CONSERVATION AND SUSTAINABLE USE OF THE MESOAMERICAN BARRIER REEF SYSTEM (MBRS) IN MÉXICO, BELIZE, GUATEMALA AND HONDURAS

Guidelines for Developing a Regional Monitoring and Environmental Information System

Final Report to the World Bank

By

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1 Executive Summary

The widely known Belize Barrier Reef has been the subject of significant conservation efforts for some years. It is the central and primary jewel in a larger regional system of barrier and fringing reefs – the Mesoamerican Barrier Reef System or MBRS extending from the northern Yucatan Peninsula, down through México, Belize, and Guatemala, to the Bay Islands of Honduras. The primary goals of the World Bank program for the Conservation and Sustainable Use of the MBRS are to enhance protection of these vulnerable and unique marine ecosystems, and to assist México, Belize, Guatemala and Honduras to strengthen and coordinate national policies, regulations, and institutional arrangements for marine ecosystem conservation and sustainable use. **This report evaluates present environmental monitoring of the MBRS, and makes recommendations that will secure region-wide monitoring of ecosystem "health", implementation of a regional Environmental Information System, a regional research program to provide baseline information on the MBRS, improved techniques for monitoring water quality, and modest improvements to fishery catch statistics. The recommendations include substantial educational capacity building, all in the context of achieving specific monitoring and EIS objectives.**

1.1 Terms of Reference, and Present Situation

Section 2 briefly summarizes our Terms of Reference. **Section 3** reviews present environmental monitoring in the region. It identifies stakeholders, likely stressors, and existing monitoring data, and evaluates current monitoring programs. The MBRS is at risk from coastal pollution, over fishing, other inappropriate uses, storms, episodes of warmer than usual temperature, outbreaks of disease and other "natural" phenomena that may have underlying anthropogenic causes. Several well conceived, and professionally done monitoring programs are in place and should be continued. A number of good baseline studies, intended to form the basis of future monitoring efforts, also exist.

However, most monitoring programs are very local in focus, there is little evidence of even a national-scale perspective, and a regional focus spanning beyond national boundaries is rare. The focus is almost entirely on coral reef systems, to the exclusion of seagrass, mangrove and other important systems. Only in Belize and México are there geo-referenced databases covering a significant portion of the region under that nation's jurisdiction, and in both of these cases, the database can be accessed and modified by only a couple of people with the necessary skills. As a result, these databases are vulnerable, and less accessible than they could be. Integrated environmental information systems for coastal marine regions do not exist, even at a national scale. Data sharing is rare, and usually occurs through inter-personal, rather than inter-agency relationships. Much of the capacity for monitoring is in the NGO sector, and, especially in the south, there is limited evidence of a governmental commitment to the value of environmental monitoring programs. **The efforts of many dedicated people maintain the current monitoring effort, but this effort is clearly fragile, insufficient in extent, severely**

constrained by a lack of resources, and does not provide a regional capacity for monitoring the "health" of the MBRS.

1.2 Monitoring methods available

Section 4 summarizes the monitoring methods available, outlines goals for building improved and sustainable environmental monitoring in the region, and makes specific recommendations for Actions that will achieve those goals.

Monitoring uses traditional (often low-cost) methods such as diver-based surveys and water sample analysis, and newer (sometimes more expensive) methods including various forms of remote sensing, and of biomonitoring. The design and implementation of monitoring programs, and the statistical evaluation of the data they yield, are as important as the data-collection techniques, yet seldom receive careful attention. The way data are archived and shared is also important. **We suggest that an effort to build capacity in program design and implementation and in data analysis will be more beneficial than an effort to introduce "standard" field methods for use in the region.**

1.3 Principles for building sustainable capacity

The fundamental problem in the region is a pervasive lack of human capacity. Capacity building has traditionally been provided with international funding in short-term contracts. Such efforts fail to create a sustainable increase in local capacity without continued infusion of funding and expertise. Both project design and the underlying frailty of economies and governments are at fault. **There is urgent need for a new paradigm, one of integrated, sustainable, demand-driven capacity development based on community-level participation and greater equity in the North-South partnership. Such a paradigm can be built into the MBRS project, using development of monitoring and EIS as a central activity.**

1.4 Recommended Actions

Coral reef ecosystems are intrinsically ecologically open, with substantial exchanges of nutrients, pollutants, and reproductive products among reefs and between reefs and other systems, including the coastal watersheds. Because of this, effective environmental management requires a regional perspective, unconstrained by national boundaries or MPA borders. We identify the lack of a regional perspective, and the lack of effective data sharing among monitoring programs as major problems to be addressed by the MBRS project. Our four Actions will build:

1) **a regional perspective** among individuals and agencies responsible for marine environmental management in the region,
2) **a management perspective based more strongly on ecosystem functioning**, and
3) **greater national capacity** for more effective monitoring and decision support for management and conservation of the resources of the MBRS.

Action 1: Implement a distributed, web-based Environmental Information System available to all participants, to include basic environmental data for all reefs and adjacent waters in the region, data on watershed outflows, and all available local and regional monitoring data, including data that form part of broader-scale programs such as CARICOMP and CPACC.

Maximizing access to environmental data from throughout the region is core to building a more regional perspective. **A regional EIS is the mechanism for data management and decision support, and will be a major product of the MBRS project.** It should be implemented early, but will grow in complexity and value as new data become accessible to it. It will be two-tiered, with an upper level designed principally as a public education component, and a deeper level designed for decision-support for managers. It will be bilingual throughout, and designed using the latest display technology. It will be a distributed system, with data maintained within the agency that generated them. Each participant agency (at least one per country) will be a node within the EIS. A regional office will maintain a central metadata catalog, with links to all nodes. The users will develop all policies on data access, data format, and interface complementarity.

Implementation of this Action will involve substantial training in GIS and database management, in monitoring program design and data analysis, and in interpretation of remotely sensed marine data. Provision of computing equipment, software, and data-transfer technology, and assistance with conversion of existing datasets to compatible formats are included.

Action 2: Implement an interdisciplinary regional project (ECONAR) for collection of synoptic data on physical oceanography and ecological connections among reefs, and between reefs and adjacent ecosystems, including coastal watersheds. Identify locations that are biodiversity hot spots, sources or sinks for recruitment of corals, fish, or other important community components, or sites at special risk for pollution due to onshore activities.

There are important linkages between reefs, other marine environments, and coastal watersheds, all mediated, partially or entirely, by water flow. These determine dispersal and recruitment patterns of organisms, and transfer of nutrients and pollutants. Characterization and modeling of these features will provide important data to the EIS for future use in management decisions, including decisions on the siting of coastal development and future MPAs. Existing MPAs and research facilities will be the sites for a regional scale experimental study of ocean currents, pollutant transport, and recruitment dynamics.

ECONAR (Ecological CONnections Among Reefs) will be sharply focused to include:

1) **building of a regional-scale numerical model of shallow (upper 50m) flows,**
2) **empirical testing of that model in two or three critical locations,**
3) **exploration of delivery dynamics for pollutants from specified coastal sources,**
4) **monitoring of fish and coral recruitment at a set of comparable locations across the region, and**

5) **application of genetic, chemical, and other techniques to collected recruits of selected species in order to establish sources of the recruitment to specific sites.**

ECONAR will be structured as a multidisciplinary, multi-organizational, and international 5-year research program, involving the management and academic communities in the region, and including some scientists from outside the region. It will be managed by a Scientific Steering Committee, and will be funded partly by leveraging funds from national and international research-support sources.

