Coral Reef Protected Areas: A Guide for Management

Prepared by the Working Group on Ecosystem Science and Conservation
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On June 11, 1998, President Clinton issued Executive Order 13089 on Coral Reef Protection (63 Fed. Reg. 32701). The order directs federal agencies to identify their actions that may affect U.S. coral reef ecosystems, to use their authorities and programs to protect and enhance these ecosystems, and, to the extent permitted by law, ensure that any actions they authorize, fund, or carry out will not degrade the conditions of coral reef ecosystems. Coral reef ecosystems are defined to mean those species, habitats, and other natural resources associated with coral reefs.

The order establishes an interagency U.S. Coral Reef Task Force and assigns to it specific duties for coral reef protection. Among the duties are coordination of a program to map and monitor U.S. coral reefs including those located in special marine protected areas such as national marine sanctuaries, national estuarine research reserves, national parks and national wildlife refuges. For these and other areas, the Task Force is directed to develop and implement research and secure measures necessary for reducing and mitigating coral reef ecosystem degradation and for restoring damaged reefs. The Secretary of State and Administrator of USAID, in cooperation with the Task Force, are directed to promote conservation and sustainable use of coral reef resources worldwide.

The Ecosystem and Science Conservation working group has developed this *Coral Reef Protected Areas: A Guide for Management* to assist those involved in planning and managing programs for coral reef protected areas. The Guide is intended to help such participants achieve the management objectives set forth in E.O. 13089. It is intended for use in developing management plans for new protected areas and for reviewing plans at established areas. Although the Guide is principally concerned with coral reef protected areas under U.S. jurisdiction, it is intended to assist those concerned with protected area management elsewhere. This is the second of two reports on coral reef MPAs that have been produced by the working group. The first report, Building a National System of Marine Protected Areas for Coral Reefs is an outline of the actions for establishing new MPAs and improving existing MPAs that protect coral reefs. The first report also includes selection criteria to be followed for evaluating candidate coral reef areas for possible designation as new MPAs.

The Guide has 12 elements. Each element is presented in two pages or less to assure that key points will be clear and readily accessible to diverse users. Those seeking additional information should consult the references provided at the end of each topic section. The elements are:

1. Coral Reef Ecosystems and Values

2. Planning and Stakeholder Cooperation

3. Management

4. Mapping

5. Marine Wilderness

6. Monitoring

7. Restoration

8. Research

9. Training

10. Education and Outreach

11. Resource Needs and Sources

12. Plan Revision and Reporting

1. Coral Reef Ecosystems and Values

Coral reefs are very diverse, complex ecosystems which occur in shallow tropical waters. They use resources efficiently and are highly productive. They usually contain a very dense and diverse assemblage of species, many of which are filtering the water for food, feeding on reef plants, or seeking common prey. Coral reefs are fragile and susceptible to harm from many sources that have differing effects. All activities, landward, seaward and skyward should be evaluated for potential impacts with this susceptibility and inter-connectedness in mind.

Coral reef ecosystems extend beyond the physical boundary of the reef structure, and actions in adjacent areas or hundreds of miles "upstream" may harm them. For example, many fish and invertebrates leave the reef to feed or spawn, with some foraging daily a mile or more away. Disturbances such as water pollution could occur outside the reef, yet within the feeding or spawning sites of these animals, and would have detrimental effects on the reef ecosystem. Similarly, many reef species have pelagic floating or neutrally buoyant eggs that may be released at the reef itself or at specific "spawning sites" miles away. Such planktonic larvae may settle to develop hundred of miles from where eggs were released. In addition, juveniles of many species develop in near shore coastal habitats and mangrove areas before moving to the reef as adults. Again, events that do not directly disturb the reef structure could have significant impact on the survival of these reef species, affecting the coral reef ecosystem.

Coral reef inhabitants have different space and resource requirements. For example, some reef inhabitants are fixed to the bottom or move about very little. Others "rove" up to miles to feed and use reefs only for shelter. Some pelagic species just pass through reef areas, and some creatures remain on reef floors, but move up into the water column at night to feed or spawn. For corals, anemones, and other stationary bottom species, reliable currents for egg dispersal and nutrient delivery, and opportunities for settlement are paramount. In addition, corals and numerous other filter feeders living on coral reefs depend on clean, low turbidity water and a good supply of nutrients. Coral reef assessments and monitoring must take into account the different behaviors and resource needs of reef inhabitants.

The value of coral reefs to mankind is only beginning to be understood. Coral reefs protect shorelines, provide habitat for commercially valuable fish species, and provide recreational and aesthetic enjoyment to people. Edible coral reef species are widely harvested (e.g., fish, crabs, lobsters, snails, clams, octopus, sea urchins, and turtles). Other species have been taken as ornamentals (e.g., coral, echinoderms, mollusks, pearls, and turtles) and for industrial use (e.g. seaweed, bulk coral, sponges, and giant clams). Many species enter the aquarium trade, including live coral, fish, and invertebrates. Coral reef species are sources of pharmaceuticals and natural-product chemicals. Similarly, many substances that coral reef species produce to harm or repulse predators or competitors are being investigated for medical application. Coral reef ecosystems provide opportunities for recreation and tourism, scientific research, education, and shoreline protection.

