Monitoring, Verification, and Evaluation (MVE) Unit
of the Egyptian Environmental Policy Program

Monitoring System Design

Building a System to Monitor Egyptian Red Sea Protection and Development: Biological Indicators

July 2002

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Chemonics International, Inc.,
Chemonics Egypt, and Environics

Monitoring, Verification, and Evaluation (MVE) Unit
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Building A System to Monitor Egyptian Red Sea Protection and Development: Biological Indicators

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List of Acronyms Used in this Report

CAPMAS	Central Agency for Public Mobilization and Statistics
EEAA	Egyptian Environmental Affairs Agency
EEPP	Egyptian Environmental Policy Program
EMU	Environmental Management Unit - RSG
EST	Environmentally Sustainable Tourism Project
GEF	Global Environment Facility
IBI	Index of Biotic Integrity
NARSS	National Authority for Remote Sensing and Space Sciences
PMP	Performance Monitoring Plan
PSU	Program Support Unit (of EEPP)
RSG	Red Sea Governorate
RSSTI	Red Sea Sustainable Tourism Initiative - TDA
SCU	Suez Canal University
TDA	Tourism Development Authority
USAID	United States Agency for International Development

Executive Summary

The Egyptian Environmental Policy Program (EEPP) is designed to initiate sustainable mechanisms for policy formulation and implementation that will eventually contribute to improving environmental conditions, specifically including protection of biological resources in the Red Sea. The EEPP Monitoring System is being designed to provide the participating agencies with information needed to measure their progress on achieving program policy objectives and to help design better programs for the future. Initial work in designing the EEPP Monitoring System showed a need for basic design of a program to monitor biological resources in the Red Sea region.

The Red Sea harbors some of the most unique and important biological resources in the world, including reefs with the highest percentage of live coral in the world. One in ten species in the Red Sea are found nowhere else on earth, so it is the special responsibility of Egypt and its neighbors to protect these resources for all humankind.

Explosive development of tourism along the Red Sea coast has created an urgent need to monitor changes in the environment and biological resources in particular. A biological monitoring program needs to identify how human interventions influence ecological processes and biological components. The information generated from the monitoring program will help guide development decision-making and biological resources management.

This analysis was done to enable the Monitoring System to identify data that could immediately be used to support biological monitoring in the southern Red Sea region as a component of the Monitoring System, and to recommend actions for improved monitoring in the long term.

Theory and practice of biological monitoring are described, including the steps of building and sustaining a monitoring program. Available data are identified and their appropriateness for biological monitoring is discussed.

Four primary recommendations are made. First, available data should be consolidated and used to establish an Index of Biotic Integrity for coral reefs. Second, available satellite

imagery and associated data sets should be used to document the area extent of mangroves and salt marshes. Third, how invertebrates can provide the indicators needed to support an Index of Biological Integrity for wadi ecosystems should be evaluated. Fourth, the institutional framework for sustaining a monitoring program in the southern Red Sea region should be established.

Introduction

The Egyptian Red Sea coast includes great diversity of habitats and species. The reefs of the Red Sea have the highest percentage of live coral in the world (MCS 2002). Ten percent of the marine species in the Red Sea are found nowhere else in the world. The Red Sea coast zone is important habitat for endangered species such as sea turtles and the dugong. Although the coastal deserts look barren to the untrained eye, they too harbor many unique and rare species. Seemingly endless tracts of land and hundreds of miles of shoreline are now imminently threatened by tourism development in the region and these irreplaceable biological resources are in jeopardy of being lost forever.

Sustainable development of tourism in the Red Sea region is critically dependent on maintaining sound environmental conditions, including viable biological resources. A large segment of tourist influx to the region is related to diving and snorkeling on coral reefs. Any degradation of these biological resources could jeopardize the long-term economics of planned tourism development. Hence, a program is needed to monitor biological resources, to detect changes early on, before irreparable damage is done and while remedial action can still correct the situation.

Establishing a full-fledged monitoring system of biological resources is a multifaceted intervention that would need to be developed incrementally over time and through a series of initiatives within a clear and integrated framework. Considering the current limitations on institutional capacity and the already observed environmental deterioration there is an urgent need for practical and manageable approaches to identify indicators of biological conditions, for these indicators to be tested, calibrated and implemented in a systematic way in the near-term, while a more robust and more informative system is developed for the future.

Eventually such indicators could lead to bio-criteria to allow decision-makers to decide on balanced "limits" between levels for development and the quality of the ecosystem. Within this context, the primary objective of this analysis is to contribute to design of the Red Sea biological resources component of a broader environmental monitoring system.

This report was prepared by Richard Warner and Mohamed Abou Zaid based on interviews with experts (Appendix 1) and review of literature. The analysis was carried out in May and June 2002, including 10 days on the Red Sea coast and 10 days in Cairo. The authors appreciate the valuable input from those interviewed and the extensive assistance provided by staff of the Chemonics MVE office in Cairo.

DEVELOPMENT OF EGYPT'S RED SEA COAST.

Until the early 1980s the coast of the Red Sea was considered a remote area even by Egyptians. The lack of transportation, jobs, health services and a shortage of drinking water were major factors limiting population growth in the region.

Tourism is one of Egypt's primary growth industries and an increasingly important source of foreign exchange, accounting for 10 percent of all earnings from 1995 to 2000 (MOT 2000). Currently, tourism is Egypt's second largest source of foreign exchange after remittances from workers abroad. Tourism is expected to continue to be a key contributor to national income growth, foreign exchange earnings, employment generation, and population redistribution. Rapid development of tourism industry and urbanization of the Red Sea coastal zone in the last twenty years has dramatically increased of the number of immigrants to the region. The all-year pleasant climate, the rich marine environment and the proximity to tourism markets of Europe have provided an incentive to develop the Red Sea coast to attract larger numbers of tourists. As early as the 1970s, the quality of coral reefs of the Red Sea coast began to attract international attention among scuba divers. The reefs make the coast one of the premier scuba diving destinations in the world. The Ministry of Tourism (MOT) had a special interest in developing the Red Sea coast and Sinai and declared both as high priority areas for coastal tourism development. At the same time the Red Sea Governorate (RSG) adopted a master plan for Hurghada which vastly extended the uses proposed for tourism, especially tourist villages along the coast.

With only 19 percent of its 1,280 km of reefs affected by development in the mid-1990s (GEF 1998), Egypt has a tremendous opportunity to develop sustainable tourism practices. However, there is considerable urgency to define "sustainable" tourism and how it will be implemented. The current populations of the region totals 220,000 persons, the majority of them (52%) inhabit Hurghada (RSG 2001). The Governorate projects its population will reach 1.26 million by the year 2022. Most of this increase will be concentrated in middle and southern sections of the coast. Improvements to the area's highway network and the added airport in Marsa Ghalib make the Red Sea Coast more accessible to Egyptians as well as international visitors and more attractive to additional investors. Many investors are moving to the southern Red Sea areas with relatively pristine reefs, precisely because their own activities around Hurghada destroyed many of the natural attractions that once drew them to that part of the coast. The growth of tourist establishments on the southern Red Sea coast in recent years is increasing pressure on the natural resources, potentially leading to the same conditions that caused environmental deterioration around the developed northern zones.