Active involvement by academic scientists and environmental managers in ECONAR will build a regional perspective based on ecosystem function and dynamics, and a tradition of collaborative research and monitoring. Worldwide, this study will be the first attempt to monitor coral reef dynamics on a truly regional scale. That it will be an international effort will enhance its stature as an example of science for management. The results will provide guidance for future management decisions locally, nationally and regionally.

Action 3: Develop and employ time-integrated measures of temporally variable impacts to augment existing water quality monitoring by measuring fluxes of groundwater and major rivers to the MBRS, and by using biomonitoring to evaluate effects of nutrients and contaminants in reef communities.

Water quality impacts are widely perceived as important influences on reef "health" in the MBRS region, yet few programs to monitor these are in place. Freshwater inputs are principally from rivers in the south, while to the north of Belize City, non-point source inputs are more important. The monitoring of non-point source inputs is less straightforward, but adequate monitoring of water quality is technically difficult in either case. Measurement of nutrient and contaminant loading requires knowledge of flux as well as concentration. Concentrations of most nutrients or contaminants are so dilute by the time water arrives at reef environments that direct assay of water samples is too imprecise to discriminate impacts from background levels. **We recommend the use of bioindicator techniques that integrate the effects of chemicals over ecological periods (hours to years) to assess impacts of poor quality water on coral reef "health", and direct flow rate and chemical analysis of water at sources, such as river mouths or sewer outfalls, to ascertain the quantities of potential pollutants being delivered to the system.**

This Action has three components, each managed directly by the Project Coordination Unit (PCU). The first is to **install gauges and monitor quality of water at mouths of all significant rivers**, and to undertake a risk assessment by tracking flood plumes for those rivers that constitute the most significant pollution sources. The second is to **commence groundwater modeling and tracer studies** to determine patterns and rates of delivery to reefs of the Yucatan. The third is a research program **to develop biomonitors appropriate to this region**. The latter two components will rely largely on the academic community in the region and will be managed using planning workshops and a small grants program. The primary goal will be to develop new monitoring techniques that are cost-effective and will track nutrification due to pollution from upstream sources. However, research to develop biomonitors useful for metals, pesticides and other contaminants likely to be present in the region is also needed.

Action 4: Foster co-operation among Departments of Fisheries, and with appropriate NGOs on collection of fishery data; to strengthen the ability to make ecosystem-based estimates of total fishing mortality.

At present, the limited data collected by Fisheries Departments in the region are all based on landings. This fact makes them of very limited value in determining whether catch (including bycatch) exceeds the ability of the ecosystem to sustain it. What is required are data on total fishing mortality for each unit of habitat.

Given that there are other important fisheries issues to be addressed (such as the issue of cooperative management of boundary-straddling stocks), and other consultants dealing specifically with fisheries issues, we propose only a modest effort to address this need for habitat-based estimates of catch. **This Action is planned as regional workshops to bring fisheries managers and the fishing industry together to consider ways of developing an effective, habitat-based monitoring of catch. Once a program is implemented to estimate fishery impact in this way, we recommend that catch data be incorporated into the regional EIS.**

1.5 Educational capacity building, and budget estimates

Section 5 of the report addresses the need for educational capacity building in each country. Since we have included specific educational components in each of the four Actions presented in Section 4, and since **we believe strongly that educational capacity building should not be done in isolation from other components**, this Section presents no additional recommendations. It briefly summarizes the perilous present situation in all countries other than México, emphasizes the value of South-South educational interaction, and stresses the need for the MBRS project to tackle educational capacity building in ways that will ensure the new capacity is kept available for future environmental management needs in the region.

The final part of Section 4 presents the budget for the Actions we have proposed. **The budget assumes that governmental agencies make new, or redirect existing core funding to sustain their monitoring activities, and that there is substantial leverage of additional funds from national and international funding agencies.**

In direct MBRS Project funds over the five-year period, Action 1 (EIS) will require $ 2.760M, Action 2 (ECONAR) will require $ 2.695M, Action 3 (water quality) will require $ 1.330M, and Action 4 (fisheries) will require $ 0.301M -- a total direct cost of $ 7.086M.

The report is completed by a Bibliography, a Glossary of acronyms and terms, a list of people contacted, and a table of interviews done.

1 Resumen Ejecutivo

La bien conocida Barrera Arrecifal de Belice ha sido objeto de significativos esfuerzos de conservación durante algunos años. Es la joya central y primaria de un sistema de arrecifes barrera y en banda de mayor extensión —el Sistema Arrecifal mesoamericano, SAM— que se extiende desde el norte de la península de Yucatán a través de México, Belice y Guatemala, hasta las islas de la Bahía en Honduras. Los objetivos primarios del Programa del Banco Mundial para la Conservación y Aprovechamiento Sostenible del SAM pretenden mejorar la protección de estos ecosistemas vulnerables y únicos, y apoyar a México, Belice, Guatemala y Honduras para fortalecer y coordinar sus políticas nacionales, sus regulaciones y mecanismos institucionales para la conservación y el aprovechamiento sostenible del ecosistema marino. **Este reporte evalúa los programas actuales de monitores ambientales del SAM y hace recomendaciones que aseguren uno que vigile la "salud" del ecosistema a nivel regional, el desarrollo y adopción de un Sistema de Información Ambiental (SIA), un programa regional de investigación que establezca la base de información para el SAM, que aplique técnicas modernas para la vigilancia de la calidad del agua y mejore modestamente los registros estadísticos de las capturas pesqueras. Las recomendaciones incluyen un desarrollo sustancial de la capacidad educacional, todas en el contexto de lograr los objetivos específicos del SIA.**

1.1 Términos of Referencia y Situación Actual

La Sección 2 describe brevemente nuestros Términos de Referencia. **La Sección 3** revisa los programas actuales de monitores en la región. Identifica los usuarios, las probables fuentes de perturbación y los datos de monitores existentes y también evalúa los actuales. El SAM está expuesto a riesgos por la contaminación costera, la sobrepesca, otros usos inapropiados, tormentas, incrementos térmicos anormales, epizootias y otros fenómenos "naturales" que puedan ser de origen antropogénico. Existen varios programas de monitores bien concebidos y profesionalmente realizados que deberían continuar. También existe un cierto número de estudios básicos que podrán constituir una línea de base para el desarrollo de futuros esfuerzos con monitores.

La mayor parte de los programas de monitores tienen un enfoque muy local, hay poca evidencia de una perspectiva aún a escala nacional, y es rara la perspectiva regional que se extienda mas allá de los confines nacionales. El enfoque se orienta casi por completo a los sistemas de arrecife coralino, con exclusión de los pastos marinos, de los manglares y de otros sistemas importantes. Solo en Belice y México existen bases de datos con referencia geográfica que cubren una porción significativa de la región bajo la jurisdicción de cada país, y en ambos casos, el acceso o modificación de estas bases de datos puede hacerse por solo un par de personas con el entrenamiento necesario. Como resultado de ello, estas bases de datos son vulnerables y menos accesibles de lo que podrían ser. No existen sistemas de información ambiental integrados para las regiones costeras marinas, aún a escala nacional. El uso compartido de los datos es raro y usualmente se da a través de relaciones interpersonales mas que a partir de relaciones oficiales interinstitucionales. Mucha de la capacidad para aplicar programas de monitores reside en el sector de las ONG y especialmente en el sur, hay poca evidencia de algún compromiso oficial que valore adecuadamente los programas de monitores. **La labor de mucha gente dedicada mantiene el esfuerzo de los monitores actuales, pero este esfuerzo es claramente frágil, de extensión insuficiente, severamente restringido por su falta de recursos y no provee de una capacidad regional para vigilar la "salud" del SAM.**

1.2 Métodos de observación disponibles

La Sección 4 presenta un resumen de los métodos disponibles, esboza los objetivos del establecimiento de programas mejorados de monitores ambientales en la región y hace recomendaciones específicas de Acciones que hagan posible cumplir con esos objetivos.