Court approved recoveries for damage to reef areas, based only on the cost of restoration and lost tourism use during recovery, have reached as high as $2,833 per square meter of reef surface. This estimate places the value of most coral reef ecosystems in the billions of dollars. Managers of coral reef protected areas should be aware of the value of coral reef ecosystems and the most current approaches to economic assessment of coral reef damage.

Additional References:

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2. Planning and Stakeholder Cooperation

Each coral reef protected area should have a management plan that is prepared in cooperation with stakeholders and which addresses the elements of this Guide. The management plan should be consistent with any statutory or regulatory mandates and should encompass legal, administrative, and educational concerns along with ecological and physical management goals. The management plan should have measurable

indicators of success and clearly specify the desired outcomes of management. For federally managed areas, management plans must meet the requirements of the Government Performance Results Act (GPRA).

National marine sanctuaries, parks and wildlife refuges with coral reefs in the United States have existing, or are in the process of developing, management plans and procedures for revision of plans. For these federal areas, a detailed environmental impact statement (EIS) was prepared under the National Environmental Policy Act of 1969 (NEPA) during plan development for each of these units and additional EISs are prepared as plans are periodically updated. The statements are prepared using a systematic, interdisciplinary approach integrating natural and social sciences, and must give appropriate consideration to presently unquantified environmental amenities and values. Cumulative environmental effects must also be considered. Within the EIS, "preferred alternatives, as well as other reasonable alternatives, are evaluated. The federal agencies preparing EISs are to emphasize cooperative consultation rather than adversary comments on completed documents: they are directed to consult early with appropriate State and local agencies, Indian tribes and with interested private persons and organizations whose involvement is reasonably foreseeable. These basic approaches of NEPA are sound principles for management planning involving any coral reef protected area, whether or not undertaken by federal agencies in the United States, although impact statements as detailed as the EISs prepared in the United States may not always be feasible or warranted.

Plans are only as good as their implementation, and public oversight and involvement in management activities have proven valuable for coral reef protected areas. This requires transparency or openness in operations which can be facilitated by public informational meetings, public participation in workshops, or establishment and regular communication with an advisory committee. An effective advisory committee will include members representing specific interests as well as those with scientific or other expertise. A typical list will include at least all levels of government, scientists, environmental organizations, and commercial interests. Federal agencies attempting to establish advisory committees need to do so in conformance with provisions of the Federal Advisory Committee Act (FACA). Agreement on actions should be sought among the interests represented in any of the above approaches, but action should not be predicated on complete consensus. Effective environmental protection such as mandated by E.O. 13089 may require one or more interests to change activities in ways that those interests will perceive as adverse.

Increasingly productive efforts have been made to engage the non-governmental public directly in activities. For example the Florida Keys National Marine Sanctuary management has developed a range of action plans and assigned leadership roles to those outside as well as within government. Some tasks such as standard setting and enforcement are fundamentally governmental, but other tasks such as public education, research, monitoring, and even serving as the eyes and ears for enforcement can be undertaken directly by citizens in teamwork with government authorities. In less developed areas of the world, such as at the remote coral reef islands and atolls in the Pacific, voluntary efforts by concerned individuals and communities may be the only

realistic immediate options for sustained monitoring and management of coral reef protected areas.

Additional References:

Berris, C. and J. Paul. 1993. Coastal tourism resource planning, in Proceedings of the 1993 Canadian Coastal Conference, May 4-7, 1993. Vancouver, B.C., Vol. 2. The coastal zone engineering program (NRCC), Ottawa.

Bohnsack, J.A. Consensus development and the use of marine reserves in the Florida Keys National Marine Sanctuary.

Crosby, M. P. 1995. Moving towards a new paradigm: Interactions among scientists, managers, and the public in the management of marine and coastal protected areas. In: M.P. Crosby (ed.) Proceedings of the Second International Symposium and Workshop on Marine and Coastal Protected Areas: Integrating Science and Management. NOAA Office of Ocean and Coastal Resource Management. pp 10-24.

Towfighi, P.S. 1994. Integrated planning and management of coastal areas. Marine Policy, 18(2):107-111.

3. Management

This Guide addresses marine protected areas (MPAs) with clearly defined boundaries. These areas often have a special body of laws, regulations, or policies, and dedicated staff and facilities. Many other coral reefs, not addressed by this Guide, are managed without boundaries and are subject to laws and regulations concerning use or pollution without specific geographic references (fisheries, water quality and tourism).

Coral reef MPA managers should assess and, as needed and feasible, address the following:

- Harvesting Activities - decline of populations and loss of higher level carnivores within the ecosystem from over harvest, physical damage from fishing gear
- Recreational Use - anchor and diver damage to corals, disturbance of reef organisms, pollution of the reef environment
- Water Pollution - various impacts ranging from loss of light to nutrient changes and disease introductions
- Coastal Development - increased sedimentation, altered upland runoff and nutrient input to the reef system, loss of juvenile nursery habitat

There are many poorly understood phenomena that have been observed to be occurring on coral reefs. The more common of these include bleaching and diseases, sudden mass

die-off of individual species, and sudden infestations or population expansions of specific species.