EEPP IN THE RED SEA REGION

The Egyptian Environmental Policy Program (EEPP) was established as a cooperative program between the US government, represented by US Agency for International Development, and the Government of Egypt, represented by various ministries, to support environmental policy, institutional and regulatory reforms. Several objectives of the EEPP relate to enhanced management and the conservation of biotic resources of the Red Sea, through a combination of improved development practices in the tourism industry and enhanced management of biological resources.

The Monitoring Verification and Evaluation Unit (MVE) of EEPP is responsible for monitoring EEPP impact and for providing empirical data for measuring the pace of reforms, provide evidence that the reforms are having their intended positive effects on the environment, and to identify areas needing attention in the future years of the program.

In the region of the Red Sea, the primary institutional partners working with USAID on EEPP are the Egyptian Environmental Affairs Agency (EEAA) of the State Ministry for Environmental Affairs and the Tourism Development Authority (TDA) of the Ministry of Tourism. In addition, the Red Sea Governorate has an important long-term role in management of the region. The EEPP Red Sea program focuses on the region from just north of Hurghada, south to the border with Sudan. The region is subdivided into a northern zone and southern zone demarcated by Ras Toronbi. Tranche 1 of EEPP primarily focused on the northern zone, while Tranche 2, launched in 2001, will bring work to closure in the northern zone and expand activities to the southern zone.

Of the ten objectives and 18 policy measures in Tranche 2 of EEPP, four objectives and six policy measures relate directly to environmentally sound development and biodiversity conservation in the Red Sea region:

Objective 2 – Enhanced management and conservation of Red Sea coral reefs, islands, and linked ecosystems of importance. Lead Agency: EEAA

> Policy Measure 2.1 – *EEAA further develops its institutional and technical capacity to manage and protect the Red Sea.* A biological monitoring program in EEAA would significantly advance their capacity to manage and protect biodiversity of the Red Sea. Staff would be better informed regarding the impacts of management actions and the data would support more directed interactions with other government agencies and private enterprises.

Policy Measure 2.2 – *EEAA develops revenue generation and funding mechanisms for Northern Red Sea zone.* Costs of the monitoring program should be paid by the tourists and related businesses that will benefit from the long-term presence of the biological resources that attract many of the tourists. In short, the tourists and associated developers are both the problem that creates the expenses and the logical and only realistic source of money to cover the expenses of monitoring.

Policy Measure 2.3 – *EEAA develops a Red Sea Southern Zone Conservation Management Plan, including a mooring buoy strategy, for selected high priority coral reef, island and terrestrial areas.* The monitoring program will report on the changes in condition of biotic resources resulting from implementation of the Conservation Monitoring Plan. This is a primary objective of the EEPP Monitoring System. Monitoring results from the mooring buoys in the Northern Zone can help inform the strategy for distribution of buoys in the Southern Zone.

Objective 7 – Sustainable Red Sea land use management linked to ecosystems of importance. Lead agency: TDA

Policy Measure 7.1 – *TDA develops and adopts ecologically sensitive zoning plans and polices for its lands in the Southern Zone.* The monitoring program will help identify differentiated areas of ecological sensitivity and eventually report on the changes in condition of biotic resources resulting from implementation of the zoning plan in the long term. This is another primary objective of the EEPP Monitoring System.

Objective 8 – Red Sea tourism development environmental monitoring policy strengthened. Lead Agency: TDA

Policy Measure 8.1 – *TDA develops and implements improved EIA review procedures and EIA monitoring system.* The monitoring program can provide new frameworks for reporting expected impacts to biotic resources. Based on predictable metrics, impacts can be described in terms of degree of human intervention (e.g., expected number of tourist days and dives per tourist day) and anticipated resulting impact on biota on nearby reefs. Data generated through the monitoring program and EIAs can be mutually supportive to develop estimates of cumulative impacts to the biota over a larger area.

Objective 9 – Environmental best practices promoted in Red Sea tourism developments. Lead Agency: TDA

> Policy Measure 9.1 – *TDA develops and adopts policies and measures to augment the use of environmental best practices.* The monitoring program can help to identify which practices are best from a biological perspective and should therefore be replicated elsewhere.

Two other objectives are potentially relevant to the Red Sea component of the EEPP Monitoring System. Objective 5 promotes "increased compliance with Law 4," which includes Policy Measures 5.2 - "EEAA institutionalizes inspection oversight at the central level." This policy measure should result in more clearly defined oversight of Law 4 inspection processes and should establish policy guidelines and procedures for inspection responsibility within EEAA. Information in the Red Sea biotic component of the monitoring system can contribute to the inspection process, and data collected through inspections can contribute to the monitoring system.

Also relevant to this analysis is Objective 6 – "Increase GOE capacity to conduct long-term strategic planning, policy formulation, analysis and coordination". Policy Measure 6.3 calls for the GOE to develop Governorate Environmental Management Units (EMU) and specify "their roles and responsibilities for decentralized environmental management." The EMU for the Red Sea should have a role in collecting and using biological and other environmental information.

EEPP Tranche 1 also included relevant policy objectives, specifically objectives 12, 13, 14 and 15. Objective 12 called for providing protection for Red Sea coral reefs, islands and linked ecosystems. The implementation of this objective was only partially accomplished since although more protection was provided in many areas no actual expanded protected area was declared. One of the reasons for not creating additional protected areas was the limited EEAA capacity to manage the extensive areas proposed for protection. A monitoring system could provide substantial and unequivocal indications of environmental deterioration such that would make obvious the need for protection and more regulated development.

Objectives 13 (and 14) called for an improved EIA system in the Red Sea to secure <u>environmentally sustainable</u> tourism development in the region. A monitoring system could substantially improve the overall quality of the EIA mechanism. It could provide useful baseline information for both consultants and reviewers. Within an organized and systematic EIA system, data and information collected for preparation of EIA studies, if done with agreed to standard methods of collection and processing, could feed back valuable inputs into the monitoring system.

Objective 14 also called for strengthening the monitoring capacity within TDA. A monitoring system that creates baseline data sets and defines methodological standards would substantially contribute to achievement of this objective.

BIOLOGICAL DATA IN THE EGYPTIAN RED SEA REGION

In 2001 MVE reviewed currently available data, and ongoing programs that generate data that are supportive of environmental planning and monitoring of the Red Sea (MVE 2001). Many data have been collected about the biota of the Red Sea and adjacent lands in Egypt, particularly in the past ten years. The MVE review found 22 data sources that could primarily contribute to a biological resources information base; this in addition to thousands of publications about some aspect of biology that relates to the Red Sea terrestrial or marine ecosystems. However, most of these data will not effectively contribute to the monitoring system, because the data were gathered using methods that serve other specific objectives, such as scientific research and land use planning, and can seldom be retrofitted to serve monitoring objectives.

