MODULE 8

RESEARCH AND MONITORING

OBJECTIVE

1. To convey the message that research and monitoring is essential for good management and stewardship.
2. To improve management success through the design and application of standard monitoring methods.

THEMES

8.1 Introduction to Research and Monitoring
8.2 Use of Remote Sensing and Geographical Information Systems in Research Plans
8.3 Ecological, Physical, and Cultural Resources Monitoring
8.4 Basic Economic and Social Science Research
8.5 Monitoring Visitor and User Data
8.6 Monitoring of Effectiveness of Restrictions and Zoning

DELIVERY TIME

2.5 Days

MODULE 8	RESEARCH AND MONITORING
THEME 1	Overview and Introduction to Research and Monitoring
OBJECTIVE	Re-affirmation of the importance of research and monitoring plans.
SIGNIFICANCE	Research and monitoring within marine protected areas is essential for good management and stewardship.
PRESENTATION	Lecture
EQUIPMENT / MATERIALS	
EXERCISE	
TIME	1 Hour

TUTOR'S NOTES

Some of the research described in this chapter may be beyond the financial or scientific capabilities of some marine protected areas in the Wider Caribbean Region. Participants should be advised that managers should be realists and understand what types of research and monitoring are feasible given the site-specific conditions.

INTRODUCTION

Research within a marine protected area (MPA) is essential for good management and stewardship. At the initial stages of MPA designation and the development of the management plan, research can provide environmental managers with a rationale for setting standards and giving quantitative predictive models for the selection of management strategies. After implementation of the management plan, research will assist administrators by monitoring the health of the marine resources, the extent of human uses of the area, and the impacts produced by humans on the resources. This information is essential for regulating and perhaps limiting use. Research programmes may perform some of the following functions:

- ♦ Inventory the marine resources that exist in the MPA;
- ♦ Observe and evaluate impacts (anthropogenic and natural);
- ♦ Determine uses and threats to MPA resources;
- ♦ Obtain fundamental scientific knowledge;
- ♦ Determine changes in the health of the resources, as well as changing uses;
- ♦ Evaluate compliance with regulations;
- ♦ Offer early warning signals of problems;
- ♦ Provide a link to broader research efforts outside the MPA; and
- ♦ Offer solutions to issues and problems in the management of the MPA.

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> The objectives of the research programme will depend on the management objective of the marine protected area.

The objectives of the research programme will depend on the management objective of the MPA. For example, if the MPA is primarily a wildlife reserve, the research would focus on population data in space and time and reproductive success. Research in a fisheries reserve would emphasize fish population data, recruitment, age structures, and migration patterns. Research in a marine national park would closely track the impacts of human uses in the area on the quality of the marine resources and ensure that the recreational uses of the area do not impact negatively on the preservation of the marine resources. A marine multiple-use area would require research that examines the impacts of various human activities on each other and on the marine resources, in an effort to minimize user impacts and conflicts while allowing activities that are consistent with long-term resource conservation objectives.

Research and monitoring activities in an MPA must be sensitive to the existing funding, although creative MPA managers might be able to extend capabilities through partnerships.

IDENTIFICATION OF RESEARCH AND MONITORING NEEDS IN SUPPORT OF MANAGEMENT

Research in MPAs includes ecological, physical, and social inventories and baseline research (preliminary diagnosis or referenced ecological and socioeconomic characteristics), long-term monitoring, and studies of impacts on the marine resources (anthropogenic and natural). Each type of research is important and plays a distinct role in the management of MPAs.

> Research should be of the applied type, and designed to addresses management-driven questions.

Research activities also cover basic scientific research that may appear to have no immediate link to management questions. Rather, they address "pure" research questions and advance the frontier of knowledge. This type of research should not be a priority for the MPA managers, although managers may recognize the long-term advantages and contributions of this activity, as well as the occasional findings that have immediate applicability. If "pure" scientific research does not conflict with management goals and is cost-effective, it serves as an added justification for the establishment and existence of the MPA (Harmon, 1994).

1. Resource Inventories and Baseline Research

Baseline inventories are essential for the development of the MPA management plan and establishment of regulations for use of the MPA resources. **Without knowledge of the existing resources and current human use of them, imposing regulations becomes impossible**.

Ideally, baseline information should be obtained prior to establishment of the MPA, and at the beginning of implementation of management strategies, in order to determine initial conditions. Subsequent changes in physical parameters, ecological data, or human uses can then be compared to the baseline data. Baseline research should also quantify human activities outside the MPA which could have an impact on MPA resources (water pollution, habitat destruction, coastal development, forestry, hunting and fishing), as well as activities inside the MPA (boating and maritime transportation, fishing, diving). This preliminary diagnosis should also measure the health, abundance, and distribution of living marine resources, as well as sediment and water parameters. Managers should search the scientific literature and archives of government agencies for existing data and current or past monitoring efforts. This often will economize limited resources.

2. Ecosystem Monitoring

Continual, long-term, statistically valid monitoring in the MPA should measure the health, abundance, and distribution of marine resources over time (Agardy, 1997). Trends in these parameters may suggest new management strategies. MPA administrators should consider innovative approaches that involve continuous monitoring and gathering of data by volunteers or students. This continuous monitoring permits analysis of changes caused by natural environmental variability and/or user impacts.

> Care should be taken to ensure continuity of monitoring sites, methodologies, and, if possible, personnel, as these factors are essential if the data are to be scientifically valid and useful for management.

Additionally, monitoring should include studies on-site and off-site of human activities and uses of the marine resources, as well as effectiveness of adopted management strategies. Researchers and MPA managers will correlate the resource variability with the changes in human uses. Conclusions regarding the human impacts on the MPA resources are key tools for managers. This information should be linked to management strategies through feedback links that consider revision of the management strategies in light of the new information.

MPA managers must develop a research and monitoring plan before any research begins. This must be an open process with input from resource users, members of local communities, MPA personnel, personnel from related government agencies, and social and natural scientists. The research planning body must identify and prioritize research needs that clearly respond to the needs of management and the relevant management philosophy. The actual research and monitoring programme may be limited by funding or personnel. Therefore, it is important to develop priorities and at least collect the information that is most critical for successful management.

In some instances, research might be planned and managed more appropriately at a national level; in other scenarios, local planning and management at the MPA-level is preferable. This choice might be based on numerous factors, such as the scope of the research question (i.e., whether monitoring is to be local or national), the institutional location of the scientific personnel, the institutional allocation of the research funding, the legislative mandate, and cost-effectiveness considerations.

RESEARCH INFRASTRUCTURE AND MANAGEMENT

1. Acquisition and Management of Research Assets

MPA managers should promote the use of their site for research activities that will provide information that they have determined is useful and essential for management of the area. An initial step involves the development of a research plan that is realistic considering the budgetary constraints (financial resources) and available research personnel (human personnel). The priority research must be closely linked to the management of the MPA and assist in the formulation and implementation of the management plan. MPA managers and scientific staff should attempt to include research activities within the budget of the MPA. Alternative sources of research funds might include user and admissions fees, rent paid by MPA concessionaires, and monetary recovery from natural resource damage assessments. In addition, managers should develop proposals for funding of research activities from other government agencies, foundations, universities, and non-governmental organizations (NGOs).

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Protected area authorities should attempt to develop cooperative linkages and partnerships via Memoranda of Understanding (MOU) with national or international universities, national or international NGOs, or local communities (fishers, mangrove users, tourists) for financing research programme and providing effort. The link with national universities should be actively explored because this institution's mission is most likely focused on national issues and protection and management of the nation's natural resources. These researchers should also be the most sensitive to the cultural and political nuances of the country's MPAs. Moreover, this link will promote the development of a cadre of national social and natural scientists. In some situations, the private business sector may be willing to support specific projects. Even if the MPA lacks the essential research infrastructure (monitoring and laboratory equipment), creative arrangements and agreements with other entities may overcome this deficiency.

2. Management of Research

The MPA must establish guidelines for the management of research activities within its area of jurisdiction. These guidelines are applicable to research that is undertaken directly by MPA resident scientists, initiated by them but carried out by outside researchers, or proposed and conducted entirely by non-MPA researchers.

> All research conducted in MPAs should make a positive contribution to the management needs of the MPA.

MPA research managers should require that all research within the MPA be approved to ensure that it is compatible with the management objectives of the area and that it makes a positive contribution to MPA management needs. The staff must evaluate the research objectives, methodologies, and the qualifications of the researchers. An initial question concerns who will establish the research objectives. MPA scientists may establish objectives in close communication with managers. MPA managers should seek advice from marine scientists and social scientists. Research plans should be open to scientific peer review. In situations where the MPA lacks staff scientists, the research initiatives may originate from the scientific community whose primary interest may not be MPA management. In this case, MPA managers must determine the information that they wish to obtain and negotiate its delivery with extra-MPA researchers.

The MPA officials should monitor research activities and require that researchers deliver copies of research results, as well as specimens, to the MPA research coordinator. The sampling strategies should cause minimal disruption as possible of the marine resources, human use of the resources, and surrounding human communities. The protected area office should maintain a comprehensive record of all research activity that has been conducted in the area, along with research results and relevant publications. This information could be of high importance to present and future MPA managers, as well as to future researchers. **When possible, research and monitoring should conform to the regional standards to allow for comparisons among the MPAs in the Wider Caribbean Region**.

3. Funding Constraints and Availability

MPA management is subject to funding availability, both in terms of baseline research and long-term monitoring. Therefore, it is essential that MPA officials develop long-term budgets that clearly determine which projects are feasible. Otherwise, there is a danger of

MPAs becoming "paper parks". Also, officials should decide early in the MPA designation process which methods and procedures they shall choose in order to reach their research and monitoring goals. For example, if remote sensing techniques are too expensive, officials should consider local knowledge and existing charts/maps instead.

MPA funding is often available from a variety of sources, including local, regional, national, and international agencies, as well as non-governmental organizations. However, projects procured must be funded for their entire duration, or they must at least include contingency plans; otherwise, there is a potential for incomplete research. Therefore, officials need to understand the limitations of funding on the long-term for their MPAs and proactively decide on the extent and efficiency of their activities at various funding levels. Finally, projects must remain considerably flexible (i.e., incorporate volunteers, utilize inexpensive equipment, etc.) to remain effective even with unexpected funding setbacks.

4. Designing a Monitoring Programme

In designing a monitoring programme, the following questions should be addressed:

- What are the objectives?
- What is going to be monitored?
- How often should data be collected?
- How long should data collection be continued?
- What methods will provide the best data?
- Who will conduct the monitoring?
- What methods are realistic, considering the available time, money, equipment, people, and skills?
- What kind of quality assurance will be used to ensure data of the highest quality?
- How will the data be subsequently analysed?
- How will the data be stored and retrieved?

MODULE 8	RESEARCH AND MONITORING
THEME 2	Use of Remote Sensing and Geographical Information Systems (GIS) in Research Plans
OBJECTIVE	To introduce course participants to the advantages and limitations of remote sensing and GIS applications.
SIGNIFICANCE	Remote sensing is increasingly being used in MPA management as a method of rapidly gathering data over large areas. Similarly, GIS applications are in increased demand due to the need for improved data management in terms of relational databases.
PRESENTATION	Lecture, Demonstration
EQUIPMENT / MATERIALS	Computer, Computerised maps
EXERCISE	Demonstration of data access from a machine-readable storage format
TIME	2 Hours

INTRODUCTION

Remote sensing is an emerging tool in marine protected area management. It can be utilized to cover large expanses and broadly assess an area's multiple resources. More advanced technology can assist in the identification and mapping of smaller features. **However, remote sensing techniques, aerial photography, aerial surveys, and satellite imagery, are generally coupled with ground-truthing surveys**. Therefore, remote sensing represents a two-tiered approach to assess a marine protected area's resources. It is an expensive technique, requiring specialized equipment and expertise. Equally important is the fact that remote sensing should not substitute for more detailed surveys. While it can provide broad-scale and, in some instances even medium-scale data, it cannot duplicate other, more detailed monitoring efforts.

1. Aerial Photography and Surveys

Aerial photography and surveys refer to data collected from an altitude at a specific scale. The scales can range from 1 to a few hundred through 1 to a many thousand, depending on altitude. Surveys generally differ from photography, as the former implies actual data collection. Aerial surveys may focus on boat counts and patterns, marine mammal data collection, and other parameters. Aerial photographs may be taken using many different types of film, including color, black and white, infrared, ultraviolet, and combinations, and others. The scale, film, and equipment used generally depend on the resource being studied, as well as the financial capability of the researchers.