Mapped boundaries may create a false impression of protection. Boundaries often exclude areas critical to the survival of the protected coral reef, such as seagrass communities, coastal mangrove forests, and even coastal uplands. Threats outside of MPA boundaries are inadequately addressed (e.g. water and air pollution, over-fishing, human alteration of coastlines, and sedimentation). MPA managers must find ways to address external threats in addition to actions taken within the MPA.

Cultural norms, local history, and political expedience may be among the factors that ultimately determine the approach to coral reef management in any given place. Creation of an MPA with boundaries usually has strong appeal. It is best to start with the most ecologically complete MPA that a government (or trust) can realistically hope to manage for the near future (approximately 5 years). MPA managers must then be alert and adaptable to significant changes in environmental, demographic, economic, and political conditions. In the long run, success will require a constantly expansive approach that (a) increasingly addresses the importance of forces outside the MPA boundaries and (b) is flexible enough to eventually become part of ecosystem management on a regional scale.

To cope with these considerable demands, the MPA manager will need to understand why the MPA was created, the state and condition of its resources, the forces that will most affect its future, and the basic management actions, equipment, staffing and facilities that have proven successful elsewhere. It is important to determine how the MPA fits into broader coastal zone management efforts. A sound understanding of the MPA's purpose usually draws from legislative mandates, existing policies, media reports, records from public hearings and other available sources. Knowledge of resource conditions and what affects them can come from existing research and publications, but other sources should be pursued. These may include discussions with local residents, with commercial operators (dive boat and tour boat operators, commercial fishermen, guides, etc.), with recreational users, with interest groups (environmental, economic, political, and others) with a close relationship with the resource, and with other state and federal resource managers.

Awareness of forces that will affect the MPA's future will come from the same sources as above but from a larger geographic area. Major economic development, population growth, environmental changes, even political trends, as well as other factors within 100 kilometers or more of the MPA can have serious impacts on the coral reef system. Discussions with economic, political, and community leaders and with officials of other government agencies in the region are important.

Knowledge of management actions, equipment, staffing and facilities that have proven successful is best acquired from others who are managing or have managed similar marine resources. Although scientific knowledge of coral reef systems is steadily growing, literature on how to manage them is still limited.

Once armed with this knowledge, MPA managers should move forward with the following basic steps:

1. Establish short-term (1-2 years) and long-term (5-10 years) objectives addressing:
    - assessment, monitoring and desired condition of resources (including non-degradation)
    - human use and impacts
    - necessary staff, facilities, and funds
2. For short-term objectives, prepare action plans for the coming year.
3. Watch for changes both outside and within the MPA that will have impacts on the coral reef system.
4. Basic operations, whether performed by just one person or a large organization, usually should include:
    - enforcing laws and regulations
    - assisting and protecting visitors and users of the area
    - providing basic information on safety, rules, and importance of the reef system
    - observing or monitoring the condition of the coral reef system
    - observing typical behavior of visitors/users
    - maintaining or repairing equipment and facilities (buildings, trails, roads, etc.)
5. Locate MPA offices within or as close as possible to the MPA and make them easily accessible.
6. Help local residents, students, leaders, visitors and the press appreciate the MPA and its coral reef system.
7. Meet regularly with local leaders and interest groups of all persuasions, including those who support the MPA and those who do not.

Active, direct management for the preservation of coral reef systems is relatively new compared to management of terrestrial resources. Experienced managers of coral reef MPAs are relatively few and substantial knowledge of any coral reef system is still usually greatest at the local level. For an agency or organization to succeed in conserving coral reef systems it will need to rely heavily on experienced local managers.

Additional References:

Broome, G. and P. Valentine. 1993. Principles of social impact assessment and its application to managing the Great Barrier Reef. CRC Reef Research Centre, Townsville.

Coral Reef Task Force (in prep). Building a National System of Marine Protected Areas for Coral Reefs. U.S. Coral Reef Task Force Working-group on Ecosystem, Science and Conservation.

Salvat, B. 1976. Guidelines for the planning and management of marine parks and reserves. IUCN Pub. No. 37: 75-90.

Salm, R.V. and J.R. Clark. 1984. Marine and Coastal Protected Areas: A guide for planners and managers. IUCN workshop on Managing Coastal and Marine Protected Areas, World Congress on National Parks, Bali, Indonesia, Oct. 1982. 302p.

Kenchington, R.A. and B. Hudson (eds.). 1984. Coral reef management handbook. UNESCO Regional Office for Science and Technology, Southeast Asia. 281 pp.

Foster, N. and M.H. Lemay (eds.) 1989. Managing marine protected areas: An action plan. U.S. MAB Prog., US Dept. Of State, Washington D.C. 63p.

Rigney, H. 1990. Marine reserves - A blueprint for protection. Aust. Fisheries 49:18-22.

4. Mapping

One of the most basic requirements of effective management of a coral reef ecosystem is understanding the extent and location of the resources to be protected. Development of a resource map is an essential step in management if one is not already available. Investment of time and money in mapping is extremely important because it will lay the foundation for developing overall management plans, it will guide future use and protection, and it will allow for detection of change at the ecosystem level. A base map of the protected area can become a useful "peg board" upon which other information can be plotted, and it will increase your state of knowledge about the resource as it is completed.