Los monitores usan métodos tradicionales (con frecuencia de bajo costo) tales como prospecciones basadas en buzos y análisis de muestras de agua, así como métodos mas nuevos (a veces mas costosos) que incluyen varias formas de medición con sensores remotos y biomonitores. El desarrollo de programas de monitores y la evaluación estadística de los datos que proveen, son tan importantes como las técnicas de recolección de datos, pero rara vez reciben atención cuidadosa. La forma como los datos son archivados y compartidos también es importante. Sugerimos que un esfuerzo para desarrollar la capacidad en el diseño y puesta en práctica de un programa y en el análisis de datos será mas benéfico que un esfuerzo para introducir métodos de campo estándar para utilizarse en la región.

1.3 Principlios para desarrollar la capacidad de manera sostenible

El problema fundamental en la región es una generalizada falta de capacidad humana. El desarrollo de la capacidad tradicionalmente ha sido llevado a cabo mediante fondos internacionales en contratos a corto plazo. Tales esfuerzos son incapaces de crear un incremento sostenible de la capacidad local sin la continua inyección de fondos y de expertos. Ambos, el diseño de proyectos y la subyacente fragilidad de las economías y de los gobiernos son deficitarios. Existe la necesidad urgente de un nuevo paradigma, un desarrollo de la capacidad inducido por la demanda, que esté basado en la participación comunitaria y mayor equidad en la asociación norte-sur. Tal paradigma puede ser construído en el proyecto del SAM, desarrollando un programa de monitores y el SIA como actividades centrales.

1.4 Acciones Recomendadas

Los ecosistemas de arrecife coralino intrínsecamente son ecológicamente abiertos, con intercambios sustanciales de nutrimento, contaminantes y productos reproductivos entre los arrecifes y entre los arrecifes con otros sistemas que incluyen las cuencas costeras. Debido a esto, el manejo ambiental efectivo requiere de una perspectiva regional, no constreñida por las fronteras nacionales o por los límites de las AMP. Identificamos la falta de una perspectiva regional y la falta de datos efectivamente compartidos entre los programas de monitores como los principales problemas a ser atendidos por el proyecto del SAM. Nuestras cuatro Acciones desarrollarán:

1) **Una perspectiva regional** entre los individuos y agencias responsables del manejo ambiental en la región,
2) **Una perspectiva de manejo basada mas fuertemente en el funcionamiento del ecosistema**, y
3) **mayor capacidad nacional** para una vigilancia ambiental mas efectiva y para apoyar la toma de decisiones sobre el manejo y conservación de los recursos del SAM.

Acción 1: Desarrollar y poner en práctica un Sistema de Información Ambiental distribuido, basado en la red y disponible para todos los participantes, que incluya datos ambientales básicos para todos los arrecifes y aguas adyacentes de la región, datos sobre las descargas de las cuencas y todos los datos disponibles de los monitores locales y regionales disponibles, que incluyan datos que formen parte de programas a gran escala, tales como CARICOMP y CPACC.

El propiciar al máximo el acceso a datos ambientales de toda la región es el núcleo requerido para el desarrollo de una perspectiva mas regional. **Un SIA regional es el mecanismo para el manejo de datos y para la toma de decisiones y será uno de los productos principales del proyecto del SAM.** Deberá desarrollarse desde el principio, pero crecerá en complejidad y valor en la medida que sea enriquecido con nuevos datos. Tendrá dos componentes, uno con un nivel superior diseñado principalmente como un componente de educación pública y un nivel mas profundo, diseñado para el apoyo a la toma de decisiones por los gestores ambientales. Será bilingüe en toda su extensión y estará diseñado utilizando la mas moderna tecnología para la presentación. Será un sistema distribuído y los datos serán actualizados por la agencia que los genere. Cada agencia participante (al menos una por cada país) constituirá un nodo dentro del SIA. Una oficina regional mantendrá un catálogo central de metadatos, con vínculos hacia los otros nodos. Los usuarios desarrollarán todas las políticas sobre el acceso a los datos, sus formatos y las interfases complementarias.

El desarrollo y puesta en práctica de esta Acción implicará un entrenamiento sustancial en el uso de los SIG y en el manejo de bases de datos, en el diseño del programa de vigilancia ambiental y en el análisis de datos, así como en la interpretación de datos procedentes de los sensores remotos marinos. Se incluye la provisión de equipo de cómputo, programas y tecnología para la transferencia de los datos, y asistencia para la conversión de conjuntos de datos ya existentes a formatos compatibles.

Acción 2: Desarrollar un proyecto regional interdisciplinario (ECONAR) para la recolección de datos sinópticos sobre la oceanografía física y conexiones ecológicas entre los arrecifes, entre los arrecifes y ecosistemas adyacentes que incluyan las cuencas costeras. Identificar localidades que sean focos de alta biodiversidad, fuentes de reclutamiento o vías de salida de reclutas de corales, de peces o de otros grupos importantes componentes de la comunidad, o bien que sean sitios especialmente susceptibles al riesgo de sufrir la contaminación por las actividades en la costa.

Existen importantes vínculos entre los arrecifes, otros ambientes marinos y las cuencas costeras, todos ellos mediados total o parcialmente por el flujo del agua. Ellos determinan los patrones de dispersión y de reclutamiento de los organismos y la transferencia del nuttrimento y de los contaminantes. La caracterización y el desarrollo de modelos de estos patrones aportará datos importantes para el SIA, para su uso futuro en la toma de decisiones para el manejo, que incluya decisiones relativas al establecimiento de nuevos desarrollos y de nuevas APM. Las APM y las instalaciones de investigación serán los sitios para el estudio experimental a escala regional de las corrientes oceánicas, del transporte de contaminantes y de la dinámica del reclutamiento.

El Proyecto ECONAR (acrónimo en inglés de Ecological CONections Among Reefs) estará enfocado específicamente a:

1) **el desarrollo de un modelo numérico a escala regional de los flujos de la capa superficial (los primeros 50m),**
2) **la prueba empírica de ese modelo en dos o tres localidades críticas,**
3) **exploración de la dinámica de los contaminantes procedentes de fuentes costeras específicas,**
4) **vigilancia del reclutamiento de peces y corales en un conjunto de localidades comparables a través de la región y,**
5) **aplicación de técnicas genéticas, químicas y de otro tipo, sobre reclutas de ciertas especies para establecer las fuentes de reclutamiento a sitios específicos.**

La estructura de ECONAR consistirá de un programa de investigación quinquenal multidisciplinario, multiorganizacional e internacional, que involucre comunidades académicas y de manejo propias de la región e incluya algunos científicos de que no sean de la región. Será manejado por un Comité Científico Organizador y será patrocinado parcialmente por fuentes de financiamiento a la investigación nacionales e internacionales.