2. Satellite Imagery

Satellite imagery has developed as a remote sensing option for smaller marine protected areas over the past two decades, especially with the introduction of the Coastal Zone Scanner in the late 1970's. Since then, satellites have been developed to detect sea surface temperatures, infrared radiation, chlorophyll, sea height, and other biological and physical factors. Representing the high end of technology, satellite imagery requires extensive funding and expertise.

3. General Methodology for Remote Sensing in Research and Monitoring

If remote sensing is a financially viable option that can be utilized for the creation of base maps and monitoring efforts, it should be utilized to characterize a marine protected area and its resources. Data should be received in the form of maps that show considerable detail, such as reef structures, seagrass communities, mangrove forests, beaches, etc. Features should be readily distinguishable.

4. Remote Sensing Imagery

A scale that shows the detail required should first be chosen, and images should be photographed or scanned at that scale. The appropriate film or imagery should be chosen for the site (i.e. infrared, black and white, etc.). If the site is sufficiently large, a composite of images should be captured such that they match each other at approximate boundaries.

5. Feature Codes and Mapping

The resulting image can only prove useful if the individual regions are sufficiently coded and mapped within the image. Named reefs, forest, and communities should be coded and traced over the image, and all other large features should be identified within their community types.

Information from remotely obtained images should go through a system of ground-truthing. This can assist in not only determining the accuracy of the information provided by remote sensing, but it can develop so-called "community signatures" or gross morphology of individual community types (Sullivan and Chiappone, 1994).

If financially feasible, the image should be digitized into a computer map. Using GIS, researchers can now link the computer maps with databases with attribute information so that the maps provide both geographical and environmental data. Like remote sensing, GIS is expensive and requires extensive training, as well as sufficient computer hardware. However, it can also manipulate and display spatial information generated from research and monitoring on base maps that change to reflect changes in the resource base.

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6. Geographical Information Systems (GIS)

GIS is a computer technology that stores, analyzes, and displays spatially referenced data. A GIS plots attributes (data) on base maps, i.e. bathymetry, habitat, fishing zones, maritime transportation routes, habitats of endangered species, sewer outfalls, etc. The GIS technology is powerful because it allows changes in legends and scales. It also facilitates creation of overlays of selected attributes, thus producing new maps that may be specifically tailored to a management issue. It is also possible to spatially track the condition of a marine resource over time. This provides insight about potential threats to the resources and user conflicts. The GIS technology creates a significant saving of time and effort.

Limitations to the use of GIS include the absence of original attribute data. Even when they do exist, data may be deficient or difficult to obtain, especially for the marine environment. For example, existing data may be spatially insufficient or may also be housed in different sources and expressed in forms that are often incompatible. Costs of obtaining the data may be prohibitive.

MODULE 8	RESEARCH AND MONITORING
THEME 3	Ecological, Physical, and Cultural Resources Monitoring
OBJECTIVE	To impress on MPA managers the need to include all of the various resources and impacts in the monitoring programme.
SIGNIFICANCE	There is growing awareness that research and monitoring programmes that focus only on flora and fauna do not provide all the information necessary to ensure success in MPA management. All the resources in an area, as well as the factors that affect those resources, must be monitored.
PRESENTATION	Lecture, Audio-visual presentations, Field exercises
EQUIPMENT / MATERIALS	Overhead Projector, Slide Projector
EXERCISE	Field Demonstration
TIME	2 Hours

INTRODUCTION

MPA managers must ask what type of resource information they most need to effectively manage the area under their responsibility. The most basic information focuses on the existing flora and fauna and involves resource inventories to determine what species are present and how their distributions vary in space and time. Researchers should focus on the ecologically dominant species, as well as species that are endangered, threatened, or of key ecological interest. They must also assess the ecological relationships between species, populations, and communities. Research should also address the essential physical requirements of the important ecosystems of the MPA (water quality, habitat requirements, food and nutrients). Given the fluid nature of the marine environment, water quality and other oceanographic parameters should be key components of an environmental monitoring programme.

An additional area of ecological research focuses on monitoring the dynamics of change. Key questions that research activities could address include the changes in species distribution with time, the invasion of exotic species, the recovery and recolonization of areas that were degraded by natural or anthropogenic processes, and the impact of pollution and other human activities on the ecological resources of the MPA. This will involve performing periodical sampling of indicator and key species and recording the trends in population size, reproductive success, and species and habitat health as a function of time.

Physical parameters of the MPA are another key focus for research activities, both at the initial stages of MPA establishment, as well as during its implementation and operation. MPA managers should ensure the collection of essential data regarding water quality (parameters such as temperature, salinity, turbidity, dissolved oxygen, nutrients, various pollutants) and water circulation. Initial research efforts should also evaluate the sources of pollutants to the MPA, whether they occur inside or outside the boundaries of the protected area.

Guidelines for establishing research priorities and planning activities are given in Appendix 8.1.

MODULE 8	RESEARCH AND MONITORING
THEME 4	Basic Economic and Social Science Research
OBJECTIVE	To introduce the social and economic perspectives into the MPA decision-making process.
SIGNIFICANCE	Patterns of exploitation of natural resources are rooted in the attitudes and social norms of the exploiting peoples, as well as the prevailing economic conditions.
PRESENTATION	Lecture
EQUIPMENT / MATERIALS	Case study
EXERCISE	
TIME	1 Hour

INTRODUCTION

Most of the problems the MPA managers face are social and political. These concern the relationship of people and the marine and coastal resources of the protected area. The central nature of these questions suggests that MPA managers and research coordinators should give priority attention to social and economic research programmes. These research questions will, at a minimum, include monitoring of human uses of the MPA, as well as economic and social impacts of the MPA. An ideal social research programme, however, would embrace a much larger set of social science issues that span the entire range of social sciences from economics, sociology, anthropology, psychology, political science, and law. These research questions relate directly to the establishment and effective management of the MPA.

> Many of the problems associated with MPA management are influenced by social and political conditions, and the research and monitoring programme must therefore cover the full range of issues.

1. Economic Research

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Economic research initially should focus on the effects of establishment of the MPA. It is important to determine the social and economic groups that gain and lose as a result of the creation and operation of the MPA. For example, researchers might determine the jobs and income opportunities which are created or lost in local communities because of the MPA. The MPA might also impact the economies of local communities through business development, changes in the tax base, and increased or decreased economic stability. These parameters should be examined and quantified. In short, research questions analyze the economic impact (costs and benefits) of the MPA establishment and operation. The MPA administrators might elect to compensate the "losers" in some manner.

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Environmental management strategies have moved away from "command-and-control" to "market-based" techniques. Economic research might provide realistic information that would permit managers to establish economic incentives to encourage compliance with MPA regulations.

The economic valuation of the contributions of MPAs to society can be important when decision-makers determine whether to establish an MPA, justify its existence, or grant sufficient funding for implementation of effective management strategies

(Dixon and Sherman, 1990). **Clearly, administrators must be cognizant of the role of the MPA in regional economic development.** They must be able to document the contribution of the MPA to the real markets of local economies. At the same time, MPA administrators must survey local user groups and the public to monitor values of the MPA that cannot be registered by local markets.

MPAs provide water, fishery resources, recreational opportunities, control of microclimates, shoreline protection, and spiritual well being. Methodologies for quantifying the values of these goods and services are still rudimentary. Seldom have the economic benefits of MPAs been documented. However, initial calculations for the values of the benefits resulting from MPAs and discussions of uncertainties are better than a total absence of information (IUCN, 1998).

MPAs offer values that may be divided into Direct Use Values and Indirect Use Values. Direct Use Values represent those goods and services that enter directly into the human economy and refer to present and future benefits. Consumptive Use Values are the result of an individual's consumption of the resource during a given period of time, compared to Non-Consumptive Use Values that may produce enjoyment for various persons at the same time. Indirect Use Values include values of ecological services, as well as values of potential future use (Uncertain Use Values).

Consumptive Uses include fishing, extraction of algae and shellfish, and harvesting of mangrove wood products. These products may be extremely important for local communities within or surrounding an MPA. Values for these products may be estimated using the direct market values and revenue and expense analyses. Non-consumptive Uses of MPAs, such as tourism and recreation, aquatic transportation, scientific research, environmental education, aesthetic values, are more difficult to estimate than Use Values. Their values have to be estimated using methods that attempt to capture the resources that people spend in carrying out these activities. Such methods involve Travel Costs, Hedonistic Valuation, or Replacement Costs.

Indirect Use Values are much more difficult to estimate than Direct Use Values. Coastal and marine ecosystems provide a number of ecological services. Mangroves and other coastal wetlands protect coastlines against erosion and storm events. Seagrass beds help maintain coastal water quality, while coral reefs are important sites for genetic and biological diversity. People may value these resources for their intrinsic values or because they hope to use them one day. However, although we recognize the importance of these functions, determination of values is controversial and uncertain, although important. Methodologies that are in various stages of evolution include estimation of the costs to perform a similar function by an alternative method, Replacement Valuation, and Contingent Valuation. Contingent Valuation Methodologies survey the population to determine its Willingness-To-Pay or Willingness-To-Accept for an ecological/environmental product or service (Barzetti, 1993).

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Economic research might also address the issue of concessions within the MPA. Financial analyses could address the question of establishment of fees that the concessionaire would pay to the MPA administration and whether these fees provide maximum benefits to the MPA, as well as to the concessionaire.

2. Sociological Research

Sociological research may examine the perceptions of resource users, residents of local communities, the general public, and national agencies regarding the purpose and goals of the MPA. This type of research will indicate to managers how gender, economic and social class, and user interest relate to the concerns, views, and expectations about the MPA. Other studies might assess the user (tourist/diver) satisfaction with the MPA experience. A trend analysis of satisfaction might assist managers in developing new regulations that would enhance the public's enjoyment of the marine resources.

Studies of public participation mechanisms may elucidate the strategies for public outreach that are most effective in conveying information about the MPA and developing active dialogue with members of the community and user groups. This information may enhance the MPA manager's ability to communicate with the public.

Additional studies may analyze the conflicts and cohesion between user groups, as well as between users and the MPA management. Information about the source and development of conflicts will greatly assist eventual conflict resolution.

Sociological research might also examine enforcement of MPA regulations. Observations regarding public perceptions regarding compliance with the law, trends in non-compliance, and spatial and temporal distribution of non-compliance all could assist the development of an improved and more effective enforcement strategy.

3. Anthropological/Cultural Research

Cultural research elucidates the organizational structure of communities and cultures (traditional and non-traditional) that are adjacent to or within the boundaries of the MPA. Through ethnographic surveys, interviews, and other observational methods, researchers characterize the value systems of communities and the role marine resources play in this value system. Themes that will be of direct use to MPA managers include: marine property rights systems of the local community, the importance of the marine resources for community well-being and stability, and the traditional and non-traditional techniques developed by local users to conserve and exploit marine resources. Because all communities must face cultural, technological, social, political and environmental change, research should explore the ability of the traditional value systems to adapt when confronted by change. The establishment of a marine reserve/MPA may cause change in the community and its ability to exploit marine resources, and the MPA manager should be aware of the impacts for which he/she and the MPA policies are responsible. Surveys and interviews of community leaders and residents can elucidate the perceptions of the community to the MPA and its objectives and to the conservation ethic (Gubbay, 1995).

One consideration of anthropological research is who is best suited to collect information about the community. It might be the outside anthropologist herself or in cooperation with existing local access channels to the community.

4. Political Science Research

Research in the Political Sciences can be important both during the establishment of the MPA, as well as during the operational phase. Institutional analyses can assess the division of governmental functions inside and outside the MPA among different agencies at different levels of government. This will indicate where possible conflict among agencies may occur and where competence is shared or repeated among various agencies. Analyses of the power and decision-making centers in the local community and at the national level can suggest the individuals or institutions that MPA administrators must approach to obtain enhanced support for MPA plans, funding, and operations. An understanding of local pressure groups and interests is essential for resolving the conflicts that inevitably arise among different user groups or between different user groups and agencies.

5. Legal Research

Legal analyses at both the national and international levels will elucidate the statutory or regulatory bases for MPA management strategies, as well as possible overlaps in competence of various institutions. The growing body of international and regional environmental conventions and protocols may present the MPA manager with additional responsibilities, as well as opportunities for action and international cooperation that support research and management. Legal analyses can also evaluate the effectiveness of the legal basis for the MPA in question and suggest revisions that may facilitate effective management strategies.

MODULE 8	RESEARCH AND MONITORING
THEME 5	Monitoring Visitor and User Data
OBJECTIVE	To reinforce the importance of recording visitor/user levels and patterns.
SIGNIFICANCE	Patterns and levels of use of the MPA resources must be monitored in order to determine the impact on the resources, use and user conflicts, and ultimately the linkage to the management objectives of the MPA.
PRESENTATION	Lecture, Case study review
EQUIPMENT / MATERIALS	Case study
EXERCISE	Case study review
TIME	2 Hours

INTRODUCTION

The research and monitoring plan must include the types and levels of human interventions in the MPA. This is important in order to subsequently assess the impacts that they cause on the marine resources, the conflicts that may arise between uses, and the levels of visitor and user satisfaction with the management strategies and quality of the resource base.