<u>It is important to recognize that no substantial on-going program is methodically collecting new information about biodiversity of the Red Sea Region or organizing the information that already exists.</u> In fact, it is surprisingly difficult to locate and make use of information collected in recent years, even those data specifically collected for the purpose of guiding and monitoring tourist development in the region. It is unlikely that biological knowledge will be effectively made to serve these purposes until there is an identifiable, ongoing program, adequately staffed and funded, specifically directed to biological data management and information development.

Still, there are <u>some</u> data sets that can make important contributions to a monitoring program. These data are described below.

EEPP MONITORING SYSTEM

The EEPP Monitoring System (MS) is the responsibility of the Monitoring, Verification and Evaluations unit (MVE). The objective of the Monitoring Systems is to track the effectiveness of EEPP. Although the EEPP Monitoring System focuses on monitoring that the EEPP is meeting its objectives, it might also serve the purposes of EEAA by providing data and information supportive of other EEAA functions including their own monitoring objectives.

Over the past two years MVE has worked to identify environmental indicators and supportive data that reveal the status of the environmental factors and institutional conditions targeted by EEPP, and for which there is existing information. The progress in developing the EEPP Monitoring System is described in the December 2001 report titled **Development of an Environmental Indicator System for the Egyptian Environmental Policy Program**. The draft EEPP Monitoring System framework includes indicators measuring environmental conditions at three levels:

1. Performance Monitoring Plan (PMP): These indicators have been established by USAID to track the effectiveness of activities that are part of SO 19, Environmental Management, including EEPP.
2. Tranche 1 & 2: These indicators track the effectiveness of EEPP Tranche 1 & 2 policy measures.
3. Macro or context level: These indicators track general trends in Egyptian environmental conditions, with a particular emphasis on areas relevant to EEPP presently or for possible future work.

Some data have been identified to support indicators directly related to management of the program (primarily the PMP indicators), while other data are related more to the state of the sector of the environment being affected, such as ambient air quality. Unfortunately, while the Red Sea is a major part of EEPP and of major importance for Egypt, there is a real lack of information about its physical and biological resources, especially of information that has been systematically and regularly collected so as to serve for monitoring as was found in the December 2001 MVE report.

This analysis reviews key data sets that can support monitoring and evaluation of the Red Sea biodiversity conservation objectives of the EEPP and makes recommendations for how to build a system to monitor development impacts on Red Sea Ecosystems.

MONITORING THE RED SEA IN THE EEPP MS

The indicators selected to monitor EEPP measure the impact of efforts to improve coastal zone management of the Red Sea region. In addition to indicators that directly relate to EEPP interventions (e.g., mooring buoys, diver fees) the monitoring system was designed also to include some indicators that measure the development "pressure" on the environment in the Red Sea region (e.g., number of tourist nights, number of diving trips).

Improvement of environmental management capacity ultimately is meant to slow the damage to Red Sea natural ecosystems caused by increased tourism development pressure. Therefore the monitoring system also includes or intends to include indicators that monitor the state of natural resources in the region (e.g., water quality, coral reef quality). Very limited data are available for these indicators now or in the near future. However, in the longer term, they will be of substantial value with the accumulation of data.

The following indicators are proposed in the draft version of the Red Sea section of the EEPP Monitoring System in Fall 2002. These should not be considered the "final" indicators.

Coral Reef Quality and Extent in the Red Sea region
Coastal water
Number of qualified EEAA rangers in RS Governorate
EEAA annual budget for Red Sea conservation
Value of fees collected for natural resources including the Red Sea Protectorate
Revenues from diver and snorkeler fees in Red Sea
Number of mooring buoys established in the Red Sea Region
Percent of tourist facilities with approved EIAs before construction
Percentage of Hotel Rooms in facilities located on TDA-owned land in the Red Sea region, which instituted Best Practices
quality Number of Dive Trips (Northern Zone/Southern Zone/Red Sea) (including projections)
Number of Tourist Nights in RS Governorate (including projections)
Value of Fees Collected for Natural Resources
EEAA annual Budget for Conservation in General/Red Sea Conservation in Particular
Percent of Respondents Who Can Identify at Least One Way to Preserve the RS
Percent of Tourist Facilities w/ Approved EIAs before Construction (PMP) (breakdown for the Southern Zone
Percent of Hotel Rooms in Facilities on TDA-Owned Land in the RS Region w/ Best Practices (Northern Zone/Southern Zone/Red Sea)
Number of Qualified EEAA Nature Protection Rangers assigned to Work in the RS Governorate (Northern Zone/Southern Zone/Red Sea)
Percent of all costs associated w/ Hurghada/Quseir Ranger Operations covered by EEAA Resources

Designing a Program to Monitor Biological Resources of the Red Sea Region

Over the past few decades many programs have contributed to an understanding of species and ecosystems in Egypt's Red Sea region (GEF 1997, MVE 2001). However, for the most part, the data collection strategies used in these studies, or subsequent analysis and reporting based on the data, have not adequately associated changes in biological condition to human activities. The absence of a monitoring program that is specifically diagnostic of human causes of deterioration in biological systems has hampered attempts to communicate these problems to the public and policy-makers, or to identify appropriate solutions.

To protect ecosystems and maintain their economic value and life-sustaining qualities, one must track biologic condition just as is done with national economies and human populations. This can be done through metrics and indices that tell early on when the systems are declining and what human activities are causing the decline.

THE BASICS OF MONITORING BIOLOGICAL RESOURCES

In the context of the EEPP Monitoring System, and a growing number of similar programs around the world, the monitoring of biological resources is specifically designed to measure human impacts on species and ecological processes. Figure 1 defines the key terms used in biological monitoring programs.

Figure 1: Key definitions used in this report (adopted from Jameson et al, 2002).

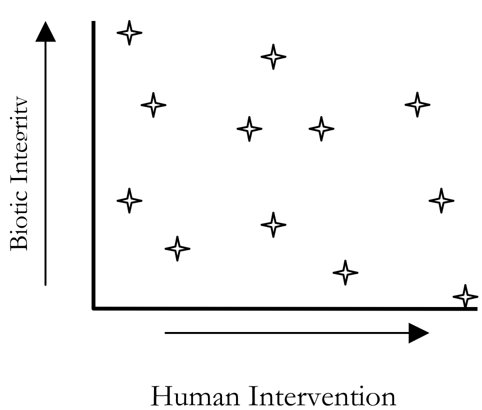
Term	Definition
Attribute	Measurable part or process of a biological system.
Biological monitoring	Systematic and periodic sampling of the biota of sites – taking measurements of the attributes of interest.
Biological assessment	Using samples of living organisms to evaluate the condition of sites.
Biological integrity	The condition at sites able to support and maintain a balanced, integrated,

	and adaptive biological system having the full range of elements and processes expected for a region. Biological integrity is the product of ecological and evolutionary processes at a site in the relative absence of human influence (Karr 1996).
Metric	An attribute empirically shown to change in value along a gradient of human influence.
Multimetric index	An index (expressed as a single numerical value) that integrates several metrics to indicate a site's condition. An example is an index of biotic integrity (IBI).
Bio-criteria	Defines a desired biological condition for a site, and defines thresholds of biological integrity below which there is a need to change management practices in order to maintain or restore integrity.