La participación activa de científicos y de administradores ambientales en ECONAR desarrollará una perspectiva regional basada en el funcionamiento y en la dinámica del ecosistema, así como una tradición de la investigación en colaboración y en el uso de programas de monitores. Este estudio será el primero a nivel mundial que intente observar a largo plazo la dinámica de los arrecifes coralinos en una escala realmente regional. Será un esfuerzo internacional de estatura como un ejemplo de la ciencia para el manejo. Sus resultados proveerán de una guía para futuras decisiones para el manejo a nivel local, nacional y regional.

Acción 3: Desarrollar y utilizar medidas integradas en el tiempo de impactos temporalmente variables que incrementen las observaciones de la calidad del agua, mediante la medición de flujos de las aguas freáticas y de los ríos principales que desembocan al SAM, y evaluar los efectos del nutrimento y de los contaminantes sobre las comunidades arrecifales mediante el uso de biomonitores.

Los impactos sobre la calidad del agua son ampliamente percibidos como influencias importantes sobre la “salud” del SAM y hay algunos programas de monitores funcionando. Las entradas de agua dulce proceden principalmente de los ríos en la parte sur, mientras que al norte de la ciudad de Belice, las fuentes no puntuales de agua dulce son mas importantes. El uso de monitores para vigilar las fuentes no puntuales es menos directo, pero de cualquier manera, la observación adecuada de la calidad del agua es técnicamente difícil. La medición de la carga de nutrimento y de contaminantes requiere del conocimiento de las concentraciones y de los flujos. Las concentrations de la mayor parte del nutrimento o de los contaminantes están tan diluídas al momaneto en que llegan a los ambientes arrecifales que el análisis directo de muestras de agua es demasiado impreciso para poder discriminar los impactos respecto a los niveles de concentración basales. **Recomendamos el uso de técnicas con bioindicadores que integran los efectos de las sustancias químicas a lo largo de períodos ecológicos (de horas a años), para evaluar los impactos del agua de pobre calidad sobre la "salud" de los arrecifes de coral. Los análisis químicos del agua y las mediciones de los flujos deberían realizarse en las fuentes que los originan, tales como las desembocaduras de los ríos o salidas de los drenajes para determinar las cantidades de contaminantes potenciales que son liberados al sistema.**

Esta Acción tiene tres componentes, cada uno manejado directamente por la Unidad Coordinadora del Proyecto (UCP). El primero consiste en la **instalación de medidores para vigilar la calidad del agua en las desembocaduras de los ríos mas importantes**, y llevar a cabo una evaluación de riesgos siguiendo las trayectorias de dispersión de las descargas de aquellos ríos que constituyen las fuentes mas importantes de contaminación. El segundo componente consiste en **iniciar el desarrollo de un modelo de las aguas freáticas y hacer estudios con trazadores** para determinar los patrones y las tasas de influjo a los arrecifes de Yucatán. El tercero es un programa de investigación orientado al **desarrollo de biomonitores apropiados a esta región.** Los dos últimos componentes residirán principalmente en la comunidad científica en la región y funcionarán a base de seminarios de planificación y de un programa de apoyos reducidos. El objetivo primario consistirá en desarrollar nuevas técnicas de monitores que sean efectivas por su costo y que permitan hacer un rastreo de la nutrificación debida a la contaminación de las fuentes corriente arriba. Sin embargo, también se requiere de hacer investigación para el desarrollo de biomonitores útiles para la detección de metales, pesticidas y otros contaminantes probablemente presentes en la región.

Acción 4: Promover la cooperación entre los Departamentos de Pesca con las ONGs apropiadas, para la obtención de datos sobre las pesquerías y para reforzar la habilidad para realizar estimaciones de la mortalidad por pesca basadas en el ecosistema.

Los datos que de manera limitada son registrados por los departamentos de Pesca en la región están todos basados en los desembarcos. Esto los hace de un valor muy limitado para determinar si las capturas (incluso la captura incidental) excede la capacidad del ecosistema para sostenerlas. Se requieren datos que permitan evaluar la mortalidad por pesca para cada unidad de hábitat.

Dado que existen otros aspectos importantes sobre las pesquerías que deben abordarse (tales como el manejo cooperativo de recursos que rebasan las fronteras de los países) y otros asuntos específicos sobre el tema, proponemos solo un modesto esfuerzo para orientar esta necesidad a las estimaciones de la captura basadas en el hábitat. **Esta**

Acción está programada como seminarios regionales que reúnan a los administradores de los recursos pesqueros junto con los industriales de la pesca a fin de buscar la manera mas efectiva de obtener registros de las capturas basados en el hábitat. Una vez que se ponga en práctica un programa orientado a estimar el impacto de la pesca de esta manera, recomendamos que entonces los datos de captura sean incorporados en el SIA regional.

1.5 Fortalecimiento de la capacidad educacional y estimación del presupuesto

La Sección 5 del reporte se refiere a la necesidad de desarrollar la capacidad educacional en cada país. Puesto que hemos incluído componentes educacionales específicos en cada una de las cuatro Acciones presentadas en la Sección 4, y puesto que **creemos fuertemente que el fortalecimiento de la capacidad educacional no debe hacerse aisladamente de los otros componentes**, esta Sección no presenta recomendaciones adicionales. Esboza brevemente la precaria situación actual en todos los países aparte de México, enfatiza el valor de la interacción educacional norte-sur y el de la necesidad de que el proyecto del SAM se aboque a la tarea de fortalecer la capacidad educacional de forma tal que asegure que la nueva capacidad permanezca disponible para satisfacer las futuras necesidades de manejo ambiental en la región.

La parte final de la Sección 4 presenta el presupuesto de las Acciones que hemos propuesto. **El presupuesto presupone que las agencias gubernamentales hacen nuevas aportaciones o reorientan los financiamientos iniciales para sostener sus actividades con los programas de monitores, así como también que prevalecerá un sustancial flujo de fondos adicionales procedentes de las agencias nacionales e internacionales de apoyo.**

Los fondos directos requeridos del Proyecto del SAM durante el período de cinco años son: Acción 1 (SIA), $ 2.760M; Acción 2 (ECONAR), $ 2.695M; Acción 3 (calidad del agua), $ 1.330M y Acción 4 (pesquerías), $ 0.301M – un costo total directo de $ 7.086M.

El reporte culmina con una Bibliografía, un Glosario de acrónimos y términos, una lista de gente con la que se hizo contacto y una tabla de las intrevistas sostenidas.

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2 Terms of Reference

2.1 Goals and objectives for this study

The primary goals of the World Bank program for the Conservation and Sustainable Use of the MBRS are to enhance protection of these vulnerable and unique marine ecosystems, and to assist México, Belize, Guatemala and Honduras to strengthen and coordinate national policies, regulations, and institutional arrangements for marine ecosystem conservation and sustainable use. These terms of reference outline the activities required to comprehensively assess and report on the baseline information needed to guide the initiation and implementation of the monitoring and EIS component of this project. According to the component's objectives, stated in the Action Plan, the current baseline information should ensure that:

- adopted techniques are appropriate, cost-effective and responsive to the monitoring capacity and needs of each country, and that

- monitoring protocols are compatible within the region to allow for cross-country comparisons and integration of data into a regional assessment of ecosystem health over time.

In this context, the specific objectives for this work are to:

- **identify and assess existing capacity for monitoring and EIS** including experience, expertise and institutions available in the region;

- **determine the most appropriate methods and techniques** which will complement current efforts and improve monitoring and the use of information on coral reef health and coastal ecosystems at the local, national and regional scale, and

- **identify capacity building needs within each country** to implement monitoring and EIS recommendations.