The user data measured will depend on the importance of the human activity in the MPA. Possible parameters measuring the uses of the MPA and the nature of the activities might include the following:

a. Research Scientists

- Number;
- Institutional affiliation;
- Activity;
- Locations of their research sites;
- Equipment used;
- Material extracted; and
- Publications and research products.

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b. Tourists/Divers

- Number per year;
- Origin;
- Frequency by month or season;
- Specific dive sites;
- Secondary activities (spearfishing, photography, collection);
- Types of vessels used to transport divers;
- Types of commercial operations involved;
- Amount of money spent on the activity; and
- Levels of satisfaction with the activity.

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c. Fishers

- Number of fishers per year, month, season, week;
- Catch (species, size, methods of catch, weight of catch);
- Multi-species nature of fishers' efforts;
- Fishing effort (catch per unit effort);
- Types of fishing arts;
- By-catch data; and
- Site-specific information on fishing activities.

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d. Mangrove Users

- Number of persons involved;
- Harvest products;
- Species harvested;
- Commercialization;
- Site of extraction;
- Frequency of harvest; and
- Harvest techniques.

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e. Boating

- Number and types of vessels;
- Home port;
- Frequency of activity (number of trips per week, month);
- Routes;
- Pollution incidents;
- Groundings; and
- Speed zones and violations.

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CARRYING CAPACITY

Concept of Carrying Capacity

The determination of carrying capacity is a complex process involving an understanding of effects that users have on the environment, and a calculation of the total number of users that can use the environment without significant degradation. Carrying capacity needs to consider the ecological impacts on the environment, as well as the socio-economic impacts on the surrounding areas. According to Dixon *et al*. (1993);

> "there is a maximum level of use that is sustainable . . . [which] may be lower than what is desired by local government or business interested, but must be respected if the investment in marine natural capital is to be economically profitable and if marine parks are going to meet both ecological and economic goals."

Definition of Carrying Capacity

A 1991 seminar on coastal and marine parks and protected areas (Clark, 1991) determined carrying capacity is a twofold management objective defined as:

a. A particular threshold level of tourist activity beyond which there will be physical deterioration of the resource, or damage to natural habitats; and

b. The maximum visitor loading acceptable to both the visitors and the people living in the surroundings of the protected area.

There are three major impacts in MPAs that are exacerbated by increased density; they include tourism industry impacts, development activities and related impacts, and pollution impacts (Clark, 1991). Tourism industry impacts include: boating damage via anchoring, groundings, and chemical pollution; diving and snorkeling damage caused by inexperienced users breaking or smothering sensitive habitats, or extensive use (Davis and Tisdell, 1995); scenery appreciation and wildlife viewing, which can negatively impact the environment and cause increased traffic that can affect the users and visitors. Development activities and related impacts include: dredging, filling and mining activities that can negatively impact the marine environment (increased turbidity, sedimentation); and coastal development that affects terrestrial-marine interface zones and impact natural systems such as runoff and erosion. Pollution impacts include: domestic sewage that may result in eutrophication and public health threats; agricultural and industrial wastes and oil spills from land or marine sources which could degrade or devastate habitats in an MPA. The impacts that concern most MPAs are those that are caused by the tourist industry. However, development and pollution impacts are often functionally related to the tourist industry, and the impacts from each source tend to rise simultaneously.

Implementation of the Carrying Capacity Concept

In order to control these impacts and sustain an MPA for present and future uses, carrying capacity objectives must be considered. The surrounding region needs to be considered as well, in terms of pollution and developmental impacts that may affect the MPA. Clark (1991) discusses the role of research, the control of visitor damage in MPAs, and mitigation and rehabilitation as measures to determine and implement carrying capacity in protected areas. Because carrying capacity differs by location, it is best implemented as a site-specific activity and left to the discretion of the management authority.

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EXAMPLE 8.1: Social impact assessment and carrying capacity in the Great Barrier Reef Marine Park (Broome and Valentine, 1995)

This report, which discusses methodologies by which to conduct social impact assessments in marine parks, also provides two well-known frameworks on social carrying capacity. They include Limits of Acceptable Change (LAC) and Visitor Impact Management (VIM).

The LAC process specifies management of use within standards rather than at use levels. It calls for the identification of issues, the definition of opportunities, selection of resource and social conditions, an inventory of those conditions, specification of indicators for each opportunity, identification of alternate opportunity allocations, identification of management options for each alternative, and the evaluation and selection of preferred alternatives.

The VIM process accepts the tenuous link between use levels and social and environmental impacts, and it attempts to address area management through three issues: identification of problem conditions, determination of potential causal factors, and selection of potential management strategies.

Another strategy suggested is to take crowding perceptions from visitors and apply those in a percentage-based matrix that suggests ameliorative action.

EXAMPLE 8.2: Diver carrying capacity study in Bonaire National Park (Dixon *et al.*, 1993)

The study determined the maximum loading of divers on the coral reef sites in Bonaire National Park, providing carrying capacity totals based on ecological and economic factors. The researchers developed a carrying capacity curve per site, suggesting that loading should be maximized at 5,000 dives per year per site. The researchers also considered means by which to limit access, including a discussion on permits and user fees, to maximize profits while minimizing ecological impacts.

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MODULE 8	RESEARCH AND MONITORING
THEME 6	Monitoring of Effectiveness of Restrictions and Zoning
OBJECTIVE	To increase management success through improved design of use areas and measurement of the impacts of user regulatory guidelines and measures.
SIGNIFICANCE	Different ecosystems/resources within the MPA have different sensitivities and vulnerabilities, and provide different ecological functions. As such, all resources cannot support the same types and levels of use. Monitoring the effectiveness of use guidelines facilitates better management of the impacted resources.
PRESENTATION	Lecture, Case study review
EQUIPMENT / MATERIALS	Case study
EXERCISE	Case study review
TIME	2 Hours

INTRODUCTION

This research overlaps into basic research that is beyond recording and quantifying the impacts of activities on MPA resources. The question addressed is whether zoning in the MPA effectively limits the negative impacts of multiple uses. Experiments might be designed to compare two MPA zones: a zone with restrictions and another without restrictions. Restrictions may include no fishing, no spearfishing, no anchoring, no wake speed limits, no dredging. Alternatively, an ecosystem in the MPA could be zoned into a "use zone" and a "no use zone". Differences in the ecosystem and physical resources over time might be due to the impacts of user activities. Limitations include slow/imperceptible changes, absence of control over human uses in the "no use zone", or unrelated variations in environmental conditions. An example of this approach is being adopted by researchers in the Sambos Ecological Reserve of the Florida Keys National Marine Sanctuary. The regulations for the reserve, established in 1997, prohibit fishing and removal of marine resources. Monitoring efforts will compare ecological changes inside and outside the reserve.

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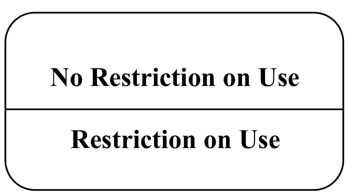
<u>Initial Time (t = 0)</u> **Newly Created MPA**

At the baseline condition, researchers would measure different environmental parameters, such as habitat quality, fish populations and species abundance, coral or sea grass cover, species diversity.

<u>Subsequent Time (t = n)</u> **Existing MPA**



At a later time, researchers would measure the same environmental parameters that they measured at the initial time. Differences in the parameters between the initial and subsequent times or between the zones with and without the restriction at a given time might be explained by the restriction itself.

INTERPRETATION AND MANAGEMENT OF DATA AND INFORMATION (Adaptive Management)

The natural, social, and managerial research described above should be based on careful experimental design, accepted and reproducible methodologies, and meaningful statistical analyses. Research results should be evaluated through peer review. Good decision-making in MPAs is based on good science. Therefore, the better the quality of the scientific data, the better the informational tools available for MPA managers.

Research results should be packaged in several different forms that target different audiences. Scientific peers will demand detailed descriptions of methodologies, results, and conclusions. MPA managers need an executive summary that will highlight results that are directly applicable to management. An additional version of research results should also target the general public.

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Provisions should exist for evaluation of management strategies and restrictions after a given period (perhaps 3, 5, or 10 years) based on research results concerning the effectiveness of management strategies and restrictions on user impacts. Taking management-based research results into account, managers should redefine the problem and revise management strategies, where necessary. Management should be flexible and adaptive. Ideally, the investments in research resources, personnel, and time will promote a more effective management of the MPA. Even though they may possess limited funds and resources, MPA managers should promote some well-targeted and focused research that will allow wiser management decisions.

Bibliography

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Agardy, T. S. 1997. *Marine Protected Areas and Ocean Conservation.* Austin, Texas: R. G. Landes Company and Academic Press, Inc.

Agardy, T. (ed.). 1995. *The Science of Conservation in the Coastal Zone: New Insights on How to Design, Implement, and Monitor Marine Protected Areas.* Gland, Switzerland: IUCN.

Aquatic Adventures, Inc. 1999. *Whales of the Silver Bank: Sanctuary for the Marine Mammals of the Dominican Republic*. www.aquaticadventures.com

Ault, J., Serafy, J., DiResta, D., and J. Dandelski. 1997. *Impacts of Commercial Fishing on Key Habitats within Biscayne National Park.* Miami, Florida: RSMAS/University of Miami.

Barzetti, V. (ed.). 1993. *Parques y Progreso: Areas Protegidas y Desarrollo Económico en América Latina y el Caribe*. Washington, D.C.: IUCN.

Birkeland, C. 1997. *Life and Death of Coral Reefs*. New York: Chapman and Hall.

Bohorquez, C. 1997. *Restauración de Manglares en Colombia: Estudio de Caso del Parque Nacional Natural Corales del Rosario*. IN *La Restauración de Ecosistemas de Manglar*, C. Field, ed., pp. 209-217. Okinawa, Japan: ITTO.

Botero, L., and H. Salzwedel. 1999. *Rehabilitation of the Cienaga Grande de Santa Marta, a Mangrove-Estuarine System in the Caribbean Coast of Colombia*. *Ocean and Coastal Management* 42: 243-256.

Broome, G., and P. Valentine. 1995. *Principles of Social Impact Assessment and its Application to Managing the Great Barrier Reef.* Townsville, Queensland, Australia: CRC Reef Research Centre.

Chapman, V. J. 1984. Botanical Surveys in Mangrove Communities, IN *The Mangrove Ecosystem: Research Methods*, Snedaker and Snedaker, eds., pp. 53-80. Bungay, UK: UNESCO.

Chiappone, M., Kelly, J., Schmitt, E., and K. Sullivan Sealey. 1998. *Tools and Methods for Assessment of Land-based Sources of Pollutants and their Impacts on Coral Reefs: A Study of the Central Bahamas*. Arlington, Virginia: The Nature Conservancy.

Cintrón-Molero, G. 1990. *Restoration of Mangrove Systems.* Puerta de Tierra, Puerto Rico: Department of Natural Resources.

Clark, J. R. 1991. *Carrying Capacity : A Status Report on Marine and Coastal Parks and Reserves*. Miami, Florida: RSMAS/University of Miami.

Continental Shelf Associates, Inc. 1997. *Long-term Monitoring at the East and West Flower Garden Banks.* New Orleans, Louisiana: MMS/DOI.

Continental Shelf Associates, Inc. (CSA), and Martel Laboratories. 1985. *Florida Big Bend Seagrass Habitat Study*. New Orleans, Louisiana: MMS/DOI.

Coyer, J., and J. Witman. 1990. *The Underwater Catalog: A Guide to Methods in Underwater Research*. Ithaca, New York: Shoals Marine Laboratory.

Crosby, M. P., and E. S. Reese. 1996. *A Manual for Monitoring Coral Reefs with Indicator Species: Butterflyfishes as Indicators of Change on Indo-Pacific Reefs*. Silver Spring, Maryland: OCRM/NOAA.

Dahl, A. L. 1978. *Coral Reef Monitoring Handbook.* Noumea, New Caledonia: South Pacific Commission.

Davis, D., and C. Tisdell. 1995. Recreational Scuba-diving and Carrying Capacity in Marine Protected Areas. *Ocean & Coastal Management* 26(1): 19-40.

DeVantier, L. M., Barnes, G. R., Daniel, P. A., and D. B. Johnson. 1985. *Studies in the Assessment of Coral Reef Ecosystems: I. Assessment Protocol.* Townsville, Australia: Australian Institute of Marine Science.