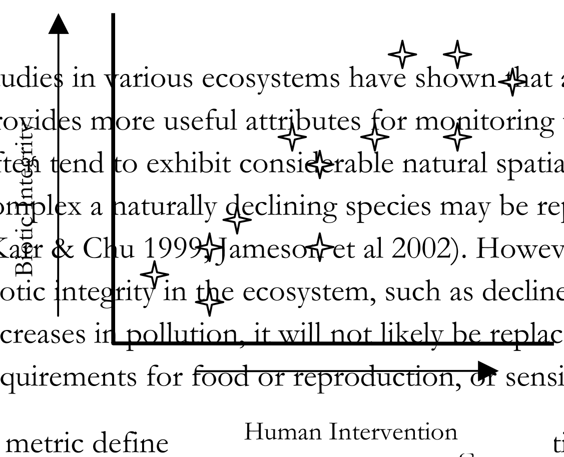
An effective monitoring program requires using the right attributes, ones that show consistent response to human activities and are otherwise relatively stable (Figure 2); they must be able to discriminate human-caused changes from natural spatial and temporal variation (Carr & Chu 1999, Jameson et al 2002). The attribute might either increase or decrease predictably in response to human intervention. For example, increases in pollution might result in decreasing populations of sensitive species, while other, less sensitive species might increase in numbers.

Figure 2. Attribute A does not vary predictably with changes in human intervention, while attribute B does exhibit a predictable increase with increasing human intervention.

Attribute A



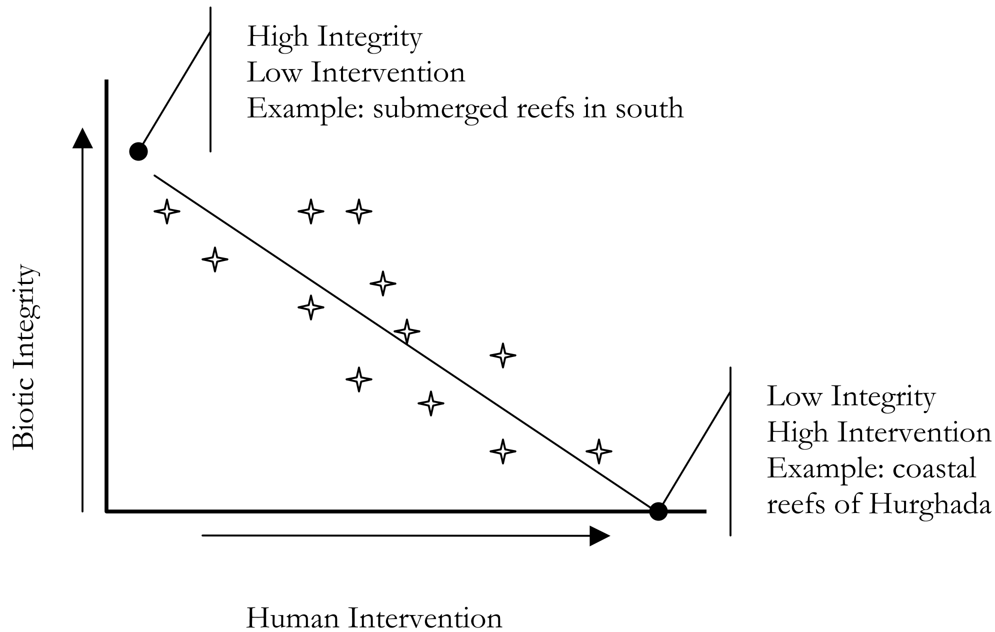
Attribute B



Studies in various ecosystems have shown that a group of species or communities often provides more useful attributes for monitoring than do individual species, because the latter often tend to exhibit considerable natural spatial or temporal variation, whereas within a complex a naturally declining species may be replaced by a species with similar requirements (Karr & Chu 1999, Jameson et al 2002). However, if a species declines in response to loss of biotic integrity in the ecosystem, such as declines in food, loss of reproduction habitat, or increases in pollution, it will not likely be replaced by another species with similar requirements for food or reproduction, or sensitivity to pollutants.

A metric define tive to human intervention (figure 3). One end of the metric identifies the condition at sites without human intervention – such sites exhibit biological integrity. Sites that fall elsewhere on the metric exhibit a loss of biotic integrity. Metrics define a continuum that can be used to compare sites and define thresholds for management intervention. Once a metric is established for an ecosystem in a region, any site can be placed on the continuum by measuring the appropriate attributes. Sites can be compared and priorities established for directing limited management budgets toward maintaining the biotic integrity.

Figure 3. A "metric" describes the extreme conditions of an attribute and the points along a line or curve between the extremes.



Useful attributes must also be easy to measure, using available labor with the proper skills, and available technology – they must be cost-effective in the context of the institution responsible for the monitoring program.

In summary, to be effective, attributes and metrics must be:

- Useful for monitoring biological response in the ecosystem under study;
- Responsive to human intervention, but stable to natural variation;
- Informative about the human caused changes; and
- Cost-effective to sample

DEVELOPING AN INDEX OF BIOTIC INTEGRITY (IBI)

The most thoroughly documented procedures for monitoring human impacts on biological resources are generally known as Indexes of Biotic Integrity – or IBI (Karr & Chu 1997). The earliest IBI were developed for freshwater fishes and stream invertebrates in North America (Karr 1987, Karr 1991). The IBI approach has since been developed for additional regions and a growing number of taxonomic groups. Of particular relevance to the Red Sea region of Egypt is the work of Jameson et al (1999, 2002) to develop IBI for marine ecosystems, primarily focused on coral reef communities.

The available data appropriate for starting a monitoring program in the Red Sea region of Egypt are fairly limited. The most abundant data about biota of the region were collected using standard methods. The broader importance of these data will be clarified in the following discussion. For now it is important to note that the data about coral reefs apparently provide the only possibility for immediately starting a monitoring program in the region and, therefore, these data are used as examples in the following discussion.

Five steps for developing a biological monitoring program are presented in figure 4 and discussed below.

Table 4. Steps in developing Indexes of Biotic Integrity (Adapted after Karr & Chu, 1999 and Jameson et al, 2002).