If adequate knowledge on the location and amount of resources is available, additional mapping may not be necessary. However, if the extent and location of resources has not been documented, aerial photographs provide a good starting point for a general survey of reef resources. At a scale of 1:5000, many reef features are visible, and if the photos are taken during calm and clear conditions, water clarity may allow resolution of major features to a depth of 60 feet or more. Aerial photographs can be used to document the distribution and extent of a coral reef ecosystem, the pattern of adjacent land and marine use which might affect the reef system (e.g., construction of tourism facilities, clearing of landscapes, and increases in boating activity), and large scale changes in the reef ecosystem or adjacent seagrass beds resulting from natural events such as storms or from human activities. These photographs can also assist in selecting appropriate detailed study sites.

Base maps of the benthic reef communities can be developed from aerial photographs of high resolution. It is best to use professionally produced, geo-referenced aerial photographs with a known scale. To allow accurate measurements of features, it is important that photographs be taken perpendicular to the surface. Aerial photographs of high resolution will usually allow identification of major reef zones and habitats, although changes in the condition or abundance of reef organisms within these zones do not generally show up in the pictures. Underwater inspection with SCUBA or snorkel will be required to determine exactly what certain areas represent. Photographs are

usually the best way to determine transition boundaries between reef zones and specific locations of prominent reef features such as drop-offs, coral buttresses, or branching coral "forests." If aerial photographs cannot be obtained, crude reef profile maps can be produced utilizing echo-sounding approaches along carefully established transectional traverses across the reef area.

If multi- or hperspectral remote sensing systems are available, they offer an advantage of increased resolution over color photography and can be used to map coral reef ecosystems (Mumby et al. 1997; Mumby et al. 1998). Hyperspectral data contain far more information per image than a single conventional red green-blue (RGB) color image (photograph), and significantly more information than multispectral data (Holasek et al. 1997). However, hyperspectral mapping generates large data sets. NOAA is currently conducting experiments in the U.S. Virgin Islands and Puerto Rico to explore the feasibility of synoptic habitat mapping using hyperspectral images.

In remote areas where the logistics are difficult and the cost is high for acquiring photography or other high resolution information, satellite imagery can be used to map general benthic habitat types (e.g., sand, seagrass, coral, hard substrate) in coral reef environments. While lacking the spatial or spectral resolution of aircraft obtained data, satellite imagery offers the advantages of increased frequency of coverage, extensive coverage at low cost, archival data and fast results. Satellite imagery also assures continuity across areas not covered by aircraft. At present, satellites can provide resolutions (pixel size) ranging from 1 km^2 to less than 10 m^2. Landsat Thematic Mapper (TM) has been used to map several types of bottom cover in coral reef environments (Mumby et al. 1997). The new Landsat 7 satellite potentially offers systematic, multispectral coverage of coral reefs at 30 m resolution, and panchromatic coverage at 15 m resolution.

Although large-scale resource maps are essential, they will not provide detailed documentation of many community level changes. In addition, it may be important to address smaller scale changes in coral reefs before they grow and become apparent in an aerial photograph**.** For this reason, area managers may also want to obtain photographs or develop detailed maps of selected reef areas for documentation and monitoring purposes. Such photographs and maps will usually require obtaining underwater photographic mosaics, use of underwater video-photography, and/or recording of information from grids placed on the reef surface. Habitat or site specific inventories and maps are recommended for known high use areas, particular underwater attractions, and as long-term randomly selected "sampling points" within each of the reef zones or habitats present (see monitoring section).

Maps developed from aerial photographs, when digitized and fed into a computerized geographic information system (GIS), can be use to conduct a multitude of assessments of reef resources. The GIS can also be used to organize and store all new spatially oriented information about reefs as it is obtained. The GIS is a powerful way to integrate and display large amounts of geographic data and can greatly help the manger in

identifying locations on the reef that meet certain criteria, documenting and assessing changes in land use patterns, and large scale changes in the aerial extent of reef resources.

Aerial photographs, base resource maps and GIS databases should be considered essential tools for the managers of coral reef ecosystems and every manager should seek to have these products available. To find out what maps or aerial photographs may be available for the area you are interested in, contact the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the U.S. Navy, your agency's Geographic Information System oversight office, or the agency responsible for mapping and charting in your country or island.

The Mapping and Information Synthesis working group of the U.S. Coral Reef Task Force has developed a comprehensive, detailed Coral Reef Mapping Implementation Plan. This plan can be found at the following web site:
http://www.coralreef.gov/MIP.html

Additional References:

Coral Reef Mapping Implementation Plan (2nd Draft). November 1999. U.S. Coral Reef Task Force, Mapping and Information Synthesis Working Group.Washington, DC: NOAA, NASA and USGS (Work Group Co-chairs). 17 pp.

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Mumby, P.J., E.P. Green, A.J. Edwards, and C.D. Clark. 1998. Digital analysis of multispectral airborne imagery of coral reefs. Coral Reefs 17:59-69.

NOAA/FMRI. 1998. Benthic Habitats of the Florida Keys. Florida Department of Environmental Protection: Florida Marine Research Institute Technical Report TR- 4. St. Petersburg, FL. 53 pp.

