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

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.