Step 1	Classification and prioritization of ecosystems at appropriate scales
Step 2	Identification of survey sites along gradient of human influence
Step 3	Biological surveys to collect data about attributes expected to be useful attributes for an IBI
Step 4	Evaluation of attributes, calibration of metrics and development of indexes
Step 5	Maintaining a monitoring and assessment program

Classification and Prioritization of Ecosystems

Distinct biotic communities require distinct attributes, metrics and Indexes of Biotic Integrity, each based on the species present that best fit the criteria as attributes. A provisional classification, modified from the classification developed during the GEF project, might include four primarily terrestrial landscapes or ecosystems and six marine systems. The terrestrial systems are:

- **Mountains**: The desert foothills and highlands of the chain of mountains paralleling the coast and Elba Mountain range.
- **Wadis**: This ecosystem includes the wadis that occasionally receive a considerable amount of rain water and end with a large delta at the sea side. The occasional presence of water supports a large variety of mammals, reptiles and plant species.
- **Coastal Plains**: These low elevation deserts are found along the extensive coastal areas not in the wadi deltas.
- **Salt Marsh**: Not truly terrestrial, but aquatic, these coast wetlands are dominated by saline tolerant plants.

The marine systems are:

- **Mangroves**: A spotty distribution along the coast and more common in the south.
- **Soft bottom habitats**: Mud and sandy bottom.

- **Rocky bottom habitats**: Rocky substrate.
- **Fringing reefs:** Coastal reefs extending from a few meters to perhaps100 meters from the shore and typically ending in a vertical reef face dropping 5 to 20 meters.
- **Submerged reefs**: Off-shore reefs.
- **Sea grass beds**: Extensive sea grass beds are found in depths of less than 1 meter to 30 meters or more. The beds are most extensive in the southern sector.

In the Red Sea region the highest priority ecosystems for investing limited monitoring resources included reefs, mangroves, salt marshes, and wadis. The reefs are likely the most economically important, and together with the salt marshes and mangroves are the most threatened. Also seriously threatened with human impacts are the wadis, while the sea grass beds are particularly important for endangered mega fauna – sea turtles and dugongs. More rigorous methods for setting priorities can be found at: http://www.natureserve.org/explorer/ranking.htm .

Methods for monitoring coral reefs need to be calibrated for the ecosystem and region to determine the best combination of attributes and their individual metrics. See Jameson et al (2002) for details.

There is much less information about potential attributes for biological monitoring of the other priority ecosystems. However, Jameson et al (2002) and Karr's bibliography in Appendix 2 provide some leads for each. In general, there is more experience worldwide with aquatic than with terrestrial ecosystems.

Identification of Survey Sites

Sites must be ordered on a gradient of human intervention. In order to evaluate each attribute being considered and to calibrate their metrics, for each ecosystem a statistically valid number of sites should be identified and distributed along the presumed metric scale, from the most pristine sites to those destroyed or nearly so, and points in between.

One of the most challenging tasks today, when nearly every place on earth exhibits some degree of human intervention, is identifying the presumed pristine condition, sites that exhibit 100% integrity, representing one endpoint of the metric scale. An effort should be made to protect or restore several pristine examples of each ecosystem so they can serve to calibrate additional attributes, refine the metrics and multi-metric indexes.

In the case of reef communities of the Red Sea, existing data can be used in preliminary selection of sites, provided that care is taken to account for possible variation in human condition between the different years when the data where collected (approximately 1996 to 2001). The sites and biological data listed in figure 5 provide a good start to identifying perhaps more than 100 sites with associated data about coral reef attributes appropriate for monitoring biological resources. Water quality data from the EIMP program might also contribute to the ranking process.

Biological Surveys and Use of Existing Data

Found below and in figure 5 are five sources of data that can likely be incorporated into a coral reef monitoring program; these are from GEF, EST, UK Marine Conservation Society, Suez Canal University, and Mohamed Abou Zaid of Al-Azhar University. Figure 5 organizes the data from these programs by attributes, so one can appreciate what existing data might be immediately applied to evaluating attributes and perhaps for calibrating metrics and constructing an index.

Red Sea Integrated Coastal Zone Resource Management Project – GEF

The Egyptian Red Sea Coastal and Marine Resource Management Project was funded by the Global Environment Facility (GEF) through the World Bank. The GEF project collected the single largest and most diverse data sets about biota of the Red Sea coast outside of Sinai. The overall goal of the project, which ran from 1994 to 1998, was to promote environmentally sound and sustainable tourism and other coastal-marine development for the Egyptian Red Sea coast (coastal and near shore marine areas including the offshore islands) from 60 km north of Hurghada to the Egypt/Sudan border. The primary participating agencies in the project were the Tourism Development Authority (TDA), Egyptian Environmental Affairs Agency (EEAA) and Red Sea Governorate (RSG). Under the project, which is locally referred to as the "GEF Project," a wide variety of biologic data were collected from terrestrial and marine ecosystems throughout the project area. Data were collected and reports prepared by teams working on major taxonomic groups (e.g., mammals, reptiles, birds, vascular plants, fishes and reef invertebrates). Much of the marine data were collected using transect methods described by English et al (1997). See GEF 1998 for a full account and list of reports. In addition, the data were aggregated by geographic sectors and a separate report prepared for each (GEF 1997 a-g). A GIS application based on the GEF data is available in TDA and EEAA Hurghada. However, the detailed data from the GEF project are not easily located. Perhaps the most complete data sets were maintained by the individual researchers.

Environmental Sustainable Tourism Project (EST)

The Environmentally Sustainable Tourism (EST) project was funded by USAID along the coast of the Red Sea in 1996. The national counterpart was EEAA with the NGO HEPCA implementing an important part of the project. The major components and activities of the project were concerned mainly with improving management of marine biological resources in the region from Hurghada to Ras Banas. Under the EST project data on reef damage, live coral coverage and fish were collected from 90 dive sites using a variety of methods, including methods described by English et al (1997), Rapid Underwater Assessment, and fixed quadrates designed for long-term monitoring of biological resources. The data are available from the EST reports (EST 1997a, 1997b). The data collected on physical damage to reefs resulted in the only attribute fully calibrated for monitoring use in the Red Sea (Jameson 1999).

UK Marine Conservation Society reef monitoring program

The Marine Conservation Society, a UK-based NGO, has surveyed for damage to the coral reefs and fish populations in dive sites around Hurghada each year from 1996 through 2000. The survey program is planned to start again in 2002. The society has primarily focused on dive sites near Hurghada, but has also reported on sites far south near Sudan. They have collected data from a small number of sites each year (12-20), but accumulative value of their work is substantial, including data on live coral coverage, reef fish surveys, and economically valuable invertebrates. The latter may be particularly valuable as baseline data prior to large scale commercial harvesting of sea cucumbers. The MCS surveys are conducted by volunteer divers (who pay their own expenses) under the supervision of scientists. The data from these surveys is available in annual reports from the society (Wood et al 1996, 1997, 1998, 1999, Wood 2000).

Suez Canal University (SCU)

The Egyptian Academy of Scientific Research and Technology provide small grants for projects to collect data from areas of Egypt where little or no information is available. One of these grants was awarded to The Marine Science Department at Suez Canal University to survey and study the coral reefs and seaweed in the southeast corner of Egypt between Shalatein and Halaib at the Sudanese boarder in 2000 and 2001. Data were collected from 29 sites using transect methods described by English et al (1997). The report from this work is available from the Academy (Suez Canal University 2000).