Dixon, J. A., Scura, L. F., and T. van't Hoff. 1993. Meeting Ecological and Economic goals: Marine Parks in the Caribbean. *Ambio* 22 (2): 117-125.

Dixon, J.A. & P.B. Sherman. 1990. *Economics of Protected Areas: A New Look at Benefits and Costs*. Washington, D.C.: Island Press.

Duke, N. 1997. Reforestación de Manglares en Panamá: Una Evaluación de la Plantación de Manglares en Areas Desforestadas por un Gran Derrame de Petróleo. IN *La Restauración de Ecosistema de Manglar*, C. Field, ed., pp. 231-258. Okinawa, Japan: ITTO.

Duke, N. C., and Z. S. Pinzon M. 1991. Chapter 6: Mangrove Forests, in *Long-term Assessment of the Oil Spill at Bahía Las Minas, Panama, Interim Report, Volume II: Technical Report*, B. D. Keller & J. B. C. Jackson, eds., pp. 153-178. New Orleans, Louisiana: DOI/MMS/GOM OCS Region.

Durako, M. J., Phillips, R. C., and R. R. Lewis III (eds.). 1987. *Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States*. Tallahassee, Florida: FDNR/BMR.

English, S., C. Wilkinson, and V. Baker (eds.). 1997. *Survey Manual for Tropical Marine Resources: 2nd Edition*. Townsville, Australia: Australian Institute of Marine Science.

Fisk, G. 1995. Impacts of Expansion at Port Everglades: A Case Study of Environmental Mitigation. In *Urban Growth and Sustainable Habitats*, D. Suman, M. Shivlani & M. Villanueva, eds., pp. 9-30. Miami, Florida, USA: RSMAS/MAF, University of Miami.

Florida Marine Research Institute (FMRI). 1998. *Benthic Habitats of the Florida Keys.* St. Petersburg, Florida: The Institute.

Food and Agricultural Organization (FAO). 1994. *Mangrove Forest Management Guidelines.* Rome, Italy: FAO.

Geoghegan, T., and A. H. Smith. 1998. *Conservation and Sustainable Livelihoods: Collaborative Management of the Mankòtè Mangrove, St. Lucia.* St. Lucia: CANARI.

Gubbay, S. (ed.). 1995. *Marine Protected Areas: Principles and Techniques for Management*. New York, NY: Chapman and Hall.

Hall, J.L. 1994. Spanish Coins, Dutch Clay Pipes, and an English Ship: The 1993 Interim Report. IN *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference*, Vancouver, B.C., Canada, R.P. Woodward and C.D. Moore, eds., pp. 32-39.

Hamilton, L. S., and S. C. Snedaker (eds.). 1984. *Handbook for Mangrove Area Management*. Gland, Switzerland: IUCN.

Harmon, D. 1994. *Coordinating Research and Management to Enhance Protected Areas*. Cambridge, U.K.: IUCN.

INRENARE (Instituto Nacional de Recursos Naturales Renovables). 1994. *Diagnóstico Socio-Económico de los Beneficiarios del Manglar del Area Chame*. Panama: INRENARE.

INRENARE. 1996. *Evaluación Preliminar de la Producción Primaria de Hojarasca en las Areas de Chame, Azuero y Chiriquí*. Panama: INRENARE.

INRENARE. 1996. *Inventario Forestal de los Manglares de Chiriquí, Azuero y Chame*. Panama: INRENARE.

Intergovernmental Oceanographic Commission. 1991. *UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change, Pilot Projects on Mangroves and Coral Reefs, Monaco, 9-13, 1991.* UNESCO.

IUCN. 1998. *Economic Values of Protected Areas: Guidelines for Protected Area Managers*, IUCN Best Practice Protected Area Guidelines No. 2, A. Philips, ed. Available at http://www.iucn.org or http://economics.iucn.org/valuationparks.htm.

IUCN. 1986. *Managing Protected Areas in the Tropics*. Gland, Switzerland: IUCN.

Jokiel, P. L., and E. F. Cox. 1996. Assessment and Monitoring of US Coral Reefs in Hawaii and the Central Pacific. IN *A Coral Reef Symposium on Practical, Reliable, Low Cost Monitoring Methods for Assessing the Biota and Habitat Conditions of Coral Reefs, January 26-27, 1995.* Silver Spring, Maryland: Office of Ocean and Coastal Resource Management, NOAA.

Kelleher, G., and R. Kenchington. 1991. *Guidelines for Establishing Marine Protected Areas.* Gland, Switzerland: IUCN.

Kenchington, R. A., and B. E. T. Hudson. 1988. *Coral Reef Management Handbook.* Jakarta, Indonesia: UNESCO.

Kirkman, H. 1990. Seagrass Distribution and Mapping. IN *Seagrass Research Methods*, Phillips and McRoy, eds., pp. 19-26. Paris, France: UNESCO.

Kuo, J., Walker, D. I., and H. Kirkman (eds.). 1996. *Seagrass Biology: Scientific Discussion from an International Workshop, Rottnest Island, Western Australia 25-29 January 1996.* Perth, Australia: Western Australian Museum.

Maarleveld, T.J. Criteria for Archaeology and Heritage Management Underwater. Available at http://www.international.icomos.org/icomos/under_e.htm.

McClellan, D. B. 1996. *Aerial Surveys for Sea Turtles, Marine Mammals, and Vessel Activity along the Southeast Florida Coast, 1992-1996.* Miami, Florida: SEFSC/NMFS/NOAA.

McRoy, C. P., and C. Helfferich (eds.). 1977. *Seagrass Ecosystems*. New York, NY: Marcel Dekker, Inc.

Milon, J. W., Suman, D. O., Shivlani, M., and K. A. Cochran. 1997. *Commercial Fishers' Perceptions of Marine Reserves for the Florida Keys National Marine Sanctuary*. Gainesville, Florida: Florida Sea Grant. Technical Paper-89.

National Oceanic and Atmospheric Administration (NOAA)/Florida Department of Environmental Protection (FDEP). 1998. *The 1998 Zone Monitoring Report for the Florida Keys National Marine Sanctuary*. Marathon, FL: FKNMS/NOAA.

Phillips, R. C., and C. P. McRoy (eds.). 1980. *Handbook of Seagrass Biology: An Ecosystem Perspective*. New York, NY: Garland STPM Press.

Phillips, R. C., and C. P. McRoy (eds.). 1990. *Seagrass Research Methods*. Mayenne, France: Imprimerie de la Manutention.

Pollnac, R. B. 1998. *Rapid Assessment of Management Parameters for Coral Reefs.* Narragansett, Rhode Island: CRC/University of Rhode Island.

Reef Environmental Education Foundation (REEF). 1999. *REEF Homepage*. www.reef.org.

Reese, E. S. 1996. The Use of Indicator Species to Detect Change on Coral Reefs: Butterflyfishes of the Family Chaetodontidae as Indicators for Indo-Pacific Coral Reefs. IN *A Coral Reef Symposium on Practical, Reliable, Low Cost Monitoring Methods for Assessing the Biota and Habitat Conditions of Coral Reefs, January 26-27, 1995.* Silver Spring, Maryland: Office of Ocean and Coastal Resource Management, NOAA.

Ricklefs, R.E. 1979. *Ecology*. New York: Chiron Press.

Rogers, C. S., G. Garrison, R. Grober, Z-M. Hills, and M.A. Franke. 1994. *Coral Reef Monitoring Manual for the Caribbean and Western Atlantic.* St. John, Virgin Islands: VINP.

Russell, D. J. 1990. 'Benthic algae: Biomass and Abundance', in *Seagrass Research Methods.* Phillips and McRoy (Eds.), pp. 115-118. Paris, France: UNESCO.

Sargent, F. J., Leary, T. J., Crewz, D. W., and C. R. Kruer. 1995. *Scarring of Florida's Seagrasses: Assessment and Management Options*. St. Petersburg, Florida: FMRI Technical Report TR-1.

Sasekumar, A. 1984. Methods for the Study of Mangrove Fauna. IN *The Mangrove Ecosystem: Research Methods*, Snedaker and Snedaker, eds., pp. 145-161. Bungay, UK: UNESCO.

Shivlani, M. P., and D. O. Suman. In Press. Dive operator use patterns in the designated no-take zones of the Florida Keys National Marine Sanctuary (FKNMS). *Environmental Management.*

Sluka, R., Chiappone, M., Sullivan, K. M., and R. Wright. 1996. *Habitat and Life in the Exuma Cays, The Bahamas: The Status of Groupers and Coral Reefs in the Northern Cays*. Arlington, Virginia: The Nature Conservancy.

Smith, A.H. 1994. 'Community Involvement in Coral Reef Monitoring for Management in the Insular Caribbean', in *Collaborative and Community-based Management of Coral Reefs: Lessons from Experience*, A. White, Hale, Renard, and Cortesi (Eds.), pp. 59-67. West Hartford, Connecticut: Kumarian Press.

Snedaker, S. C., and J. G. Snedaker (eds.). 1984. *The Mangrove Ecosystem: Research Methods*. Bungay, U.K.: UNESCO.

Stoddart, D. R., and R. E. Johannes. 1978. *Coral Reefs: Research Methods*. Norwich, U.K.: Page Brothers Ltd.

Sullivan, K. M., and G. Bustamente. 1997. 'Geographic Priorities of Marine Conservation: The Nature Conservancy's Ecoregional Platform for the Wider Caribbean', in *Proceedings of the 50th Annual Meeting of the Gulf and Caribbean Fisheries Institute*, Merida, Yucatan, Mexico, November 9-14, 1997.

Sullivan, K. M., and M. Chiappone. 1994. *Rapid Ecological Assessment: Montego Bay Marine Park, Jamaica.* Arlington, Virginia: The Nature Conservancy.

Suman, D. (ed.). *El Ecosistema de Manglar en América Latina y la Cuenca del Caribe: Su Manejo y Conservación*. Miami, Florida, USA: RSMAS/MAF, University of Miami.

Thorsell, J. 1992. Guidelines for Managing Research in Protected Areas. IN *Science and the Management of Protected Areas*. J.H.M. Willison, S. Bondrup-Nielsen, C. Drysdale, T. Herman, N. Munro & T. Pollack (eds.). Elsevier Press: Amsterdam. pp. 175-179.

Vega, M., Chiappone, M., Delgado, G. A., Wright, R., and K. M. Sullivan. 1997. *Evaluación Ecológica Integral del Parque Nacional del Este, República Dominicana. Tomo 2: Recursos Marinos.* Arlington, Virginia: The Nature Conservancy.

White, A. T., Hale, L. Z., Renard, Y., and L. Cortesi (eds.). 1994. *Collaborative and Community-based Management of Coral Reefs: Lessons from Experience.* West Hartford, Connecticut: Kumarian Press.

Appendix 8.1
Guidelines for Research Priorities and Activities

This guide is not meant to be an exhaustive handbook for MPA research activities. It describes potential research questions and activities that could center around three important ecosystems in the tropical coastal and marine environments of the Wider Caribbean Region: coral reefs, mangroves, and seagrass beds.

CORAL REEFS

Coral reefs are often considered the marine equivalents of tropical rain forests because of the marine biodiversity they harbor (Birkeland, 1997). They serve as reservoirs for a variety of marine species which are important for many economic purposes, including genetic research, commercial fisheries, recreational fisheries, and marine tourism. Coral reefs are subject to various natural and human stressors, including increased temperatures (global warming, El Niño events), species shifts (sea urchin mortalities, crown-of-thorn starfish epidemics), diseases, pollution, and harvesting (direct coral harvests, associated faunal harvests). Because of these and other impacts that coral reefs can suffer, it is imperative that a designated MPA identify all potential sources and minimize their deleterious effects.

Coral Reef Ecological Characterization

The most important aspect of the ecological characterization is to determine the type(s), extent, and condition of coral reef resources present in the MPA. Monitoring of the resources can only take place **after** the characterization is complete.

In order to effectively characterize the coral reefs and their associated benthic and pelagic communities in the MPA, it is important to follow a set of guidelines that require detailed descriptions and accuracy. This ensures that the baseline information can be compared with subsequent monitoring results (Kenchington and Hudson, 1988).

EXAMPLE 8.3: Assessment and monitoring of US coral reefs in Hawaii and the Central Pacific (P. L. Jokiel and E. F. Cox)

The article discusses a case study on the Hawaiian Island, that of Kahoolawe Island where volunteer and agency support led to fish/coral/sediment surveys costing approximately $3,000 per transect. The authors believe that permanent transects would cost $5,000 per station, followed by $3,000 costs per station for subsequent surveys.