NOAA/FMRI. 1998. Benthic Habitats of the Florida Keys CD-ROM. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD

5. Marine Wilderness

Resource exploitation in the form of fish and shellfish harvest is allowed in almost all coral reef sanctuaries parks and refuges under United States jurisdiction. While reserves prohibiting resource exploitation have been established on land in the United States, they

are generally absent from the sea. However, many studies indicate that marine non-harvest areas, where they have been established, can increase the number, size and age of species within such zones after they are established, and fishery yields have increased in adjacent areas.

Because coral reef ecosystems are relatively susceptible to degradation from human activities such as fishing, current science suggests that a substantial portion of any coral reef protected area should be set-aside as marine wilderness or no-take zones, free from any resource exploitation to insure preservation of ecosystem biodiversity, help preserve natural ecosystem structure and function, and provide refugia for reproduction and growth. Human use of the coral reef protected area, particularly consumptive uses such as fishing, have been shown to result in altered community structure, including changes in the abundance and age structure of selected species. The establishment of one or more no-take marine wilderness zones can provide areas where the marine community structure and functions are protected. These areas can serve as valuable controls for evaluating the extent of impacts elsewhere, and can provide refugia to help maintain the biodiversity of the protected area.

Choosing the size, type, and location of marine wilderness zones within a protected area depends on a variety of factors and should be based on the best available information and input from constituents (see sections 2 and 3). To be effective, the designation process for marine wilderness should provide the opportunity for full participation by interested groups and take into account appropriate legislative and regulatory authorities. Criteria for choosing marine wilderness sites should include the extent to which the natural ecosystem is intact, the level of biodiversity, and how well protection will contribute to recruitment and maturation of populations within and outside of the zone. Knowledge of key spawning habitats and fish aggregation sites should also be incorporated into the design of marine wilderness.

Science cannot dictate a set percentage of marine area that must be completely protected to ensure survival of marine populations. Actual percentage of the total area needing to be protected may vary depending on the type, diversity, amount and species use of habitat existing within the MPA. However, many marine fisheries scientists have called for protection of over 20 percent of the total potential fishing area as a minimum to be considered (whether or not in a sanctuary, park or refuge) to ensure population sustainability. A National Research Council report on sustainable marine fisheries recently recommended that this figure provides a worthwhile reference point when insufficient information is available to determine necessary no-take area size based on species life histories, use of habitat and community function.

The capacity of coral reef ecosystems to sustain resource exploitation is uncertain and, in the United States, Federal agencies are required by Executive Order 13089 to go beyond sustainable use and to ensure that their actions will not degrade coral reef ecosystems. Coral reef sanctuaries, parks, refuges or other protected areas have already been recognized as priority areas for protection by virtue of their park, sanctuary, or refuge designation and they should take the lead in providing no-harvest wilderness refugia. In

the absence of other information, coral reef protected areas should designate, as a minimum goal, at least 20 percent of their area as marine wilderness or non-harvest zones. Effective monitoring and research (see below in this Guide) should be implemented to test the adequacy of such areas for protection and restoration, and for replenishment of adjacent areas.

Additional References:

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Dugan, J.E. and G.E. Davis. 1993. Application of marine refugia to coastal fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 50(9):2029-2042.

National Research Council. 1998. Sustaining Marine Fisheries. National Academy Press, Washington, D.C.

6. Monitoring

The ultimate purpose of monitoring is to provide early detection of change, and monitoring programs should be linked with and made an ongoing part of overall management strategies. Monitoring programs should trigger responsive actions of additional investigation when signs of change beyond normally anticipated levels are observed.

In general, managers of coral reef protected areas need to know: 1) where the reefs are located; 2) what condition the reefs are in; 3) how the reefs are changing; 4) which human induced and natural events could be causing reef deterioration; and 5) whether the existing protective measures are adequate to prevent degradation and, where necessary, allow reef recovery. Monitoring of reef resources can provide information relative to all of these information needs.

The location of reefs can be documented using aerial photography and other remote sensing techniques (see Mapping discussion). Photography, either still or video, can also be used to record baseline reef conditions and serve as a valuable monitoring tool.

Photographs provide a permanent record of reef or surrounding landscape appearance at a given time. Ideally, a combination of photographic and non-photographic techniques, such as direct in-water censusing of reef organisms or sampling of water quality is used. Fortunately, monitoring does not have to be complicated or expensive to be effective. However, monitoring programs should be designed to be statistically rigorous which requires sufficient replication in sampling and treatment-control site comparisons whenever possible.

Reefs in good condition generally have relatively high amounts of living coral, low incidence of coral disease, large numbers of fish (including large carnivores), and low amounts of fleshy algae. Perhaps the single best indicator of poor reef condition is the persistence of large amounts of fleshy algae that appear on reefs with excess nutrients or low numbers of herbivorous fishes from over-fishing. Both natural processes such as hurricanes and human activities such as fishing and dredging stress reefs. Although the cause of some damage is obvious, as when a ship runs aground on a reef, slow changes in the abundance or condition of reef organisms, such as may result from chronic pollution, can be difficult to track. Long-term monitoring (repeated surveys over time) is often required to determine if and how reefs are changing. Such long-term monitoring should include indicators of coral stress such as frequency of bleaching and occurrence of disease.