Mohamed Abou Zaid

Dr. Abou Zaid and his students, with partial financial support from Suez Canal University, and the Academy of Scientific Research, from 1999 through 2001 studied 75 sites from Hurghada to Sudan. The effort is a long-term research project of M. Abou Zaid to compare populations of butterfly fish and human impacts as measured by percent of live coral. Using methods from English et al (1997) they collected data on percent of live coral and butterfly fish. The data are being prepared for publication and are available from M. Abou Zaid.

Evaluation of Attributes, Calibration of Metrics, and Development of Indexes

A coral reef IBI can most likely be built based on the existing data outlined in figure 4. Each potential attribute should be evaluated, using existing data, to determine which attributes work, that is, change most predictably with regard to human intervention and are cost effective to measure. Figures 6 and 7 show how some of these data compare. While many researchers have pointed to butterfly fish as important indicators of reef health, Jameson (1998) and others he cites question the added value of attributes based on butterfly fish, arguing that measuring percent of live coral supports equivalent analysis at a lower cost. The recent work of M. Abou Zaid, comparing percentage of live coral coverage and number of butterfly fish, can help to resolve this question for the Red Sea. This analysis needs to be expanded to consider other potential attributes and the costs for data collection. The criteria for ranking human intervention need to be reviewed and expanded.

The values from these metrics must be evaluated as components of the Index for Biotic Integrity for coral reefs in the Red Sea. Figure 8 shows how potential indicators might be used to prepare an index of biotic integrity for Red Sea coral reefs. In addition to evaluating each metric, consideration should be given to how the individual metrics might be weighted in the Index. The index and its component metrics should be evaluated for natural breaks, areas along the curve where biotic integrity changes most rapidly, indicating points for possible bio-criteria. Finally, the Index should be presented as a numerical scale with the values broken into ranges that represent grades of biological integrity of coral reefs in the region.

Figure 6. The graph compares % living coral with the number of individuals of Megaprotodon trifascialis, an obligatory coralivore butterfly fish. It shows that as the % of coral declines, so do the number of fish. Data provided by Mohamed Abou Zaid.

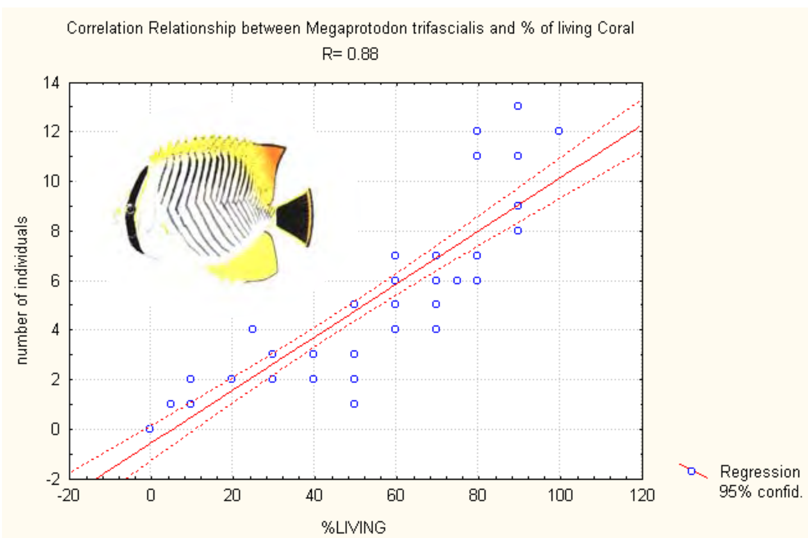


Figure 7. The graph compares the number of nine species of butterfly fish with the % living coral.

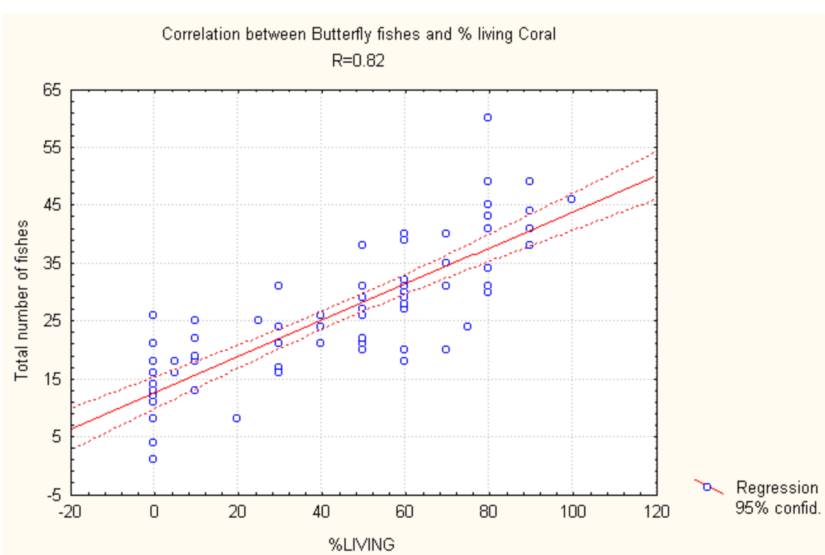


Table 8. Possible components of an Index of Biotic Integrity for Coral Reef Ecosystems of the Red Sea

Indicator	Description	Status of Data
1. Live coral coverage	Observations along transects and photos of frame-plots are used to measure percent of live corals. Methods are used in other oceans and are partially tested/calibrated for the Red Sea.	Data can likely be used from four sources: GEF 80 sites; British MCS for 48 sites; Suez Canal University 19 sites, Abou Zaid 75 sites.
2. Coral Species	Requires more research. The available data might support attributes of richness, dominance or other attributes.	Data on 80 sites from GEF project.
3. Percentage of damaged hard coral	Based on the percentage of coral rubble and broken formations observed in a 20 meter transect. The metric is fully calibrated for the Red Sea.	Results published for 37 dive sites in the Hurghada area (Jameson 1999); may need to acquire original data. Need to collect data for sites in the south.
4. Reef fishes	Requires more research. The available data might support attributes of richness, dominance or other attributes.	Data can likely be used from four sources: GEF 80 sites; British MCS for 48 sites; and Suez Canal University 19 sites.
5. Abundance of butterfly fish	The number of individuals of obligatory coralivorous butterfly fish per area / transect. The method has been used to develop metrics for other oceans, but needs to be calibrated for the Red Sea.	Data can likely be used from four sources: GEF 80 sites; British MCS for 48 sites; Suez Canal University 19 sites, Abou Zaid 75 sites.
6. Taxonomic richness of butterfly fish	The number of species of obligatory coralivorous butterfly fish per area / transect. The method has been used to develop metrics for other oceans, but needs to be calibrated for the Red Sea.	Data can likely be used from four sources: GEF 80 sites; British MCS for 48 sites; Suez Canal University 19 sites, Abou Zaid 75 sites.
7. Economically valuable invertebrates	This metric will require more research to determine what has been learned in other oceans and to evaluate potential attributes that might be derived from the Red Sea data.	Data can be used from 20 or more sites surveyed by British MCS.
Coral Integrity Index	Sum of 7 or more indicators that may be developed from the above list. The index needs to be calibrated. Weighting of individual metrics should be tested.	Bio-criteria could then be proposed, establishing minimally acceptable integrity of coral reefs.