The authors argue that monitoring studies must be designed to answer a specific question. An extensive literature base on reef research methods exists which can be used for future assessments. Finally, sufficient funding is necessary for quality research, without which programmes are often prematurely discontinued.

Remote Sensing

Remote sensing refers to the preliminary characterization of coral reef communities using tools such as aerial photography, aerial surveys, or satellite imagery. In cases where such activities cannot be undertaken, reasonable proxies such as pre-existing maps, nautical charts, and local knowledge may be used.

a. Aerial Photography

Aerial photographs can show locations of different ecosystems within the MPA and even reveal smaller features, depending on the quality of the equipment utilized. Photographs should be taken on calm days, when water clarity is best.

b. Aerial Surveys

Aerial surveys can be utilized to identify smaller features, which are first revealed in aerial photographs. Aerial surveys, more so than aerial photography, require considerable effort and may thus prove financially impractical.

c. Other Information

Existing information, such as pre-existing maps from other agencies and conservation groups, can be used where aerial methods are unavailable. Users, such as local fishermen, divers, and others can also provide a wealth of information that managers would otherwise not obtain with or without aerial methods. This local user information can assist in various management aspects, including the location of geographical features, the identification of fishery-based aggregations, and knowledge of threatened and endangered species' habitats. However, it is imperative that coordinates be obtained for all information gathered from users, as these features should be incorporated into base maps.

Base Maps

Base maps can be created by tracing all information obtained from remote sensing onto basic maps or charts. Maps developed from aerial photographs have the added advantage that they are scaled and can thus be digitized or entered directly into computers. Using Geographical Information Systems (GIS), computer maps of an MPA can be transformed into multi-layered spatial maps that may be linked to a variety of databases. Changes in the databases can show changes over the spatial map. However, GIS may not be financially practical in some areas, as it does require considerable training, as well as computer hardware and software.

EXAMPLE 8.4: Benthic habitats of the Florida Keys (FMRI, 1998)

The Florida Marine Research Institute (FMRI), with the assistance from the National Oceanic and Atmospheric Administration (NOAA), developed a GIS-based atlas and CD-ROM of the benthic habitats in the Florida Keys National Marine Sanctuary. The process commenced with aerial photography in 1991-92, when pilots took a total of 450 photos along the study area at a 1:48,000 scale.

The photos were interpreted by ecologists who developed a 24-class benthic community structure under 4 major habitats: coral reefs; seagrasses; hardbottom; and bare substrate. Ground-truthing was performed to verify the habitats described from the photographs. Data was then digitized on the photographs, and in some cases, additional detail was added. The data, now in digital format, was combined to form regional mosaics. The mosaics were then joined together to create a Florida Keys-wide, benthic habitat, data set.

Ground-truthing and Preliminary Surveys

After the base maps are complete, it is important to determine whether the information obtained from remote-sensing and/or from local users is reasonably accurate. Smaller regions, representing the various coral reef community types, should be identified from the base maps. These smaller regions should then be surveyed using the Manta Tow Survey technique (see English *et al*., 1997). All boundary coordinates of the survey areas should be recorded, as well as preliminary observations.

Selection of Sample Site

Sample sites, representative of the coral reef types and zones in the MPA, should be selected and surveyed in detail (see Rogers *et al.*, 1994; Dahl, 1978) The information provided by the preliminary surveys shall assist in the determination of the overall complexity in the MPA. In cases where certain sites are affected by suspected anthropogenic activities, it may prove useful to set up control and sample sites.

Site Characterization Surveys

Because a wide variety of methods to survey the physical and ecological characteristics of coral reef sites exist, this section shall focus mainly on the factors that need to be surveyed (see Coyer and Witman, 1990).

a. Physical Parameters

The physical parameters of the water and sediments at a coral reef site can provide valuable information on the health of the site. Factors such as increased temperature and fluctuating salinity cause bleaching events in corals, and lowered dissolved oxygen and lower pH can point to changes caused by pollution. The following factors should be measured as part of a characterization study, as well as part of a monitoring program:

- Temperature;
- Salinity;
- Dissolved oxygen;
- pH;
- Light transmission/Turbidity;
- Detritus;
- Sedimentation;
- Nutrient concentrations;
- Chlorophyll concentrations; and
- Pollutant concentrations.

EXAMPLE 8.5: Study of land-based pollutants on coral reefs in the Bahamas (Chiappone *et al*., 1998)

This study assessed water quality in patch reef near areas of development and offshore areas to determine the effects of land-based pollution on coral reefs. The objectives of the assessment were to:

- determine differences in temperature, salinity, and dissolved oxygen according to proximity from variability, area, and coastal development
- determine differences in turbidity, sedimentation, nutrients, and chlorophyll concentrations according to area, coastal development, and tidal patterns
- determine differences in sediment nutrient concentration according to area and proximity to coastal development

The researchers took sub-surface water samples using Niskin bottles, and measurements of temperature, salinity, and dissolved oxygen were taken during dusk and dawn hours using a combination temperature/salinity/oxygen meter. The study also deployed four temperature meters that provided continuous readings. Most other measurements, conducted in the laboratory, were measured during ebb and flow tides to quantify effects of land-based pollutants.

b. Benthic Habitat Surveys

Benthic habitat surveys should sample the epifaunal, sessile, and relatively sedentary life forms in the sample sites. Percent coral cover (living and dead coral), damselfish totals, and sea urchin, gorgonian, and mollusk densities should be recorded. Other important indices are percent cover of algae, sponges, and octocorals. Coring, if performed, can provide information on prior reef growth rates, past climatic conditions, and previous reef associations. Because of the seasonal variability in many regions, benthic habitat surveys should be conducted at least during the summer and winter or dry and rainy seasons, as part of the characterization study.

A variety of survey techniques are available to study benthic habitats, including line intercept transects; chain transects; quadrats; and photo-quadrats. Each of the techniques has its advantages and disadvantages, and the appropriate technique should be selected according to the complexity of the reef system.

c. Fish Surveys

These surveys should determine the density, structure, and biodiversity of fish species present in the reef site (Sluka *et al.*, 1996). In all surveys, the number and types of species should be recorded. Surveys should be conducted at different times during the day to account for diurnal and nocturnal species, and they should also be conducted during the summer and winter seasons.

Fish survey techniques include a stationary fish census, belt transect census, and random swim technique (or the modified Roving Diver Method). Other advanced techniques include fixed video recordings, ROV video recordings, hydroacoustic techniques, and modified fish traps and catch methods. The latter three techniques are generally utilized for deeper regions where divers cannot safely conduct fish surveys.

EXAMPLE 8.6: Reef Environmental Education Foundation's (REEF) Fish Survey Project (www.reef.org)

REEF, a non-profit organization, conducts the REEF Fish Survey Project, which enables the collection of fish distribution and relative abundance data using a standardized visual survey method. The objectives of the project are: to provide training and educational opportunities for SCUBA divers and snorkelers; provide information to the scientific, management, and conservation communities; include the diving community as a partner in underwater research; and to encourage support and implementation of management strategies.

d. Coral Diseases and Bleaching

As part of the benthic surveys, corals with diseases or those exhibiting bleaching should be recorded. Coral colonies with black band or white band disease should be marked on survey sheets and recorded on databases and base maps. It is important to estimate the percentage cover of dead and diseased corals. Bleached corals, which are most common in the summer months, should also be recorded.

e. Biodiversity

As part of the site characterization study, scientists might determine indices of biodiversity, such as inventories of species of particular taxonomic groups or communities and analyses of community structure. Biodiversity might be measured at the community, species, or genetic level (Ricklefs, 1979).

EXAMPLE 8.7: Montego Bay Marine Park, Jamaica (Sullivan and Chiappone, 1994)

The Nature Conservancy, with its Jamaican partners, conducted a rapid ecological assessment of the Montego Bay Marine Park in 1992. The assessment had two objectives: to prepare an ecological community base map of the park, and to study patterns of benthic and inshore communities in the park. As part of the assessment, the group used three different methods to characterize the benthic community of corals, sponges, and algae. These methods were substrata and lifeform characterization, species inventories, and belt quadrants. Based on aerial photographs, the team set up a total of 32 benthic communities that they surveyed during a 4-day period.

Transects of 20-35 m, marked in 1 meter increments, were placed along communities in the park and oriented from inshore to offshore locations, parallel to shoreline. Coral cover, community type, and substrate type were recorded along square meter quadrants, and lifeforms and substrates were recorded separately. Species presence and absence inventories were performed using checklists for previously described species along the north coast of Jamaica. The group performed several post-collection analyses to determine species diversity and hierarchy indices. Belt quadrants, similar to the line transact procedure, measured the spatial density of species, including coverage of benthic algae and density and size-distribution of corals, sponges, and octocorals.

This effort included several months of preparation, training workshops, and aerial surveys. In effect, rapid ecological assessments represent an expensive form of site characterization (Sullivan, personal communication).

Coral Reef Socioeconomic Characterization

The socioeconomic characterization of coral reefs and the use of coral reef resources is of paramount importance if the MPA is to be protected. Humans are a part of the coral reef ecosystem and, in many cases, the most prolific predators on the reefs. Therefore, the population, users, and uses need to be identified, and generalized patterns of future uses need to be determined. Depending on the type of access allowed in and the overall health of the MPA, it can be expected that exploitation levels shall generally remain at their current levels and most likely increase in the future.

a. Characterization of the Coastal Population

The human population in and near the coastline that relies on the coral reefs and their resources should be characterized (see Pollnac, 1998). The criteria should include political, economic, social, and cultural factors at the national, regional, and local levels which, if changed, may accelerate or retard reef exploitation or management.

EXAMPLE 8.8: Rapid Assessment of Management Parameters (Pollnac, 1998)

The author provides a set of indicators of reef-related human behaviors which can be used to assess, predict, and potentially manage these behaviors. He discusses the importance of understanding the economy and policy at the national, regional, and local levels in order to predict how changes in these parameters may accelerate or retard reef management. Factors such as GDP (gross domestic product) and unemployment at the national level, population levels and types of employment opportunities at the regional level, and social structure and political organization at the local level are just a few of the factors that he suggests that managers must incorporate to predict reef use changes.

As part of the management characterization, Pollnac also suggests identifying all reef uses. These include local reef nomenclature, a detailed description of the ten most important fisheries in the region, and the types of reef tourism and recreational activities. Reef governance must also be understood, which include indicators such as local knowledge concerning coral reefs, use rights, management efforts, as well as local and national governance settings.

An important inclusion by Pollnac is that of cognitive mapping, or mapping the region in concern with local names. This provides a common map from which decisionmakers and users can discuss management aspects. Related to that is the standardization of names for species, or as Pollnac refers to it, "folk taxonomy". Both features, and the overall research approach, can provide invaluable information for a baseline study prior to monitoring.

b. Determination of Uses

All uses of the reef, both extractive and non-extractive, should be determined. The uses should then be separated into their artisanal, commercial, and recreational segments, and they should be considered separately.

1. Boating

Boating can refer to commercial glass-bottom or pleasure cruises, or it may refer to recreational vessels. The total number of boaters and their frequency of visits should be determined as part of the baseline characterization.

Aerial surveys can be used to determine the use patterns and densities of boats in sites which have many access points. In smaller, less accessible areas, the total number of vessels in the region generally equates to the total number using the MPA. Boating frequencies can also be determined by mail or intercept surveys.

EXAMPLE 8.9: Aerial surveys of boats in the Florida Keys (McClellan, 1996)

The study, conducted by NMFS researchers, consisted of aerial surveys taken over South Florida to assess boating usage (as well as marine mammal counts). The overflights occurred from 1992-1996, on calm Fridays. The information collected on boats included the size of the vessel, the type of vessel, and the activity in which the vessel was involved.

All the information collected from the aerial surveys was compiled, and percentages on the types of boats by specific areas were determined. This type of analysis showed the most dived, fished, and visited regions in the Florida Keys.

2. Diving and Snorkeling

Among the most popular activities in coral reefs, diving and snorkeling are conducted by both commercial operators and recreational users. Although patterns of diving and snorkeling activities can be determined through aerial surveys, intercept surveys with recreational users and interviews with commercial operators may provide more detailed information, such as areas of use and use frequency.

3. Fishing

Fishing includes a variety of different activities on coral reefs. Fishing may occur at artisanal, recreational, and commercial levels, and it may consist of various gear types (including traps, hooks, nets, spears, and even illegal explosives and poisons in some areas). Moreover, most coral reef fisheries are based on multiple species.

To characterize fishing use, it is important to target each fishery group separately.

Information necessary from all groups, however, are the total amounts of each species harvested, the amount of effort exerted, and the specific areas utilized in the coral reefs (Ault *et al.*, 1997). The most effective means of obtaining information from the artisanal fishing sector is through personal interviews. Commercial and recreational fishing data may be available through governmental agencies. However, both groups are best characterized by intercept or mail surveys.