The study area is composed of the MBRS region stretching from Quintana Roo (México) to the Bay Islands of Honduras including adjacent marine ecosystems and coastal watersheds in México, Belize, Guatemala and Honduras. The inland and ocean boundaries must capture all areas that have a possible influence on reef health.

2.2 Requirements and Key Tasks

Requirement #1: Identify and evaluate existing EIS and monitoring programs in the MBRS region:

- Identify key stakeholders involved in coastal management, and determine their information needs with respect to reef health and stressors.

- Identify and assess the availability of core data sets and their potential use in estimating reef health and coastal ecosystem condition. Consider databases of biophysical variables, geospatial data sets, socio-economic data, and data about types and locations of reef stressors.

- Summarize the methods currently used in the MBRS region for monitoring reef health and coastal ecosystem condition. Identify any gaps and overlap between existing monitoring and EIS programs and document and report "good practice" case studies regarding the use of relevant methods and techniques.

- Assess the actual use of the information derived from monitoring into coastal management and decision-making at the local and national level.

Requirement #2: Provide a strategic framework and guidelines for the development of the monitoring component:

- Propose key indicators and variables, and recommend the most appropriate combination of methods and techniques responsive to the needs and conditions outlined in the MBRS Action Plan for multilevel assessment of reef and coastal ecosystems condition at the regional scale.

- Compare and contrast new technologies, which have the potential for monitoring coral reef and coastal ecosystem condition, examine their benefits, cost effectiveness, strengths and weaknesses.

- Coordinate and discuss proposed monitoring strategies with technical committees established in each country under the MBRS initiative.

- Identify and assess existing capacity for the application of additional tools such as simulation models, and GPS that will be needed in estimating coral health and coastal ecosystem condition.

Requirement #3: Identify capacity building priorities to implement monitoring and EIS recommendations:

- Review each country's institutional, technical and human capacity for adopting recommended methods.

- Recommend steps to strengthen or expand national and local capacity to carry out regional coral reef initiative and adopt more appropriate monitoring and EIS programs.

- Identify budget needs to implement these recommendations.

3 Existing Monitoring and EIS Programs

3.1 The stakeholders.

A broad range of governmental agencies, non-governmental organizations, private industries, and the local populations have interests in the good management of coral reefs in the region. In each country, government departments responsible for fisheries and tourism, the fishing and tourism sectors, and the general public who care about their environment and their quality of life should all have a vested interest in the sustainable management of coral reefs and surrounding inshore environments. We found, however, that tourism (both government departments and the industry) was rarely an active participant in projects to advance sustainable environmental management, and was sometimes identified by other groups as a part of the problem, rather than as a participant in the solution. Other industries (agriculture, manufacturing, shipping), and the government departments regulating them, should be aware of, and concerned about possible impacts of their activities on the near-shore marine environment. With few exceptions, we found government departments of agriculture, environment, or industry and commerce placed marine environmental concerns low on their priorities.

Although our opportunity to meet the general population was limited, we did not sense a widespread recognition of the economic and aesthetic value, and the need for effective management of near-shore marine environments and coral reefs. In each country, but with greater importance in Guatemala and Honduras, the NGO community plays a vital role in raising consciousness about the need for effective environmental management. The NGO community has also been responsible for initiating and sustaining much of the progressive action for marine environmental conservation in the region.

3.1.1 Governmental agencies

Responsibility for coastal zone management is not centralized in a single agency in any of the four countries. Instead, fisheries, management of protected areas, management of pollution from shore-based activities, and other responsibilities are distributed among several governmental departments. Marine environmental management is also poorly integrated with terrestrial management.

3.1.1.1 Fisheries & marine environmental management

México: Fisheries and environmental management are within the single umbrella agency, SEMARNAP (Secretaría de Medio Ambiente, Recursos Naturales y Pesca):

Government agency	Responsibilities
INP (Instituto Nacional de Pesca)	fishery management
INE (Instituto Nacional de Ecología):	
UCANP (Unidad Coordinadora de Areas Naturales Protegidas)	terrestrial and marine protected areas
CNA (Comisión Nacional del Agua)	water quality of effluent
PROFEPA (Procuraduría Federal de Protección al Ambiente)	enforcement of environmental regulations and laws

INP includes regional centers responsible for catch statistics. UCANP manages designated terrestrial and marine protected areas, while PROFEPA is responsible for enforcement of their regulations.

Belize: The Coastal Zone Management Authority, established only recently as a statutory authority, has a broad responsibility for sustainable management of the coastal waters of Belize, but little regulatory power. It and the Department of Fisheries have overlapping responsibilities:

Government agency	Responsibilities
DOF (Department of Fisheries)	collection of catch statistics, and fisheries management, declaration and management of Marine Reserves
CZMA (Coastal Zone Management Authority):	
CZMI (Coastal Zone Management Institute)	sustainable management of the coastal waters of Belize

The CZMI grew out of the very successful Coastal Zone Management Project, funded initially as a UNEP-GEF initiative within the Fisheries Department. As now established, the CZMA, despite its limited regulatory power, is the only umbrella organization for coastal zone issues in the country. Its CZMI is the only organization with a national (all Belizean coastal waters) perspective and management approach, an active water quality monitoring program, and a georeferenced database of environmental information for the coastal waters of Belize. The CZMA, including its Institute, although an official governmental Authority, is still largely funded from external (GEF) sources.

Guatemala: Fisheries and marine environmental management are within the single ministry, MAGA (Ministerio de Agricultura, Ganadería y Alimentación). In addition, CONAMA (Comisión Nacional para el Manejo del Ambiente) exists for overall environmental management:

Government agency	Responsibilities
UNEPA (Unidad de Ejecución Pesquera y Acuicola)	fisheries management
CONAP (Consejo Nacional de Areas Protegidas)	management of protected areas

CONAMA interacts closely with CONAP and other units of MAGA, however it has little regulatory power and must work through other agencies.

Honduras: Fisheries management and marine environmental management are in separate ministries:

Government agency	Responsibilities
Secretaría de Estado en el Despacho de Agricultura y Ganadería:	
DIGEPESCA (Dirección General de Pesca y Acuicultura)	monitoring of the commercial fishery
Secretaría de Estado en el Despacho de Recursos Naturales y Ambiente (SERNA):	
DAPVS (Depto. de Areas Protegidas y vide Silvestre)	management of protected area

In reality there is little attention to the marine environment by any of SERNA's units.

3.1.1.2 Oceanography and Meteorology

The collection and evaluation of marine hydrographic data is a responsibility of the meteorological department in each country. The extent of that monitoring activity is limited, and the data are rarely seen as being collected for purposes of environmental management. Meteorological and tidal data are collected and handled best in México. In Belize, the Department of Meteorology cooperates with Raleigh International in WRIScS, a coastal zone research project to explore the sedimentation and pollution impacts on reefs from three river systems in the Stann Creek region, and is the implementing agency in Belize for CPACC. Under the latter, it had deployed tide gauges and marine met instruments at Sapodilla and Half Moon Cayes plus a met station at Glovers Reef. Mitch removed the marine instrumentation packages and gauges, and they have not yet been replaced.

The Instituto Nacional de Sismología, Vulcanología, Meteorología y Hidrología, INSEVUMEH, the national meteorological agency of Guatemala, has responsibility for oceanographic data, and has plans for an oceanographic monitoring platform off Punta Manabique. At present there is not even a functional tide gauge on the Atlantic coast of Guatemala. The situation in Honduras is even weaker.