MONITORING OTHER HIGH PRIORITY ECOSYSTEMS

Ecosystem maps, based on GIS and remote sensing provide another sort of data useful for monitoring biological resources, particularly the area extent of well-defined biotic communities, such as mangrove stands. The GEF program produced one of the early digital maps of the Red Sea coast, showing the location of mangroves and other shoreline features. The Red Sea Governorate, through a contract to NARSS, produced more recent (approximately 2000) digital maps that include mangroves in those segments managed by the RSG. Now EEAA and TDA, both funded by USAID, are each producing digital maps of the Red Sea coastal zone including mangroves in 2002. Clearly, there is an opportunity now presented to make sure that these maps are compatible. The old and new data represented by these maps and managed in the GIS system can be applied to biological monitoring, providing both baseline data and change detection over the past five to ten years. Furthermore, archival images made by satellites over the past 20 years or more might be used to provide an even older baseline dataset. Vegetation mapping based on remote imagery can successfully be applied to mangroves and salt marshes with today's technology, equipment and experience present in the region.

Techniques under development may extend the use of these technologies to shallow water marine ecosystems. Mumby et al (2001) have used a Compact Airborne Spectrographic Imager (CASI) system, combined with dives to collect baseline information needed to supervise the classification, to demonstrate how airborne technologies can be used to measure reef health. With images taken from aircraft at 250 meters elevation they have successfully applied this technology to reef at a depth of 7 meters. This procedure should be particularly useful for monitoring flat back reefs in the mainland and island coastal shallows.

It should be noted that use of these tools, while they are cost-effective, does not negate the need to identify attributes measured from the species on site. Data and maps from images often identify only the presence or absence of a vegetation type, or perhaps extreme conditions of degradation. They are not sensitive enough to give early warning of degradation of biological integrity of a site, and do not provide the insight into causes that we can sometimes learn from the component metrics of a multi-metric index.

There likely are not enough data available to develop indexes for the other major ecosystems or landscape identified above. However, the search must continue among existing data sets and worldwide experience to determine if other data and methods exist to evaluate potential attributes in other selected ecosystems. The methods are developed for evaluating attributes and developing metrics for selected organisms in marine substrates other than coral reefs (See Jameson et al 2002 for suggestions). And recent experience is showing the potential to develop indexes for terrestrial ecosystems. Of particular interest is the recent work to develop an index based on invertebrates in arid lands (Kimberling at al 2001). New data must be collected to fully evaluate the most promising attributes.

MANAGEMENT AND REMEDIATION PROGRAMS

Bio-criteria are useful regulatory tools that provide straightforward means for describing how far a site has diverged from its expected natural condition and the probable causes, thereby suggesting appropriate management actions needed for restoring biotic integrity. Bio-criteria may be used as legal tools, designating a point on the metric scale below which biological resources are legally considered to be impaired, management actions are needed, and legal actions can be pursued.

The obvious application for bio-criteria in reef systems is to manage boat and diver impacts on the biota. In the case of coral reef systems in the Red Sea, it may appropriate to have different bio-criteria for different sections of reef, one for a reef in a national park prescribing management intervention when the IBI shows the earliest signs of reef decline, and different bio-criteria allowing for more (but not unlimited) impacts on reefs in front of hotels.

MAINTAINING A MONITORING AND ASSESSMENT PROGRAM

Monitoring biological resources requires dedicated resources, including staff and operating funds. Core staff positions should include two biologists (one marine specialist and one terrestrial specialist) and an information manager. Once the attributes are identified for measuring biological integrity and human impact, a program must be established to collect the required data. For example, reliable data are likely needed about the number of boats and divers (scuba and snorkel) per day on monitored reefs. While some of these data might be provided by tour operators, rangers will likely need to provide independent verification as a component of quality control.

Procedural manuals are needed to describe the precise methods used to collect biological data and how the data are converted to a numerical assignment of biotic integrity. The methods for measuring and calibrating human intervention must also be documented.

There is a common misunderstanding that monitoring requires re-measuring the same place over and over, perhaps with permanent plots and that only valid results are reported by comparing data of one year with data of another year from the same site. While re-sampling a site is certainly valuable, it is not strictly needed. Once a metric is established, the condition of any site in the same biotic community and geographic range can be determined with only one year's measurements, and it can be immediately be compared to other sites.

New data should be regularly collected and used to refine the metrics and indexes, and most importantly to report on the changes detected, probable causes, and potential solutions. The program must include permanent archives for preserving data. An independent quality control process must be periodically implemented.

Institutional Roles in Maintaining a Biotic Monitoring Program

The Nature Conservation Sector in EEAA, with support from USAID, maintains an office in Hurghada with more than 20 rangers responsible for managing and protecting biological resources in the region. They maintain a boat mooring system, review EIAs, inspect construction sites, patrol reefs, and manage the protected area at Elba. Developing and maintaining a biological monitoring program in the Red Sea region clearly falls within the mission of the EEAA staff in Hurghada and elsewhere along the Red Sea Coast.

Other offices in EEAA can participate in monitoring activities. The National Biodiversity Unit can provide basic biodiversity information to the Hurghada office and in turn can receive data resulting from new inventories. The EIMP provides data on physical properties of water, which can be applied to ranking of sites. Other offices in EEAA are potential users of the data and information from the monitoring program, and many are potential contributors of data to the monitoring program. All parties involved with EIA have this sort of potential for multifaceted cooperation with the monitoring program.

The TDA and the RSG are perhaps the most important users of the information provided by the monitoring program. From long-range tourism development planning to specific site evaluations for resorts, marinas and other infrastructure, the data from monitoring should be taken into account. Furthermore, TDA and the RSG should also contribute data to the monitoring program. They can collect and provide data on the volume of tourist visitors and their activities.

Other government agencies can provide valuable assistance to the program. The National Center for Documentation of Cultural and Natural Heritage in the Transportation and Communications Ministry might provide useful general information about biodiversity of the region. The census data from CAPMAS can contribute to ranking of human intervention. NARSS might provide technical assistance and access to images. These are but a few examples among government agencies. Universities certainly have a role in collecting and analyzing biological monitoring data and documenting the procedures, and can provide training to local personnel. In the private sector, resort, dive center and boat operators can all contribute to the collection of data about tourist activities, such as number of boats, divers per dive site, and number and location of desert safaris.

Recommendations

There are four primary recommendations for biological monitoring of the Red Sea region:

1) Establish a coral reef monitoring program
2) Establish a program to monitor the area extent of selected ecosystems based on satellite imagery
3) Create pilot projects to evaluate potential attributes for monitoring other ecosystems
4) Build permanent institutional infrastructure in EEAA for biological monitoring in the Red Sea region

Each of these recommendations includes several components that can be addressed as individual tasks.