EXAMPLE 8.10: Characterization of the commercial fishing industry in the Florida Keys (Milon *et al*., 1997)

This study surveyed 15 percent of the 2,400 commercial fishermen in the Florida Keys on socioeconomic issues concerning the implementation of the Florida Keys National Marine Sanctuary. The study, which was conducted in person, consisted of an 8-page survey that solicited responses on: demographic information; economic information; catch and effort information; perceptions; and enforcement.

Fishermen were contacted through a variety of purposes. The research team collaborated with commercial fishing organizations and fish houses, and also used the fishing license list. Surveys were prepared in English and in Spanish, and they were conducted at the fishermen's places of residence, docks, and fish houses.

c. Socioeconomic Base Maps

Base maps showing areas of socioeconomic use- boating, snorkeling and diving, and fishing- should be developed from the data provided by users. The maps should depict the densities, totals, and spatial segregation of use by each group. This information can be best displayed by GIS. Where GIS is unavailable, uses can be traced on pre-existing maps or nautical charts to delineate categorical areas of use, i.e. low, medium, and high use.

EXAMPLE 8.11: Diving and snorkeling patterns in the Florida Keys National Marine Sanctuary (Shivlani and Suman, in press)

This study, conducted with commercial dive operators through personal surveys, determined the total level of trips and divers and snorkelers taken by Keys operators in 1995. Operators also reported on the percentage of trips and users they took to designated "no-take" zones in the Sanctuary, and the study determined the overall importance of these zones on dive operator trips.

Linking the trip and diver totals database with GIS, the study created commercial operator use base maps. These maps demonstrated the overall importance of "no-take" zones to operators, as well as the selective use of zones in certain Keys regions over others.

d. Future Use Predictions

Based on the population characteristics and the extent and types of resource uses, it may be feasible to create a risk factor matrix. This matrix can then be used to determine which combination of uses would adversely impact the coral reefs of the MPA in the future and to use that information as a tool in adaptive management.

Coral Reef Ecological Monitoring

Ecological monitoring is an essential component that must be planned and implemented carefully. A monitoring plan should generally determine the parameters to be measured. However, any such plan must remain sufficiently flexible to allow for future threats that are not evident at the time of implementation. Therefore, general parameters such as physical and ecological measurements should be monitored periodically. Further activities that research can develop include mitigation and restoration. Finally, monitoring programmes should be developed with the knowledge of the financial capability of the management agency; otherwise, such programs too often become part of the "paper park" syndrome which, while functional in design, remain idle due to lack of funding.

For a detailed description of coral reef ecological monitoring, as well as monitoring protocols, refer to the Coral Health and Monitoring Program (CHAMP) at www.coral.aoml.noaa.gov.

EXAMPLE 8.12: Monitoring difficulties in St. Lucia (A. H. Smith, 1994)

The author demises over the paper parks in the Caribbean, arguing that only 16% of those outside of US jurisdiction enjoy meaningful protection. He describes the case of St. Lucia, part of the Windward Islands. In 1986, most of the coral reefs in St. Lucia were declared MPAs, but the boundaries were not defined, making enforcement almost impossible. In 1987, the government requested assistance from the Organization of American States in the preparation of a proposal to create a terrestrial-marine park in the Soufriere area. Monitoring began in 1988 with the following objectives: to test reef monitoring techniques with relevance to the needs of local management and development planning; use local expertise in monitoring, especially dive operators; facilitate their contribution to and responsibility toward the coral reef resource; and to design programs that were both appropriate and cost-effective.

The author summarizes that the dearth of active reef monitoring programmes in the Caribbean is due to: research being conducted by regional or external scientific organizations, whose methods are too expensive for smaller islands; survey methods that are designed have little regard for the different requirements of monitoring for management; most programmes do not include monitoring of potential impacts, such as levels of use and environmental variables; monitoring programmes are too often started through external funding which, when stopped, terminates all or most monitoring efforts and outside expertise.

a. Site Monitoring

A number of sites, according to the levels of complexity of the protected area, should be set aside as permanent monitoring sites. Alternatively, monitoring can occur as general surveys (as described in the ecological characterization section) at least once a year.

1. Permanent Monitoring Sites

Permanent sites can be set up using the research methods described in the ecological characterization section. Whatever technique is utilized, it is important to assure that the same area that was first characterized is the one that is then monitored. The use of coordinates, permanent quadrats, marked bottom, and other techniques can ensure that the same regions are re-sampled over time. Sites may be temporary or permanent. Although randomly selected sites may be considered less biased than permanent sites, random sites may not be sensitive to change because of reef patchiness. Rogers *et al*. (1994) recommend permanent sites for long-term monitoring of reefs because of consistency and reliability.

2. Physical Parameters

Physical parameters, such as temperature, salinity, light penetration, and others, should be measured during each monitoring session. For sites that have suspected anthropogenic inputs, nutrient levels and dissolved oxygen are important physical parameters to consider for potential eutrophication.

3. Coral/benthic Habitats

The benthic habitats should be remapped periodically, to determine changes in benthic composition and coral cover. Using the techniques of the initial characterization survey, monitoring can determine whether there are losses or gains to the region. Also, monitoring can determine gross changes such as bleaching, diseases, and physical impacts to the resources.

EXAMPLE 8.13: Long-term monitoring in the Flower Garden Banks National Marine Sanctuary (Continental Shelf Associates, Inc., 1997)

The Flower Garden Banks were designated as a National Marine Sanctuary in 1992 to protect the northernmost tropical coral reef community on the North American continental shelf. Environmental threats to the banks include development of hydrocarbon resources and associated activities in the proximity of the Sanctuary.

To protect the region from such activities, the Sanctuary has determined the following objectives for its long-term monitoring study: to provide timely information to agencies that develop oil and gas exploration policies and decisions; to document long-term changes in the ecological communities in the Sanctuary that may be related to human activities, and to differentiate that from natural variations.

Field data for the monitoring study were collected using random transects, which were photographed and analyzed for population levels of corals, associated biota, and other organisms. Coral growth rates were determined by measuring metal spikes implanted within live coral. Additional data collection included video transects, quadrant sampling, and visual growth measurements, as well as ancillary measurements (temperature, oxygen, light, salinity).

4. Fish

Fish surveys over time, using the same techniques described above, can determine changes in the density, structure, and diversity of the fish populations on coral reefs. These surveys should also be conducted periodically. However, the monitoring efforts do not necessarily need to be coupled with the benthic surveys. Depending on the type of activities allowed in the protected area, fish surveys can determine whether the objectives of the plan are being met.

EXAMPLE 8.14: Zone performance in the Florida Keys National Marine Sanctuary no-take zones (NOAA, 1998)

As part of the Sanctuary's monitoring effort, NOAA and a group of independent researchers have been studying the changes in fish and invertebrate populations in the no-take zones implemented in 1997. Allowing no fishing in a majority of the zones, the researchers have determined whether the reduction of effort has led to larger individuals and bigger populations of species targeted by the fishing sector.

EXAMPLE 8.15: The use of indicator species to detect changes on coral reefs: the example of butterflyfish (Family Chaetodontidae) in Indo-Pacific coral reefs (E. S. Reese, 1996; Crosby and Reese, 1996)

Results from this study suggest that traditional environmental monitoring, while measuring change in a system, is expensive, intensive, requires technical expertise, and is often inaccurate and intrusive. Reef-feeding fish can be used as an indicator of the health of the entire coral reef community. Butterflyfishes leave the reef prior to complete collapse and, thus, represent an "early warning system" that can serve as an inexpensive proxy for monitoring agencies.

5. Pollution

Protected areas that have suspected or known human inputs of pollutants, such as nutrient or thermal pollution, require monitoring of impacts. Benthic surveys of permanent sites chosen near areas of human input can be compared with control sites chosen in areas away from human inputs. Such studies should incorporate measurements of physical parameters (nutrients, turbidity, chlorophyll, dissolved oxygen) with those of ecological observations (extent of bleaching, algal overgrowth of coral colonies, frequency of coral diseases) to determine whether human inputs have significant effects on the resources of the protected area.

b. Restoration Activities

Coral and benthic habitat restoration activities may require significant funding. Less expensive restorative activities may include removal of sediments and uprighting coral heads following a storm or vessel grounding, scouring of macroalgal mats, and others. More expensive restoration would include transplantation of corals from laboratories or from other sites to affected areas. If restoration or rehabilitation of the coral reef ecosystem is undertaken, the success of these efforts must be closely monitored.

Coral Reef Socioeconomic Monitoring

Socioeconomic monitoring is as important as ecological monitoring, as it determines the changes in the types and extent of human activities on coral reefs. Depending on the uses permitted on the reefs, users can greatly change the patterns and efforts of their use of the natural resources in and around the protected area.

a. Changes in Uses

In areas that are closed to all uses, changes generally occur adjacent to the protected boundaries. Conversely, in areas that allow certain uses, use patterns may change greatly inside the protected boundaries. Although there is a gradation of effects that uses cause in protected areas, it is important nevertheless to monitor all uses inside the boundaries. This greatly facilitates the understanding of connections between the ecological health of a protected area and the intensity of uses, thereby improving management.

1. Use Types

Use types, in and around the protected area, can be best monitored by surveillance. Surveillance data can be compared on a monthly or yearly period to determine what types of activities are occurring.

2. Use Intensities

Use intensities can also be monitored by surveillance data, but the intensities can be best measured through aerial techniques and user surveys. Data provided directly by users can determine the levels of effort they place on and around the protected area.

3. Users' Perceptions

User satisfaction may greatly facilitate cooperation in monitoring, as well as enforcement and other activities. Therefore, monitoring efforts should attempt to gauge user perceptions on resource health, protected area performance, and support for the protected area. These perceptions, obtained through surveys, provide information to managers on how best to reach users and even solicit their assistance in monitoring efforts.

b. Impacts of Uses

Impacts of uses can also be determined over time using simple monitoring techniques. Impact quantification can provide means by which to devise management strategies that mitigate unacceptable activities or otherwise minimize impacts while accommodating users.

1. Immediate Impacts

The monitoring of immediate impacts can be conducted through surveillance, aerial surveys, user reports, benthic surveys, and other techniques. Incorporating a "whistle-blowing" system may assist in reporting infractions. However, it is best to integrate or "buy-in" users into research and enforcement activities, such that management efforts are seen as complementary to users' activities.

2. Cumulative Impacts

Cumulative impacts are best determined by correlating the ecological monitoring results with user intensities. Impacts such as coral degradation and fish abundance may be related to levels of user activities. Therefore, user surveys can be used to determine types and levels of activities in the affected area. However, it is important for comparative studies to unequivocally demonstrate the effects of human activities on the ecological health and to prove cumulative impacts; otherwise, the protected area may lose valuable user support.

Mangroves are salt-tolerant (halophytic) floral species present in the tropics and sub-tropics. Belonging to various families, mangroves are distinguished mostly by their growth in the coastal zone, rather than by phylogentic similarities. Forests are described by the major species and mangrove associates they contain. Mangroves are highly productive ecosystems, providing detrital and leaf litter biomass to adjacent communities. Many unique species of flora and fauna rely on mangrove communities, as well as several juvenile marine species that spend much of their younger life stages within the ecosystem. Mangroves protect coastlines by providing a buffer zone against hurricane storm activity and associated storm surge effects. Humans across the world also utilize mangroves for other purposes, including shelter, wood, and charcoal production. However, mangroves, like other coastal ecosystems, are under threat of coastal development and agricultural conversions. Because of their links to the other major ecosystems (sea grasses and coral reefs), mangrove conversions would have negative effects on adjacent ecosystems. Therefore, mangrove ecosystems need to be protected as strongly as the other, more apparent ecosystems in an MPA.

Ecological Characterization of Mangroves

To effectively characterize mangrove forests in an MPA, it is important to assess the location and types of mangrove communities present, the species diversity in the communities, and the level of naturalness, representativeness, and degree of critical habitat provided for key wildlife species (Hamilton and Snedaker, 1984; FAO, 1994). Although it is generally accepted that mangroves display a level of succession along their distribution, species are more commonly distributed along a vertical gradient perpendicular to the coastline or channel which is dependent also on nutrient availability and other abiotic factors (zonation). Local residents could play an important role in data collection in mangrove forests.

a. Delineation of Mangrove Forest Boundaries

Mangrove forest boundaries and forest types can be delineated and classified by the use of remote sensing and/or ground-truthing. Remote sensing methods, such as aerial photographs, can provide the total area occupied by a mangrove forest, and ground-truthing surveys can verify those boundaries (FAO, 1994). All boundary gathering data must be documented by GPS (Global Positioning Systems) or other coordinates to ensure that the mangrove forests are correctly delineated. The boundaries at the seaward side should extend to the high-water mark of spring tides, and the landward boundary must include all mangrove associates, especially where there is visible zonation.

b. Mangrove Forest Structure and Productivity

Using existing floral and faunal species lists and any other existing data, researchers should survey the mangrove forests to document all species present (Chapman, 1984). Species that are not readily identified, including associated lichens, fungi, and algae, should be collected and examined in the laboratory. Mud samples, taken at different depths and at different elevations, should also be collected and analyzed where possible. These samples can provide basic data on the macrofauna and flora and the meiofauna and flora present in the community.