3.1.1.3 Land-Based Activities

In each country, other governmental agencies have responsibilities that relate directly or indirectly to the coastal marine environment. While we found people in these agencies readily acknowledged that land-based activities could have significant impacts on coastal marine environments, there was little evidence that assessing such impacts was a high priority.

México: The Instituto Nacional de Estadística, Geografia y Infomatica, INEGI, maintains an extensive, georeferenced, national database of environmental, economic, demographic and social information, but maintains no data on México's coastal waters. CNA's concern is with the provision of potable water supplies, and the application of regulations governing effluent quality. In the latter case, the emphasis is on possible human health risks, rather than on environmental impacts. All new hotels and other developments require environmental impact assessments, but while INE is asked to comment on coastal development projects, it lacks authority to regulate these.

Belize: The Department of the Environment has responsibility for environmental management onshore. Through its National Biodiversity Committee, it recently produced the Belize Biodiversity Strategy and Action Plan (October 1998). Earlier it developed an Environmental Water Quality Monitoring Program (June 1995) with the assistance of the USAID NARMAP Project. This planning document makes specific recommendations for water quality assessment and management within watersheds, for capacity building, and for improved inter-agency cooperation within Belize, and intra-regional cooperation with México and Guatemala in water quality assessment. This plan has not yet been put into operation, despite the recognition that pollution from intensive agriculture may have significant impacts in coastal waters. The National Hydrological Service maintains some information on flow regimes in the major rivers. Also within the Ministry of Natural Resources and Environment, the Land Information Centre, LIC, maintains a georeferenced Conservation and Environmental Data System (CEDS) of environmental information for the country, but this does not include coverage of the coastal ocean. Because of the requirement that LIC charge for CEDS data (even though funds generated go to general revenue rather than to the LIC budget), there has developed some reluctance among government departments to place data with LIC.

Guatemala: CONAMA chaired the Comisión Nacional de la Biodiversidad, CONAB, which recently completed a biodiversity strategy for the country. The Instituto Geográphico Nacional, IGN, maintains land, geographical, and other data, but does not include coastal marine information. The focus throughout relevant government departments is very largely terrestrial.

Honduras: Within SERNA, DAPVS, COHDEFOR (Comisión Hondureno de Desarrollo Forestal), and DiBio (Directorate Biodiversidad) all focus almost entirely on terrestrial systems, and concerns about land-based sources of marine pollution are slight. The Consejo Nacional de Desarrollo Sostenible, CONADES, recently created to coordinate the Honduran response to its international environmental obligations may be able to encourage greater commitment to sustainable environmental management.

3.1.1.4 Interaction of Agencies

In México and Belize, some steps have been taken to facilitate effective interaction among the various governmental departments.

México: SEMARNAP exists as an umbrella uniting all departments with environmental responsibilities. In addition, Marine Park Directors meet regularly in México City with senior members of INE, and with other members of SEMARNAP, usually including the Secretary of Environment.

Belize: The CZMA exercises its responsibility to advise on coastal zone issues through a formally constituted Board with representatives of government departments, the University College of Belize, UCB, and the private sector. In addition, the Belize Barrier Reef Committee, originally formed to fulfill World Heritage requirements, and now officially the N-STAC for the MBRS project, includes representatives from a broad range of government, NGO, and private sector groups. The Ministry of Natural Resources and Environment also has formed a committee to ensure a comprehensive Protected Areas policy. This includes representatives of Departments of Fisheries, Environment, Land, and Archeology, the Tourist Board, and Belize Audubon, and is currently chaired by Fisheries.

Guatemala and Honduras: In Guatemala, CONAMA may be able to encourage effective inter-agency interaction. CONADES may do this in Honduras. However, the low level of government activity in marine environmental management in both these countries makes this relatively unimportant. Far more important is the growing effectiveness of structures such as TRIGOH that integrate the efforts of the NGO community (see below).

3.1.2 The Research and Education Community

Academic institutions, including appropriately skilled faculty, make use of the coastal marine ecosystems for teaching, to advance fundamental knowledge, and to apply their skills to questions of management concern. The research capacity of these institutions is limited, except in México. There, institutions such as CINVESTAV in Merida, ECOSUR in Chetumal, and UNAM, with a branch campus in Puerto Morelos include well-qualified faculty, some advanced instrumentation, and a tradition of research, while several other institutions are oriented more strongly to undergraduate teaching. Research-intensive Mexican institutions outside the Yucatan also will have some capacity to contribute because México can afford the additional travel costs for work at a distance from the home campus. The Universidad de Honduras, and the Universidad de San Carlos, and

Universidad del Valle, both in Guatemala include a few faculty active in marine environmental research, but they are constrained by time, and a general lack of research funding. The University College of Belize offers only a two-year undergraduate program, and currently has no marine research capability.

Even in those institutions where there are skilled faculty and some opportunity for research, there is a tendency to value basic research more highly than research on topics needed for better environmental management, and to do single-investigator projects. While there are obviously important exceptions to this general rule, the result is that the research capacity yields less of immediate value than it might. The academic community should be encouraged to become an important contributor to the improved management of the MBRS.

3.1.3 The NGO Community

The NGO community is a major player in coastal marine environmental management, particularly in the southern portion of the region. This community comprises numerous, locally based organizations, some larger national or regional ones, and the international conservation agencies such as WWF and TNC. Many examples of environmental conservation or management are the result of collaboration between small, local, and larger, regional or international agencies, which provide guidance and financial support.

México: Los Amigos de Sian Ka'an A.C. is the largest, and oldest NGO (established 1986) active in the coastal region of Quintana Roo. It maintains a head office in Cancún, and small branch offices in Chetumal, Carillo Puerto, Sian Ka'an, and Xcalac (combined staff ca. 20 persons). Amigos de Sian Ka'an was responsible for the establishment of the Sian Ka'an Biosphere Reserve, and is presently in the final stages of guiding implementation of a marine protected area at Xcalac. It has carried out a number of other environmental assessment, or planning studies on the coast of Quintana Roo, and has collaborated with both TNC, and the Coastal Zone Management Unit of University of Rhode Island. At its Cancún office, it maintains the only georeferenced database for the coastal waters of Quintana Roo. While Amigos de Sian Ka'an has achieved major accomplishments, and has a very positive relationship with SEMARNAP - providing environmental assessment expertise, and access to its database - it remains a small, fragile institution. Its database, for example, is maintained by a single individual who has the necessary skills and experience.

Centro Ecológico de Akumal, CEA, is typical of the several, small NGOs in México. It is deliberately local in its focus, providing informed advice, public education, and limited data-gathering capacity on environmental issues impacting on the Akumal community -- one that is typical of the Cancún - Tulum Corridor, growing rapidly as tourism expands to the south. CEA funds its activities through limited rental income, T-shirt sales and donations, and occasional small grants, and by the recruitment of volunteers (chiefly North American graduate students) to carry out environmentally relevant projects with in-kind support from CEA.