Recommendation I. Establish a coral reef monitoring program

Development of an IBI for coral reefs will contribute to the EEPP Monitoring System in the near-term (1-2 years) and significantly support long-term objectives of EEAA in the region. A list of the steps to be included in such a program follows:

1) Calibrate the metrics and Coral Reef Index of Biotic Integrity based on the attributes for which data are currently available. See Figures 5 and 8 and the associated cited literature for more details. This task will result in a preliminary IBI for coral reefs of targeted region.
2) Use the existing data to report on the condition of, for example,100 reef dive sites between Hurghada and the Sudan border. This effort will establish a baseline of data based on present condition and describe the condition of individual sites relative to expected biological integrity.
3) Prepare a plan for continuing data collection to support the coral reef IBI. Production of the preliminary IBI based on existing data should include identification of additional data needed. The plan should address biological data and those data needed to determine degree of human intervention. The plan should also provide for identifying different kinds of reefs – refining the classification of reefs so that future monitoring efforts and management intervention will be more specific.
4) Document the procedures related to the coral reef IBI. See recommendation IV for details.

Recommendation II. Establish a program to monitor the area extent of selected ecosystems based remote imagery

Digital data sets developed with USAID funding to map the location of mangroves and other sensitive ecosystems should be captured and established as a baseline data set for the EEPP Monitoring System to track the area extent of these ecosystems. EEAA should use the current USAID project as a foundation to build a long-term monitoring program at the landscape/ecosystem scale.

1. Use imagery and data being developed by PSU/EEAA and RSSTI/TDA to establish current extent of mangroves and salt marshes. Compare these data to older data from GEF and RSG to determine changes in mangrove coverage.
2. Prepare a report on the current status of mangroves and salt marshes in the region. To the extent possible, describe changes in area extent of these ecosystems in the recent past and the probable causes for the changes.
3. Implement a pilot program in the Wadi Gamal / Wadi Hamata region (terrestrial and marine) to test use of high-resolution images to classify and map other ecosystems (i.e., sea grass beds, coral reefs, terrestrial vegetation in wadis) as a baseline for monitoring. Test the capacity of new technologies to measure the health of ecosystems and to measure the extent of human intervention. The technology should also be used to refine the classification of ecosystems, including coral reefs.
4. Document the procedures used for successful components of the pilot efforts. See recommendation IV for details.

Recommendation III. Create pilot projects to evaluate potential attributes for monitoring other ecosystems

Identification of effective attributes and calibration of metrics should be done for each of the major ecosystems in the region. Building the knowledge base needed to monitor all the major ecosystems will require years of focused research. Through a combination of pilot projects targeted at the most promising options in the most diverse and threatened ecosystems, and opportunistic research into less well understood options, EEAA and their cooperators should methodically build foundations for future components of the monitoring program.

1. As a high priority, create a pilot project to assess the potential use of invertebrates to support an index of biotic integrity in wadis. A complex array of invertebrates is presumed to be living in the vegetation and the enormous fields of dead and slowly decaying wood and other biological material deposited on the wadi floor by periodic floods. Recent experience in the US suggests that the invertebrate fauna of arid lands can be used to support a cost-effective index of biotic integrity. Particular attention will need to be focused on establishing procedures for measuring the degree of human intervention in wadi biotic communities.
2. Review data and technologies that may support indicators for other priority ecosystems. Identify the most promising lines of research and develop funding so that they may be pursued. For example, this might include support for students willing to pursue one of these

options as a thesis project. The research options should include topics related to measuring human intervention.

Recommendation IV. Build permanent institutional infrastructure in EEAA for biological monitoring in the Red Sea region

1. Establish a viable monitoring program in the EEAA office in Hurghada. The program should have a minimum three-person inventory/monitoring staff including a terrestrial biologist, marine biologist, and data manager. In view of the poor track record regarding maintenance of previous data sets, the task of data management will likely require special attention. It is essential to have a person made responsible and held accountable for data management. The core team should be provided with the resources needed to conduct their work, including assistance of other rangers to collect data. There tasks should include:
    a. collecting data
    b. establishing cooperation with stakeholders willing to help collect data
    c. storing and managing data used in the monitoring program
    d. documenting procedures
    e. assuming responsibility for quality control of data sets
    f. periodic reporting
    g. assisting others to access the data
2. Establish a data access policy that encourages data sharing among institutions and public access to the data. The monitoring program will not be credible if access to the data is restricted. Transparency is an essential component of the monitoring program.
3. Fund the monitoring program through fees paid by tourists and the industries supporting them. These are the people who most threaten biological resources in the region and have the most to gain from a program that monitors changes to the resource base and informs stakeholders how to maintain the health of the environment needed to sustain their business.

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Appendix 1 – List of people interviewed

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Hesham Abd-El Monsef, PSU – GIS consultant.

Ahmed Abu El Seoud, Director, Environmental Information Management Program (EIMP), EEAA

Hala Barakat – National Center for Documentation of Cultural and Natural Heritage, Ministry of Transportation and Communications

Moustafa Ahmed Baraka, TDA – GIS consultant

Edward Coe, Senior Tourism Development Planner, RSSTI

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Sherif Baha El Din – Biologist, Consultant to EEAA and PSU

Hossam El Shief, PSU

Mohamed Gad, Manager of Elba Protectorate, EEAA

Jack Gisiger, Chief of Party, RSSTI

Mohamed I. Habib, General Secretary of Red Sea Association for Diving and Water Sports, Hurghada.

Mahmoud H. Hanafy, Head of Monitoring Unit, PSU

Ahmed Hassan, Task Manager, RSSTI

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Tarek A Seoud, TDA – GIS consultant

National Biodiversity Unit, Department of Nature Protection, EEAA

Appendix 2 – Bibliography Provided by James Karr

BIOLOGICAL MONITORING AND ASSESSMENT

Selected Bibliography provided by James Karr, June 2002

This bibliography focuses on publications appearing after publication of the book *Restoring Life in Running Waters: Better Biological Monitoring* (Karr, James.R. & E.W. Chu. 1999, Island Press, Washington, D.C. 206 pp.)

The entire bibliography provided by Karr contains the subjects in the "Table of Contents" below. This present report contains only the sections of:

Assessment
Statistics and Analyses, and
Coastal and Marine Environment

COMPLETE BIBLIOGRAPHY

CONCEPTS AND PRINCIPLES
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Manuals and Web Sites (State and Fed)
Books
Special Journal Issues

TYPES OF ENVIRONMENTS
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Algae and Diatoms
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Amphibians and Reptiles
Terrestrial Invertebrates
Plants

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Statistics and Analyses

First a few general introductions to statistical issues and concepts:

The USEPA bioindicators web site (http://www.epa.gov/bioindicators/index.html) has an excellent primer on statistics and statistical concepts in monitoring See: (http://www.epa.gov/bioindicators/primer/html/primer.html)

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