-11 June 1993, University of Miami, Miami. Collected Case Studies

1992 It was predicted at the 7th International Coral Reef Symposium in Guam that coral reefs of the world would suffer massive losses if effective management was not implemented. The Global Coral Reef Task Team formulated a monitoring strategy for coral reefs.
Wilkinson, C.R. (1993). Coral reefs are facing widespread devastation: Can we prevent this through sustainable management practices. Plenary Address - Proc. 7th International Coral Reef Symposium, 1992, Vol.1: 11-21

1992 The Caribbean Coastal Marine Productivity Program (CARICOMP) commenced monitoring at marine station sites at 25 locations performing long-term monitoring of reefs and other coastal ecosystems. (www.uwimona.edu.jm/centres/CMS/caricomp/)

1980s Drs Terry Done, Terry Hughes and other scientists started long-term monitoring programs to detect interactions and change on the Great Barrier Reef, Jamaica etc.

1978 Dr Yossi Loya published a line transect monitoring method developed for reefs of Israel that forms the basis of most monitoring methods.

1978 Richard Kenchington published Manta tow method to assess the crown-of-thorns starfish; still used for large-scale monitoring.

Appendix 5

The Authors

Clive Wilkinson is the Global Coordinator of the Global Coral Reef Monitoring Network and also coordinator of the International Marine Project Activities Centre (IMPAC) which are both based in Townsville. Prior to this he was the Chief Technical Advisor for the ASEAN-Australia Living Coastal Resources project that operated in Philippines, Indonesia, Malaysia, Singapore and Thailand to develop capacity to monitor and research tropical coastal resources using Australian AusAID funding. At the same time he Chaired the United Nations Global Coral Reef Task Team. He graduated with a PhD from the University of Queensland in coral reef ecology and joined AIMS in 1980 to research sponges and corals on the Great Barrier Reef. Clive is contactable by email at c.wilkinson@aims.gov.au

appendix 5

Alison Green is the MPA Science and Strategies Coordinator for the Asia Pacific and California Division of The Nature Conservancy where she assists in providing scientific advice for existing MPAs in the Asia-Pacific region and also assisting in the design of a larger network of MPAs aimed at conserving the rich tropical marine biodiversity in this region. Prior to this she directed the Science, Technology and Information Group of the Great Barrier Reef Marine Park Authority where she was responsible for designing much of the research and monitoring on the GBR. She has conducted considerable research and monitoring in the Pacific, especially in American Samoa. She obtained a PhD from James Cook University in fisheries biology and she may be contacted at email: agreen@tnc.org

Jeanine Almany has a MSc in Marine Resource Management and Marketing from Oregon State University and a Bachelors degree in Marine Biology from the University of California at Santa Cruz. Her interests are in marine conservation, particularly with regard to the management of marine protected areas (MPAs), sustainable community development, and biodiversity and habitat conservation. She is now working with The Nature Conservancy (TNC) and the Global Coral Reef Monitoring Network (GCRMN) through the International Marine Project Activities Centre (IMPAC) on a variety of MPA monitoring and marine conservation projects. Jeanine can be contacted via email at jeanine_4@yahoo.com

Shannon Dionne is completing a Masters of Arts in International Environmental Policy, with a focus on Marine and Coastal Policy at the Monterey Institute of International Studies in Monterey, California. She has a Bachelors of Science in Environmental Science from the University Of Rochester in Rochester, New York. Shannon will take up a Dean John A. Knauss Marine Policy Fellowship via the National Sea Grant College Program at the United States National Oceanic and Atmospheric Administration's (NOAA) in 2004. Her interests are in international marine policy, particularly focused on marine protected areas, biodiversity conservation and sustainable fisheries. Shannon can be reached via e-mail at shannon_dionne@yahoo.com