Belize: The NGO community has been responsible for the establishment of many of the marine protected areas, and continues to be responsible for the management of several of these. Belize Audubon established Half Moon Caye, the first marine protected area in Belize in 1982. Protected areas in Belize have been variously established as Natural Monuments – Half Moon Caye and Blue Hole, or National Parks – Laughing Bird Caye, as well as Marine Reserves. Jurisdiction varies with designation, and for several areas, management has been delegated to an NGO. Preparatory studies for proposing additional protected areas are under way, led by NGOs such as the Toledo Institute for Development and Environment, TIDE. The international NGO community has been active in Belize primarily through its support of Belizean organizations. At present, TNC is closely involved with TIDE, and Guatemalan and Honduran NGOs in several projects in the Gulf of Honduras. Smaller, overseas NGOs have also contributed significantly. Coral Caye Conservation, CCC, has used groups of UK undergraduate volunteers to conduct a number of ground-truthing surveys, and some monitoring on behalf of the CZMI. Raleigh International, in collaboration with University of Exeter, uses undergraduate volunteers from the UK in a Watershed-Reef Interconnectivity Scientific Study, WRIScS. This is a well-designed, clearly focused study on impacts of water-borne sediment, nutrients and heavy metals being delivered to the coastal lagoon from the Stann Creek catchments.

Honduras and Guatemala: The NGO community in these two countries plays an even larger role because of the lack of capacity in government departments. As well as a number of local NGOs formed to conserve/manage specific local areas (such as BICA in the Bay Islands), there are several large organizations with a national, or regional perspective, who view their roles, primarily, as providing financial and technical support to many smaller organizations, and lobbying the government on environmental issues. PROARCA/Costas is a regional entity primarily funded by USAID, with assistance from TNC, WWF, and Univ. of Rhode Island, and with two main objectives: 1) to promote regional objectives of CCAD on marine management, and 2) to support a system of MPAs in the Gulf of Honduras region. FUNDAECO, Guatemala's oldest NGO (1989), employs about 250 staff nationwide, of which 10-20 are professionals. Smaller, local NGOs frequently lack professional staff, and in general, despite the important role being played by the NGOs in these countries, they have limited technical expertise, particularly with respect to research and management of coral reefs and associated marine ecosystems.

One important, and promising recent development has been the establishment of the Tri-national Alliance for the Gulf of Honduras, TRIGOH. This group of 12 NGOs from Belize, Guatemala and Honduras was formed with the assistance and encouragement of TNC and with support of PROARCA/Costas. It includes all the major NGOs active in the Gulf, meets regularly, and seeks to build collaboration and complementarity within this community.

3.1.4 The private sector

The fisheries and tourism industries have major stakes in a sustainably managed marine environment. Individuals in these industries recognize that their economic success depends upon the continued existence of healthy natural systems. However, with rare exceptions, they do not see the implementation of sustainable use of marine resources as their responsibility. This unfortunate circumstance is not unique to the MBRS region. It probably arises because their contact with government is largely in the context of regulation/restriction of their activities, while the conservation movement has tended to paint industry as the cause of environmental problems, instead of as a potential partner in their mitigation.

The fishing industry, and several components of the tourism industry contain significant capacity to make observations and collect environmental data from broad areas of the MBRS region. An effort to involve them more actively would pay off directly, as well as indirectly. The quality of fishery catch data would improve if fishermen were better informed about why it is needed and how it is used. The enforcement of fishery regulations is greatly enhanced if the fishery understands, and buys into the regulations. In tourism, dive operators, in particular, recognize that their clients increasingly value environmentally sensitive actions, and can become very willing participants in regulating use of specific sites. The first marine protected area off Roatán was developed through the efforts of the proprietor of Anthony's Key Resort.

The shipping, oil, construction, and agro industries, all have potentially large impacts on the quality of the coastal marine environment. Economic success of each of these industries is largely independent of the quality of that environment, so there is little incentive to act in ways that will minimize negative impacts. There is also little evidence that individuals in these industries are aware of the sensitivity of coastal marine ecosystems to pollution. There are preliminary plans for oil spill mitigation for the Gulf of Honduras, developed by industry, government and other personnel. There is a broadly held view that these are far from adequate. **The limited and weak capacity of governmental agencies with responsibility for marine environmental management, and their limited authority over agriculture, shipping or oil and similar industries, mean that impacting actions by these industries are scarcely monitored, and poorly regulated.**

3.1.5 The local community

Sustainable management of the coral reefs and other coastal marine ecosystems is compatible with continued growth of tourism, and with sustainable fisheries. These industries contribute very importantly to the wealth of these countries, and to the quality of life of their coastal populations. (Tourism in Cancún alone accounts for 25% of the GNP of México, and supports a city of 500,000 people, for example.) They have the potential to contribute more. A well-informed population can help ensure the success of sustainable environmental management in situations where it would otherwise fail, and the benefits of marine environmental conservation for tourism and fisheries should be an important part of public education. **Too often, the message conveyed is that a community must choose conservation instead of economic prosperity. The MBRS project should avoid that common error in order, more effectively, to build community support for sustainable environmental management.**

With few exceptions, the general community in these four countries is not well informed about the economic or the biodiversity value of their coastal marine resources. Nor are the people well informed about the sensitivity of coastal marine ecosystems to mismanagement, or to the impact of pollution caused by activities upstream. There is a major need for public education. Particularly towards the south, this education must be combined with development of new employment options, so that members of the artisanal fishery can gain new livelihoods.

Certain NGOs appear to be having some success in directly engaging the local population in conservation initiatives, or in modifying their own activities in ways that improve environmental management. Amigos de Sian Ka'an worked with the people of Xcalac to develop a management plan for a new MPA, and TIDE, working with the people of Punta Gorda, is leading community-based monitoring efforts on water quality at Monkey River. TIDE also runs a training program that moves artisanal fishing from netting to the more sustainable catch-and-release fly-fishing tourism.

Our recommendations for monitoring and EIS include components that can become integral parts of an effective public education program aimed at the schools, the tourism operators and staff, and the general public.

3.2 Existing data on environmental quality

3.2.1 Potential and current stressors affecting environmental quality

The MBRS is impacted by fishing, other activities (chiefly tourism) that bring people into the reef environment, and human activities outside that environment that affect the quality of water delivered to it. It is also subject to storms, episodes of anomalously high temperature, outbreaks of disease, and other events that may not be caused directly by human activities (although these may indeed play a role). In these respects, the MBRS is like every other coral reef in reasonable proximity to human populations. Fishing activities extract living biomass, and frequently also modify the environment, chiefly by reducing complexity of structure. Other human presence in the reef environment causes damage due to anchors, diver and snorkeler contact with living organisms, effects of fuels, effluents, and garbage. Agriculture, land-based industry, and coastal communities impact the reef through the nutrients, other chemicals, and sediments they introduce into water that subsequently passes over the reef. While storms physically break up reef structures, high temperature events and disease outbreaks potentially lead to the death of calcifying organisms, and a reduction in the ability of the reef structure to maintain itself and resist erosion.

While human activities may cause a number of deleterious impacts, properly managed human activities are compatible with a "healthy" reef ecosystem. Viable, high-value fisheries and tourism are compatible with sustainable management of reef ecosystems. The problem is not human use of coral reefs, but inappropriate or over-intensive use, including negative impacts from human activities upstream.

The particular stressors vary along the length of the MBRS. Pressure of tourism is particularly high in Cancún where the 2,500,000 visitors per year contribute 25% of México's GDP. But tourism declines as one proceeds down the coast of México. It is high again on Ambergris Caye, Belize, and on Roatán, but over-fishing is the greater direct impact from Cozumel south, with the exception of very local, high tourist pressure at sites like Hol Chan channel in Belize. The people we spoke with consistently identified poor water quality as a very important stressor throughout the region, despite the relative lack of information on it. Given the extensive, chemical-dependent banana, citrus, sugarcane, and oil-palm agriculture, growing coastal communities with inadequate sanitation, and the existence of some heavy industry, we concur with this assessment. Poor land-use practices also suggest that very heavy sediment transport (heavier than in pre-industrial times) will be an important feature during floods each rainy season.