The choice of monitoring methods (parameters selected) will depend on anticipated threats, long-term objectives and management actions taken. For example, if you need to determine whether hotel sewage is causing an increase in algae on a nearby reef, both the algal abundance and nutrients in the water or sediments would need to be documented. In other situations, measuring variations over time in the relative abundance of corals and other organisms on an unstressed reef can provide a basis for evaluating observed changes on nearby reefs that are stressed by human activities. Most coral reef protected areas receive considerable human recreational use, and monitoring should document the number of users, areas of concentration and the activities in which they are participating. Because threats to the coral reef ecosystem may come from upland areas long distances away, monitoring programs should attempt to include observations of changes in local watersheds, stormwater discharges, sewage treatment facilities and agricultural activities.

The monitoring of reefs can also play a vital role in evaluating the success of specific management actions. For example, censusing of the sizes and numbers of commercially important reef fishes before and after fishing has been prohibited within a prescribed area can indicate whether fish stocks are recovering. It is important that considerable thought be given to management objectives and desired information when designing and implementing a monitoring program.

While managers have no control over hurricanes or outbreaks of coral disease, they can control recreational use of reefs, fishing intensity, anchoring of boats and, in some cases, sedimentation from careless coastal development. Therefore, a well-designed monitoring program can alert managers that reefs are deteriorating, indicate what corrective measures may be required as well as document recovery following management action.

Additional References:

Rogers, C.S., G. Garrison, R. Grober, Z. Hillis, M.A. Franke. 1994. Coral Reef Monitoring Manual for the Caribbean and Western Atlantic. U.S. National Park Service, Virgin Islands N. P., 89pp. + Appendices.

CARICOMP (Caribbean Coastal Marine Productivity). 1991. Manual of methods for mapping and monitoring of physical and biological parameters in the coastal zone of the Caribbean. Florida Institute of Oceanography. 35pp.

7. Restoration

Resource restoration is often an important part of the necessary management actions for a coral reef area manager, and there is a growing body of literature for reference on this topic. Restoration may take many forms, including improving water quality, restoring fish or shellfish populations depleted by over harvest, and restoring coral structural damage from such things as ship groundings. Reef area managers should make themselves aware of the potential tools available to conduct restoration activities and seek assistance in designing restoration programs once damage is recognized.

Ship and small boat groundings can heavily damage coral reefs and virtually every coral reef system near human population centers experiences these impacts. For example, Biscayne National Park, a unit of the National Park System, reports over 300 small boat and ship groundings a year impacting seagrass beds and coral reefs. Virgin Islands National Park, Buck Island Reef National Monument, Dry Tortugas National Park, and the Key Largo Coral Reef National Marine Sanctuary all have reported massive reef damage from ship groundings and anchoring. These reefs will take hundreds of years to recover fully.

Remote coral reefs are likewise not immune from the damage caused by ship groundings, such as those that have occurred recently at three existing protected areas in the US Pacific: Rose Atoll National Wildlife Refuge (American Samoa), Kure Atoll State Wildlife Refuge (Hawaii), and Ritidian Point National Wildlife Refuge (Guam). The 1993 grounding of a foreign longline-fishing vessel at Rose Atoll resulted in collision damage and a massive fuel spill that killed off major portions of the reef flat and upper reef slope. The ship then quickly broke up, spilling gear, clothing, line, food, fish, and furniture over the reef and into the lagoon. Metal debris was scattered over a wide reef area. Invasive species of algae have since colonized the dead reef areas preventing the recovery of resident reef building organisms. There is evidence that dissolved iron from the corroding wreckage is maintaining, if not stimulating the growths of the invasive seaweeds. This incident underscores the importance of conducting clean-up and reef restoration operations following grounding incidents.

Massive amounts of derelict fishing gear and operational waste from ships in the north Pacific have drifted and accumulated on reefs and beaches of the Nation's largest coral reef protected area, the Northwest Hawaiian Islands National Wildlife Refuge Complex. Derelict fishing gear and operational waste are also problems at many other remote US reefs.

Coral reef protected area managers should seek to recover damage costs from private initiates that damage natural resources within their areas. The National Marine Sanctuaries Act, the Park System Resources Protection Act, and other legal authorities can often be used to recover damages. Damage assessments can include the costs of surveying the damage, the value of the resources lost, and the costs of restoration (including monitoring of results for success). Coral reef protected area managers should make maximum use of appropriate legal authorities in obtaining restitution for damages and finding funding to restore damaged coral. Recovery actions should be taken as soon as possible after the damage occurs. Many reef organisms can be saved and impact reduced if efforts are started immediately. This will require that the managing agency have an established process to determine damage cost estimates.

Restoration techniques following impacts include transplanting live corals, seeding coral larvae, replacing limestone substrate in deeply gouged reef areas, and transplanting seagrasses and other organisms.

Additional References:

Maragos, J.E. 1992. Restoring coral reefs with emphasis on Pacific reefs. In: G.W. Thayer, (ed.) Restoring the nation’s marine environment. Maryland Sea Grant College, College Park Maryland. 141-221.