To determine the density and dominance of species present, researchers should employ a set of available methods. Density refers to the number of plants of a single species per unit area and the total number of plants per unit area (Chapman, 1984). Because mangrove forests are generally vertically zoned, density studies should focus on the canopy layer; the sub-canopy layer, consisting of shrubs and ferns; and the herb layer. Random quadrant sampling, can be used for these surveys. Dominant species in each layer should also be recorded. Additionally, belt transects can be performed in areas that have a homogeneous habitat, and line transects, across environmental gradients. Chapman (1984) concludes that a combination of quadrants, transects, and aerial photographs can "provide the best overall picture" (p. 79) (see also FAO, 1994). There are many other studies (productivity, community structure, and species richness, among others) that researchers can perform to more completely characterize the mangrove community (Snedaker and Snedaker, 1984; English *et al.*, 1994).

Depending on the goals of the MPA, it might be appropriate to perform mangrove forestry inventories that would measure the available wood resources. Volume of wood may be estimated through remote sensing imagery or limited field sampling of tree diameter and height in a few representative forest plots (FAO, 1994)

EXAMPLE 8.16: Rapid Ecological Assessment of Parque Nacional del Este, Dominican Republic (Vega *et al.*, 1997)

As part of a rapid ecological assessment (REA), the group determined the terrestrial and marine resources available in the Parque Nacional del Este in the Dominican Republic. The park, designated in 1975, is located southeastern coast of the Dominican Republic and encompasses almost 42,000 hectares. Among its various habitats, the park contains extensive mangrove forests. The REA, among its objectives, assessed the mangrove communities of the park. First, researchers utilized relief maps and aerial photography, as well as satellite imagery, to create a coastal community map. To better identify community types, the group also recorded in situ observations which included: 15 sample sites with 10 x 10 meter quadrats which were chosen during overflights and ground reconnaissance; the physical conditions and general community types at each quadrat; global positioning system (GPS) ground-truthing of each sample site; soil sample studies; and forest cover. The results of the characterization determined the floral and faunal diversity present in the mangrove communities, including canopy cover types, soil composition, and crustacean and mollusk fauna associated with the mangroves.

EXAMPLE 8.17: Evaluación Preliminar de la Producción Primaria de Hojarasca en las Areas de Chame, Azuero y Chiriquí (INRENARE), Inventario Forestal de los Manglares de Chiriquí, Azuero y Chame (INRENARE, 1996)

Panama's Mangrove Management Project selected three mangrove areas on the Pacific coast and conducted socioeconomic and ecological baseline evaluations. The goal was to develop management plans based on principles of conservation and sustainable development. Staff of Panama's Natural Resources Institute (INRENARE) measured the following parameters:

- floral composition and spatial distribution
- average diameter, volume, and number of mangrove trees
- primary production measured by leaf litter
- identification of potential areas of forestry production and protection for purposes of research, ecotourism, and environmental education

c. Mangrove Fauna

Series of stations along a transect that bisects the mangrove forest from the low to high shore should be created to determine the faunal types in the different forest zones (Sasekumar, 1978). Soil samples should be taken to collect all infauna. Macrofauna and meiofauna can both be studied from soil samples. Such samples should be collected during different tidal regimes to accurately account for a majority of the species that inhabit the ecosystem.

Tree samples of ephypthic fauna, such as snails, should also be taken. Marine species, such as fish and invertebrates, can be collected during high and low tides. Other mobile species, such as birds and small mammals, may be observed during different hours and seasons and can be documented via observational sheets, photographs, and other non-invasive methods. These observations can provide basic species total and frequency data.

All species collected should be cataloged into their major phyla, and they can be described in terms of species' totals as well as biomass and productivity.

d. Mangrove Soils

Mangrove soils should be sampled to determine their characteristics because they represent the most important factors affecting mangrove productivity and structure. The chemical and physical properties of the soil, including pH, eH, salinity and particle size, can all be determined using simple field techniques (English *et al.*, 1994).

Socioeconomic Characterization of Users of Mangrove Ecosystems

All human uses in the mangrove forests should be determined, categorized, and quantified. Uses such as inhabitation, subsistence use, commercial use, and recreational activities should be considered. In cases where there is a human population or local community living in and using the resource, it may prove useful to characterize that population through interviews and surveys. Such baseline information can reveal potential threats to the mangrove ecosystems in the MPA over the long-term, and it can also provide solutions on how best to monitor and even mitigate those impacts. Baseline characterization can also determine the social and economic values that the users place on the mangrove resources.

EXAMPLE 8.18: Diagnóstico Socio-Económico de los Beneficiarios del Manglar del Area de Chame (INRENARE, 1994)

Panama's Natural Resource Institute (INRENARE) conducted a socio-economic characterization of users of three mangrove areas as part of its Mangrove Management Project. In one of the three areaa, Chame, the research focused on the 400 persons who depended on the mangroves for their livelihood. INRENARE determined these individuals' educational levels, housing, and health; the mangrove productive systems present in the community, social organization, and artisanal production techniques.

a. Inhabitation

Simply put, the number of dwellings and residents in and adjacent to the mangrove forests should be determined. This can be performed by a visual survey and census in many locations. In other more densely populated areas, demographic data available from the government may be used. The inhabitants should then be surveyed to gather the following data: demographic information, economic information, uses of mangrove areas, and acceptance of the MPA.

Also, the overall socioeconomic factors involved in the mangrove forests should be determined and quantified, as Pollnac (1998) recommends for coral reef management. Therefore, local economic indices, as well as social and cultural structures, should be studied.

b. Subsistence Use

All types and levels of subsistence use should be determined and quantified. Note that subsistence use implies use for personal or community purposes and is different from recreational and commercial uses. There are several subsistence uses of mangroves, including the actual harvest of trees for firewood and charcoal, timber, crafts, medicines, dyes, paper, and others (see Hamilton and Snedaker, 1984; Suman, 1994). Species associated with mangroves are also affected by subsistence use, including fish and marine invertebrates, bees (for honey), and birds. The best means by which to determine subsistence use may be to conduct personal surveys with the users, as well as utilize available government data on the types and amounts of subsistence products.

c. Commercial Use

Commercial use of mangrove communities may include several of the subsistence use products, except that they would be sold at commercial levels. Of particular importance are activities such as timber cutting and commercial fishing. Mangrove forest conversion for agricultural and development purposes is also important. These activities should be itemized and quantified, with the use of government information and personal surveys.

EXAMPLE 8.19: Mangrove Restoration at John U. Lloyd State Recreation Area (Florida, USA) (Fisk, 1995)

John U. Lloyd State Recreation Area (JULSRA) in Florida, USA, is the site of a mangrove restoration project performed by the Port Everglades Authority. As mitigation for conversion of 18 acres of mangrove forest at the port, the port authorities financed a 23 acre mangrove restoration project at the adjacent state protected area in 1989. Exotic species of Australian pine were removed, nursery-grown propagules were planted on scraped land at 1 foot intervals. The port was responsible for assuring 80 percent survivorship for a 10 years period.

d. Recreational Activities

Mangrove forests offer a myriad of recreational activities, including boating, fishing, hunting, hiking, swimming, and nature-based activities (Hamilton and Snedaker, 1984; Suman, 1994). To determine the types and frequencies of such activities, baseline research may consist of aerial surveys and visitor surveys. Visitor intercept surveys, if sufficiently detailed and well-designed, can assist in the quantification of the value of the mangrove forests to recreational users.

Ecological Monitoring of Mangroves

Ecological monitoring should include periodic surveys of the factors considered in the baseline characterization. Permanent survey plots can be utilized to determine changes in forest and soil composition, and other surveys can be conducted to determine faunal changes. Aerial photography can determine gross changes to the forests. If mangrove restoration projects occur, their evolution must be monitored.

EXAMPLE 8.20: Restauración de Manglares en Colombia: Estudio de Caso del Parque Naturales Corales del Rosario (C. Bohorquez, 1997)

Mangroves have been successfully restored and transplanted in the Corales de Rosario National Park near Cartagena, Colombia, where local residents have degraded the mangrove ecosystem by extraction of wood products. Researchers employed two techniques: 1) transplant of small trees between 1 – 1.5 m height and 2) direct planting of propagules.

EXAMPLE 8.21: Rehabilitation of the Ciénaga Grande de Santa Marta, a Mangrove-Estuarine System in the Caribbean Coast of Colombia (Botero and Salzwedel, 1999)

The Ciénaga Grande de Santa Marta (CGSM) estuarine lagoon system is part of the exterior delta of the Magdalena River, the largest river in Colombia. The CGSM is the largest such system in the Caribbean Sea, and it has historically contained significant mangrove resources. However, due to human activities such as highway construction and water diversions, the mangrove communities have suffered extensively from hypersalinity and sedimentation, resulting in almost 70 percent mortality. In 1988, the Colombian government started a project to restore and manage the coastal resources of the CGSM via an environmental management plan and major programs. Related to the restoration of mangrove forests, one such program called on the improvement of institutional capacity and users resulting in improvement of mangrove soil conditions, regeneration of mangrove communities, and the development of a joint restoration plan between the government agencies and users.

Mangrove restoration has clearly occurred in areas adjacent to newly dredged canals and culverts, and other restoration projects have been designed for future implementation depending on the improvement of soil conditions. Monitoring studies have demonstrated that soil conditions and propagule availability are the two most important factors in regeneration. However, the authors warn that the results can only be sustained if there is continued local participation and if the upstream sediment loads are reduced. Otherwise, mangrove restoration may not only fail, but it may also lead to further degradation.

EXAMPLE 8.22: Long-term Assessment of the Oil Spill at Bahía Las Minas, Panama (Duke and Pinzón, 1991; Duke, 1997)

As a result of the 1986 oil spill in Panama which resulted from a ruptured oil storage tank in a coastal refinery, the region's mangroves were heavily impacted. There were two major impacts to the mangrove community: deforestation and sublethal effects, including altered patterns of growth and development. In order to understand how mangroves react to such catastrophic events, this study looked at the recovery of mangroves following the oil spill. Specifically, the study used three monitoring approaches to determine spill impacts and recovery rates. The researchers mapped the vegetation boundaries to determine the extent of the impact on the forest. The maps displayed the effects of currents and winds on the forests, as well as the areas planted as restorative activities by the refinery. Second, the researchers examined surviving trees and associated biota, including primary producers and consumers. Third, the study examined the recovering biota in forests where trees were killed, including studies on recruitment, growth, and census of primary consumers.

<u>Socioeconomic Monitoring of Mangroves</u>

Socioeconomic monitoring should consist of periodic surveys within the different user groups to determine changes in the types and levels of activities. Monitoring efforts should be developed depending on the activities allowed within the protected area. In areas that do not permit any uses, monitoring should focus on uses around the forests and enforcement effectiveness. In forests where uses are allowed or zoned, monitoring should determine changes in use types and intensity. As described in the characterization section, a variety of information sources and survey techniques can be utilized for monitoring purposes. Another important aspect of socioeconomic monitoring should focus on the social changes resulting from management measures, as well as the economic welfare of the groups affected. Government data on quantities of mangrove products, visitor surveys, and user interviews can be used, depending on the type of monitoring data required.

EXAMPLE 8.23: Conservation and Sustainable Likelihoods: Collaborative Management of the Mankóté Mangrove, St. Lucia (Geoghegan and Smith, 1998)

St. Lucia's mangroves have been recently reduced as a result of human activities, including clear cutting, dumping, and charcoal use. Although nearly all of the country's mangrove areas were protected as marine reserves under the Fisheries Act of 1984 and subsequent legislation, none of these initiatives have led to effective mangrove conservation. Poor public support, multiple agency jurisdiction over the mangrove resources, limited surveys in the actual marine reserves, development conflicts, and mixed ownership schemes are among the reasons for the lowered effectiveness.

A group of users and a non-governmental organization have collaborated in Mankóté, the country's largest remaining mangrove area, to manage a sustainable harvest of the mangrove resources since 1983. As part of the management strategy, the following components have been installed: mitigation of harvesting impacts through improved techniques; reduction of harvesting pressure by offering other fuelwood sources and income opportunities to charcoal producers; and the replacement of the open access system to a system based on communal management.