8. Research

Research on reefs with the greatest potential benefits for managers includes 1) monitoring (see Monitoring section), 2) experimental research, 3) research on new techniques and technologies, 4) research on the links between human actions and reef degradation, and 5) research on the synergy between natural and human processes which affect reefs. Managers need to know the condition of their reefs and whether the reefs are "holding their own", improving or deteriorating. Effective monitoring will alert managers to problems, but the causes of reef deterioration will not always be obvious. In some cases, experimental field or laboratory work will need to be done to pinpoint causes of reef stress. For example, more research is needed on coral pathogens and on their possible link to sewage, sedimentation, or other factors associated with humans. New techniques which have great potential for management include new or improved monitoring methods, e.g. use of digital video cameras in underwater housings to document abundance of reef organisms, particularly living coral and the "fleshy" algae ("seaweed") that are useful indicators of reef status. Current attempts to use aerial photos and in-water

"hyperspectral" sensors, e.g., to identify specific spectral "signatures" for diseased or dead corals, may expedite reef assessment over large areas. More research on the potential of using coral larvae to restock denuded reefs, now showing some promise in the Pacific, may lead to more use of this method in reef restoration.

Managers cannot control natural stresses, but they can not ignore them either. Natural stresses can combine with damage from recreational use or shoreline development. Hurricanes, for example, might delay the recovery of an area set aside as a marine reserve (or "recovery zone") where fishing is prohibited, or the recovery of an area damaged by a boat grounding. By identifying and addressing the combined effects of natural and anthropogenic stresses, managers can better protect coral reefs. For example, managers could shift recreational use from a hurricane-damaged site to another reef that escaped storm damage.

To benefit management, research should be tailored to the stresses that are most likely to affect the reefs in a particular MPA. Managers and scientist should work together to define research programs. For example, reefs located near sewage outfalls should be monitored for effects of high nutrient loads. However, some of the most devastating stresses in the last 2 decades have involved natural (or apparently natural) stresses. In these cases, long-term monitoring to document trends in reef organism abundance will help quantify the effects of the stresses.

Additional References:

Stoddart, D.R. and R.E. Johannes (Eds.) 1978. Coral reefs: research methods. UNESCO Monographs on Oceanographic Methodology. 581p.

Richardson, L.L. 1998. Coral diseases: what is really known. Trends in Ecology and Evolution 3(11):438-443.

9. Training

Training is key to maintaining an efficient and professional management staff at coral reef protected areas. Training usually increases job effectiveness in the employees' own resource management specialties as well as in related resource management areas. Because the management of coral reef ecosystems is still a relatively new and evolving science, additional training is often highly valuable in helping employees and managers keep abreast of new information and technologies. Coral reef area managers should also keep in mind that additional training may be essential for employees to become knowledgeable in activities such as law enforcement, safety and first aid, operation of specialized equipment, public speaking, and other practices that are necessary for effective management but not normally included in school curricula.

Training may take many forms and all should be used and encouraged. These include formal training (workshops or universities); in-service training (agency training courses or workshops); on-the-job training (special duty assignments, working with other specialists, work-group or team assignments); and self-training (self motivated reading and study or correspondence courses).

A personal training plan should be developed for every employee, and managers should motivate employees to do additional training. Progress toward achieving management objectives is often a direct function of personnel management practices and philosophy and how motivated people are to perform their duties. Generally employees will be more motivated if they are knowledgeable in their area of responsibility and feel they have management support to improve that knowledge. In addition, progress toward achieving management objectives for the protected area can be enhanced if the employees are instructed in what the management objectives are, what actions are necessary to achieve these goals, and what role they play in reaching the management objectives.

Sharing management experiences and information among managers and scientists working with coral reef protected areas is extremely useful. An information network for area managers has been established on the Internet for the Caribbean area. This initiative was undertaken by marine park managers within the Caribbean region who have created a group called Caribbean Marine Protected Area Managers (CAMP).

Additional References:

Gubbay, S. (ed.) 1995. Marine protected areas: Principles and techniques for management. Chapman & Hall, London.

10. Education and Outreach

Public support for coral reef protection programs will only come through public knowledge and understanding of the area's resources and management goals. The public must also be knowledgeable about potential resource impacts and their causes before they can participate in helping to alleviate those impacts. It is human nature to covet what we best know and understand, and thus, an informed community creates better stewards for our protected areas. Therefore, every area manager must make public education and outreach one of the major elements in their management program.

One of the biggest challenges to coral reef managers is getting information out to the general public, the local community, decision-makers, students, and other interested parties. Information to disseminate can include how the coral reef protected area was designated, why it exists, what the species and communities that inhabit it are and why they are important, how it is managed, what is happening to the reef over time, current events that affect the protected area, or any other factor that may make the public more aware of the area’s resources or management issues. An additional challenge exists in

getting information distributed to a wide audience with varying levels of knowledge. To best accomplish information dissemination it is critical to remember the area objectives, consider the target audience, and assess the most effective information tools.

Education and outreach should include a variety of program types including: 1) User-oriented programs that may focus on recreational or commercial user groups and their particular interests; 2) School groups and education classes with programs that will arouse interest and make students aware of protection needed; 3) Local community programs that might focus on overall reef values and economic benefits of protection to the community; 4) Active participation programs that require involvement of the public in carrying out management or protection activities; 5) Education of decision makers at all levels of government; and, 6) Interpretation for the press and media.

While often not distinguished, education and outreach activities can have distinctly different messages and concepts and be widely applied for different circumstances. *Education* is usually more formal and begins with introducing the marine realm with a specific curricula. It is "educating" various audiences about the species, habitat, dynamics, management issues, etc. in a relatively formal setting. Environmental education is often on-site, in or around the water, with specific lessons provided and objectives to be met. Although in a formal setting, techniques of active learner engagement and participation should be encouraged to help develop topic interest and information retention. O*utreach* is informal education that is actively offered to the community. For example, a story about how a sponge spawns or the latest data showing increased fish populations in a designated marine reserve presented to a local community organization may be a form of outreach. Outreach is simply "reaching out" to one or more chosen audiences with information, often conducted in a public forum in an informal setting (e.g. a meeting speaker, slide show presentation, newsprint, or radio program).

Among the proven avenues for dispensing information are: guest teacher presentations, establishing curricula, field trips, articles in newspapers and newsletters, brochures, booklets, radio interviews or programs, guest presentations, slide shows, visitor centers, and various types of exhibits and displays.

Additional References:

Alder, J. 1996. Cost and effectiveness of education and enforcement. Great Barrier Reef Marine Park Environmental Management 20:541-551.

Wells, S. and A.T. White. 1995. Involving the community. In: S. Gubbay, (ed.) Marine protected areas: Principles and techniques for management. Chapman & Hall, London. pp 61-84.

Moffat, B. 1993. Marine Environment Students Manual. Wet Paper Publications. Queensland, Australia.

11. Resource Needs and Sources

To adequately administer a coral reef protected area and make conservation a reality, managers will need adequate personnel and funding. Too often, coral reef areas are designated for protection and receive park or refuge status only to exist on paper and in name, with no effective management due to lack of funding and personnel. However, managers should think beyond agency provided base funding to seek support from a variety of sources. It is often the most entrepreneurial manager that is the most successful.

Adequate personnel should be either employed or sought from volunteers for important basic functions. These include an area manager and one or more staff with responsibilities in administration, maintenance, resource monitoring and management, law enforcement and rescue, and public relations. Minimum equipment and facilities are needed to ensure proper protection of an area and these may include buoys or markers to indicate boundaries; boats of sufficient size to patrol and access the area; dive, monitoring and research equipment necessary to observe, document and evaluate resource conditions; facilities for recreational access and enjoyment; and sufficient boats and safety equipment for surveillance and law enforcement.

Although at least minimal agency base funding must be available to establish a protected area and initiate management activities, there are usually several potential additional sources of funding available to area managers to support management activities. In the United States, these may include non-governmental support organizations such as the Fish and Wildlife foundation, the National Park Foundation, the National Park and Conservation Association, the Center for Marine Conservation, or any of many other organizations interested in the conservation of coral reef resources. Managers should also look to local communities, and corporate sponsors who may benefit from the presence and protection of the MPA resources. Development of a "friends group," a trust fund, or a "coral reef stewardship fund" on a local level can often provide additional funding for the MPA's programs. Cost recovery through user fee programs is also being used at many designated parks and refuges to supplement area base funding.

Regional and interagency networking should be a priority for MPA managers. Networking can afford benefits to management that are far-reaching but not always apparent. Coral reef communities are linked in an inextricable web of commonality. Creatures of the sea do not recognize political boundaries, and spawning sites, larval dispersion, pollutant pathways, disease transmission, and many other influences are a function of prevailing currents and winds. Duplication of coral reef protection efforts is not always necessary when coordination of activities, information, and methodologies and sharing of infrastructure, training opportunities, and products will increase efficiency. Regional networking needs coordination and constant nurturing. Managers must commit to routine correspondence and reporting to colleagues. Partnerships that are fiscally and

logistically responsible, can draw on individual strengths and provide for better management.

12. Plan Revision and Reporting

Any successful management program must be periodically evaluated. The results from these evaluations should be reported, and management plans must be revised as necessary to achieve goals. Evaluation should be continual and begin at the time of implementation, but a formal evaluation mechanism or procedure is desirable. Marine protected area management plans should be formally reviewed and revised as necessary at a five-year minimum interval. However, management plans will be more effective if they contain measurable indicators of success that may be monitored annually to serve as a "barometer" of successful management.

In evaluating the need for plan revision and management success at five-year intervals, managers should consider bringing in an evaluation team to review the effectiveness of the plan and to recommend any needed revisions of management procedures. Establishing an evaluation team of managers from other marine protected areas is a good way to obtain a more technical and perhaps objective review of management effectiveness. Whatever the mechanisms used, evaluation and plan revision are essential to a responsive management system.

Reporting of management results should be considered critical element to gaining and maintaining public support for the marine protected area. Marine protected area managers should view themselves as public servants and a custodian of public resources. A periodic "corporate report to the stockholders" is an essential part of that relationship. These reports should come frequently in the form of newsletters or informational updates, periodically when information of significant proportion is obtained (e.g. at the conclusion of a study, annual completion of monitoring observations, or following a particular event that may have affected area resources), and at the time of formal review and update of the areas management plan.