SEAGRASSES

Seagrasses constitute an important inshore feature in many coastal communities. They are sites of high primary productivity, provide habitat for many juvenile and adult species, are a principal contributor to the marine food web, and improve water quality by stabilizing mobile sediments (Sargent *et al*., 1995). However, seagrasses are threatened by many human activities, including pollution, dredge and fill activities, and boat scarring. Because of their ecological and economic importance and due to their susceptibility to damage, any research and monitoring plan must characterize, monitor the seagrass community present in the designated MPA, and collect data for its protection.

Ecological Characterization of Seagrasses

The ecological characterization of seagrasses should be conducted to determine the amount of the resource present in the area, the species of seagrasses present, zonation, and the level of biodiversity that characterizes the communities. Once characterized, additional baseline research may measure the primary productivity and linkages to other systems, such as mangroves and coral reefs. However, the characterization research should at least determine the amounts and types of seagrasses present in the protected area.

a. Remote Sensing

Seagrass distribution must first be determined by remote sensing techniques, preferably aerial photographs and surveys. Satellite imagery, a developing field, may also be utilized if available. In cases where the above options are not available, boat surveys determining the average extent of the seagrass communities can be utilized. User data, if associated with coordinate-backed boundaries, may be useful in other instances. Finally, existing maps and charts can also be used in all remote sensing efforts.

b. Ground-Truthing Surveys

Once the outline of the seagrass area has been obtained, ground-truthing may be done by using a sled or a manta tow (Kirkman, 1990). GPS or compass triangulation is necessary to fix the location. Different meadows, based on species, should be determined and cataloged during the ground-truthing session. All areas containing decaying, dead, or scarred seagrass beds should also be documented.

EXAMPLE 8.24: Florida Big Bend Seagrass Habitat Study (CSA and Martel Labs, 1985)

This study, which was funded by the Mineral Management Service, characterized the seagrass community in the Big Bend region. As part of the methodology, the researchers conducted a pre-overflight ground-truthing cruise, remote sensing overflights, and a final post-overflight ground-truthing cruise. While the level of sophistication in this study may be too expensive for other regions, the ground-truthing methodology may prove useful. The researchers had two objectives in the pre-flight cruise: to survey the deep portions of the study area using underwater video, as well as to select, mark, and sample representative control stations. They used a transect method to sample the sites. The post-flight cruise sought to determine the outer boundary of the seagrass growth with divers and video, to investigate questionable signature areas, and to resample previously sampled areas in a different season.

c. Community Base Maps

Based on the data obtained during the ground-truthing surveys, community base maps can be prepared for the different seagrass communities in the marine protected area. These may consist of the large meadows, and they may depict different species of seagrasses by meadows. The base maps should attempt to provide as much species-specific zonation as possible.

d. Species Composition, Biomass, and Associated Flora

Species composition can be best determined through a line transect or related survey technique, where the survey plot is placed along the seagrass community. Sample sites should be chosen to include all species of seagrasses present in the protected area, and the sites must also include the various depths at which the seagrasses are present. All species of seagrasses present in sample sites should be recorded, as well as associated flora. Samples of leaves and roots may be collected for biomass, density, and productivity estimates (Philips and McRoy, 1990). Ephiphytic and benthic samples may be collected to identify encrusting and benthic algae in the laboratory (Russell, 1990).

e. Physical Parameters

Physical parameters, such as temperature, salinity, dissolved oxygen, and turbidity, should be collected at each sample site. In sites that are susceptible to pollutants, nutrient levels and sediment content should also be analyzed.

f. Associated Seagrass Fauna

Seagrass-associated fauna may be collected at the same sites as above. Fauna includes all mobile and sedentary species, as well as infauna and epifauna. Collection methods includes nets and cores, and sampling should take place during different tidal regimes and times of day to collect all potential inhabitants. Following collection or sighting, all seagrass-related fauna, including manatees and sea turtles, should be cataloged in a list that can be utilized for monitoring efforts

Socioeconomic Characterization of Human Interactions with Seagrass Ecosystems

Socioeconomic characterization of seagrasses generally refers to the interactions of humans with the communities, e. g. transport over the seagrasses, fishing on the beds, bottom-altering activities (such as dredging and filling), and pollution. All such uses should be documented and quantified wherever possible, especially in regions where user impacts are evident or suspected.

a. Transport over Seagrass Beds

Seagrasses grow in a variety of depths, including in very shallow water. Because seagrasses are also prevalent along coastlines, they are generally threatened by boat propeller impacts. Therefore, baseline research should determine the extent and patterns of boating traffic over seagrass communities. Scarring impacts can be determined by aerial surveys (discussed above), but the potential for future effects can also be assessed by quantifying boat totals in the marine protected area, docks and marinas located near target seagrass communities, and by boat surveys of drafts and propeller types.

EXAMPLE 8.25: Scarring in Florida seagrasses (Sargent *et al*., 1995)

The Florida Marine Research Institute (FMRI) determined the distribution of scarred seagrass beds in Florida using aerial photography and aerial surveys. The group utilized color infrared (CIR) transparencies and other photography to determine the extent of seagrass scarring. FMRI also conducted aerial surveys to verify scarring and to refine delineations of scarring intensity. Based on a categorical system of scarring patterns, the researchers determined the extent of damage that boat propellers had caused in Florida's seagrass communities.

b. Fishing on Seagrass Beds

Fishing on seagrass substrate or in the water column above should be documented. Fishing can be accounted for by aerial techniques to determine the number and patterns of users, and also by surveys with fishermen. The latter method can provide more detailed information, such as harvest totals, species, and effort, as well as patterns.

c. Bottom-Altering Activities

These activities are generally related to development and channelization. All such activities, either in progress or planned, should be accounted for via surveys with agencies and development groups. Characterization of these activities shall provide valuable information on changes that occur over time in the seagrass environment. The extent of the activities, i.e. the locations being altered, the approximate boundaries of alteration, and potential mitigation, should also be determined.

d. Pollution

All potential polluting sources, such as sewage plants and coastal developments, should be identified, and the pathways and amounts of pollutants should be determined. This information can be obtained through from the actual facilities themselves or from pre-existing studies. Actual pathways can be approximated utilizing nearshore circulation models.

Ecological Monitoring of Seagrasses

Ecological monitoring of seagrass sites can determine whether the management of these resources is effective, and it can also identify potentially deleterious factors that need to be remedied to protect the seagrass communities. Ecological monitoring should encompass the sampling of permanent sites, including surveys of physical parameters, community composition, density, and structure, and associated flora and fauna. In sites that are suspected or known to contain pollutants, sediment samples and additional physical analyses may be necessary. Also, such sites should be sampled concurrently with control sites that do not contain such pollutants.

a. Physical Parameters

Parameters, such as temperature, salinity, and dissolved oxygen, should be monitored periodically. The interval (tidal, daily, monthly, seasonally) will depend on available funding, seasonality, and water circulation. These should be compared with earlier data to determine whether sites are being subjected to equal or more stressful conditions, as well as to understand the effects of changing parametric conditions on the resource's health.

b. Community Composition, Density, and Structure

The community should be sampled periodically to determine whether there have been losses or gains in seagrasses, whether the species have changed over time, and if there are larger or smaller densities of seagrass. Related studies may include those to examine changes in standing biomass and productivity.

c. Associated Flora and Fauna

Using methodologies described in the characterization section, the monitoring efforts for associated flora and fauna should study the changes in benthic and epiphytic flora and mobile and sedentary fauna. Efforts, where applicable and available, should also focus on potential shifts in grazers and types of commercially viable species present. Additional monitoring may look at changes in species biomass and structure, as well as productivity of associated flora.

EXAMPLE 8.26: Sabana-Camagüey Archipelago Protected Area in Cuba (I. Fernandez, personal communication, 1999)

On Cuba's north coast, the Ministry of Agriculture manages the Protected Area of Managed Resources of the Sabana-Camagüey Archipelago which contains important coral reeks, seagrass beds, and fringing mangroves. Resource monitoring covers: mangrove fish communities, reef fish, fish on seagrass beds, rocky bottom fish communities, coralline communities and associated flora and fauna, sea turtles, and manatees.

d. Mitigation and Restoration Activities

All mitigation and restoration sites should be closely monitored to evaluate their success. Factors such as percent survival rate and productivity should be considered in any restoration study.

Socioeconomic Monitoring of Human Uses of Seagrass Ecosystems

Socioeconomic monitoring objectives shall be determined by the allowable activities on seagrasses. In marine protected areas where no activities are permitted, socioeconomic monitoring shall study the effects on users displaced from the seagrasses. In other areas that allow certain uses, monitoring shall consider the changes in use levels and intensities both on and around the seagrasses. Monitoring the boating activities, fishing, development, and pollution are of high importance (Phillips and McRoy, 1990; Durako *et al.*, 1987).

a. Boating

Boating patterns and scarring can be best determined by aerial surveys, and this data can demonstrate whether users continue to impact seagrass communities or if other management plan strategies (such as enforcement and education) have resulted in lowered impacts. In other areas, surveillance data can serve as a proxy for actual aerial photography to obtain similar information.

b. Fishing

Monitoring fishing effort and catch in seagrass beds can be best performed by periodically surveying the users that fish those areas. Aerial surveys can assist in understanding general fishing patterns on seagrasses. The fishing data can then be used in combination with the ecological monitoring data to determine factors affecting changes in flora and fauna in seagrass beds.

c. Development Activities

Development activities that were planned or approved during designation of the MPA or already existed should be monitored closely to quantify changes in seagrass communities, both in terms of their size and their health. Monitoring efforts should optimally occur at sites where these activities are occurring, and the ecological monitoring parameters should be applied at these sites to compare these communities with others that experience little to no human interference. Also, all changes to these communities should be documented and mapped wherever possible.

d. Pollution

As part of the ecological monitoring program, the socioeconomic monitoring segment should periodically record levels of effluents and other anthropogenic runoff. This could also be measured in plants tissue samples. The information may be obtained through government agencies or through the actual polluting sources. Comparison of the ecological health of the seagrasses with the proximity of pollutants may assist in the determination of potential pollution causes and their long-term results.

MARINE MAMMALS/SPECIES OF SPECIAL INTEREST

In areas that have marine mammals and/or species of special interest (threatened or endangered), it is important to identify population totals, essential habitats, and/or migratory pathways within the marine protected area. Aerial surveys may be the best means of detecting and surveying larger marine mammals. Smaller boat surveys may also perform the same function, especially for resident populations. The identification and survey of smaller species, both mammals and others, may depend more on boat or in-water surveys, and these activities should be conducted according to the species concerned. When complete, all such species should be documented and recorded in a database. Important nesting, breeding, and feeding habitats should be noted on base maps. Future studies should concern periodic population surveys, habitat conditions, and conflicts with users. Officials might encourage recording of sightings of the more rare species by local community residents and tourists.

EXAMPLE 8.27: Silver Bank Sanctuary, Dominican Republic (Aquatic Adventures, 1999)

The Silver Bank Sanctuary was created in 1986 by presidential decree in the Dominican Republic. In 1996, the sanctuary, a known Humpback whale breeding ground, was enlarged and renamed the "Sanctuary for the Marine Mammals of the Dominican Republic". As part of its protective regulations, the sanctuary requires that all operators attend mandatory workshops to qualify for operator permits within sanctuary boundaries. Using such educational approaches, as well as working with national and international agencies, the sanctuary can provide effective protection for its marine mammal seasonal residents.

EXAMPLE 8.28: Hawaiian Islands Humpback Whale National Marine Sanctuary (Sanctuary Web Site (A. Tom, Manager, HIHWNMS, personal communication, July 29, 1999)

The Hawaiian Islands Humpback Whale National Marine Sanctuary conducted a whale census in 1998, as called for in its management plan. The procedure for whale surveys consisted of a series of overflights, or aerial surveys, along random transects. The study, conducted over a period of months, showed that the whale population in the Sanctuary is slightly higher than previously estimated, and the census provided invaluable baseline data for future research and monitoring activities.

CULTURAL RESOURCES

The research programme should include an initial inventory and mapping of submerged or coastal cultural resources, such as shipwrecks, artifacts, and historical building and ruins. Subsequent work will evaluate the state of the submerged cultural resources and how well they have been preserved. Archaeological research will focus on the origin of the artifacts and their importance and value as historical records of culture, politics, and maritime transportation. (See Maarleveld).

EXAMPLE 8.29: Monte Cristi Shipwreck Project (Hall, 1994)

The author summarizes the state of ongoing excavation and analysis of a 17th Century northern European merchant vessel located in Monte Cristi Bay, Dominican Republic.