The problem posed by poor water quality is exacerbated by the fact that the landmass of the northern half of the region is a karst bench without surface drainage streams. In general, the karst underlying the Yucatan Peninsula imparts high permeability to the groundwater flow system. This results in rapid infiltration of precipitation and a short lag time between introduction of water to the subsurface and discharge to the near-shore environment. Consequently, there is little opportunity for biological processes to attenuate organic pollutants that may be introduced to groundwater. This effect is particularly significant for the northern Yucatan where surface water flow systems are absent. Throughout this region, the delivery of contaminants from the land will be non-point source, and therefore much more difficult to monitor.

3.2.2 Extent and availability of environmental data among countries

Environmental data of three types exists for parts of the MBRS region (Table 1). These are baseline surveys, monitoring time-series data, and data collected in the context of specific research projects.

Reliably collected time-series exist for fisheries landings, for river outflows, for water quality, for coral abundance (percent cover), for abundance of fish or conch, and for physical parameters such as temperature and salinity. Except for catch statistics, these data sets are few, seldom of long duration, and limited to a few isolated locations. The most notable ones are the CZMI monitoring of coral cover at a number of Belizean locations, the monitoring of coral cover and other environmental parameters in the Mexican MPAs, the Caribbean-wide CARICOMP monitoring of biotic and physical attributes for reef, seagrass, and mangrove environments, which includes five sites in the MBRS region, and the CZMI water quality monitoring program. Resulting data are reasonably accessible, and there is continuity and consistency of methods. Data on fishery catch statistics are more extensive, but related to landing site rather than collection site, and are of low reliability because of inadequate, inaccurate, or incomplete surveys of the catch.

Baseline data can be quite comprehensive when collected as part of the planning for management of a marine protected area. In this case they may include detailed bathymetry, habitat characterization, and assessments of biodiversity and abundances of selected species, particularly corals, other sessile invertebrates and fish. Other baseline data have been collected in recent years with the intention of commencing long-term monitoring of environmental data, but those intentions have not always been realized.

Table 1: Environmental Monitoring Data available in the Region

Institution	Storage method	Description of Data
México		
CNA	Spreadsheet	contaminants, phosphate, solids, nitrates, and BOD (bimonthly, 17 sites, Nichupe Lagoon, Cancún)
CRIP/INP	Spreadsheets and paper copies	routine fisheries catch statistics, limited environmental data and data on stocks of lobster, conch, black coral.
INEGI	extensive GIS database	extensive geographical, statistical, environmental, demographic database for México, no marine data.
Amigos de Sian Ka'an	ArcInfo GIS database	base maps for Q. Roo, extensive terrestrial data (INEGI data up-dated), with some mapping of shallow sub-tidal communities, some fisheries data from CRIP.
CEA	Spreadsheets and on paper.	AGRRA sites surveyed in 1997, 1999. various other marine monitoring (turtle nestings, black coral status, coral bleaching. groundwater flow through local cenotes (3.5 yrs), water quality: salinity & coliform (3.5 yrs, sporadic)
Belize		
Fisheries Department	Mainly on spreadsheets, some monitoring data on paper	routine fisheries catch statistics limited monitoring data, Hol Chan, Bacalar Chico, Glovers Reef, other sites, trailing chain, belt transects, roving diver method, Bohnsack method
Coastal Zone Management Institute	Video tapes, some data into GIS database Spreadsheet, & Arcview GIS database	two series video transects (1995-6, and 1998-9), 17 permanent sites on fore reefs throughout Belize. chain transect data at several sites, commencing 1993, replaced 1995 by video transects. water quality: Nitrates, Phosphates, Chlorophyll, temperature, salinity, turbidity, pH, DO (some erratic data from 93-96, 96-present monthly samples of approx. 50 sites distributed across the Belize shelf. detailed reef maps, with habitat information mostly ground-truthed, data from other Belizean agencies/projects frequently archived on the CZMI database.
Dept. of Environment, & Dept. of Hydrology	Spreadsheet & GIS at LIC, some on paper	- some flow data for main rivers - map of watersheds
Land Information Center	Environmental GIS database (SEDS)	Conservation and Environmental Data System (CEDS), includes extensive data on terrestrial and freshwater environments in Belize. Repository for much governmental environmental information, but no marine data.

National Meteorological Service	NMS spreadsheets, databases. Also, marine data sent also to CPACC regional office, Barbados.	river flows (18 rivers) standard Met. data sea level and tidal data (prior to Mitch), but recommencing shortly.
University College of Belize	Spreadsheet, and copies to CARICOMP regional office, Jamaica.	Calabash Caye, CARICOMP Level 1, several sites, limited data.
WRIScS Project	GIS database (ArcInfo compatible), plan to archive at CZMI.	water quality, flow rate, three rivers in the Stann Creek District commenced 1998. filtered, suspended sediments & cored river bed sediments on a monthly basis. sediment samples at 3 sites, and temperature and conductivity weekly at 40 sites in the lagoon.
Guatemala		
UNEPA	Spreadsheet & paper copies	routine fisheries catch statistics enumeration of artisanal fishery (PRADEPESCA Project)
CEMA, University of San Carlos	Reports on paper	Five year research project on shrimp fishery, including catch, stock, bycatch, various environmental factors in Bahia de Manabique.
FUNDAECO	ArcView GIS database	base maps of Guatemala's terrestrial protected areas, no marine data.
Honduras		
CRIPCA	Spreadsheet	routine fishery catch statistics
DIGEPESCA	Spreadsheet, and on paper	routine fisheries catch statistics
BICA	Spreadsheet	19 belt transects off Roatán, surveyed once 1997
CSSMM	spreadsheets and paper reports	extensive preliminary data: belt transects at 75 sites surveyed 3 times. 7 CARICOMP mangrove & seagrass sites with 1 year of data (Level I).
HCRF		meteorological data (NOAA)
RIMS	Video & Spreadsheet	transect and photo-quadrat data on coral cover at 4 sites off Roatán, annually since 1996

Many research projects undertaken in the region yield useful environmental data. There has been considerable research at some sites over the past 20 years, both by scientists based in the region and by scientists from North America or Europe. The UNAM campus and CRIP facility at Puerto Morelos, the UCB field station at Calabash Caye, the Smithsonian Institution facility at Carrie Bow Caye, the Glovers Reef Research Station operated by the Wildlife Conservation Society (WCS), and the research lab of the Honduras Coral Reef Foundation (HCRF) at Cayos Cochinos (initially a partnership with the Smithsonian) have all made this region accessible to scientists wishing to do coral reef research. Their research contributes ecological, taxonomic, biogeographic, geographical, geological, and other forms of data about the places where the work is done. The WRIScS project, and the TNC-TIDE-Univ. of South Carolina-Mellon Corp. study of current patterns and grouper spawning in the vicinity of Gladden Spit, Belize are two on-going projects that are clearly fundamental science while being of potential benefit for environmental management in this region.

3.3 Existing monitoring programs, and management and use of data.

3.3.1 Reef condition

The great majority of environmental monitoring programs aim to assess reef condition, most typically as percentage cover of living coral, but frequently using additional or alternative indices. Most are locale-specific with no attempt to achieve a regional focus. Table 2 lists all on-going monitoring programs we learned of in the region. Twenty-three of them monitor reef condition, however they do this using a number of different approaches. Some, like the video transect monitoring being done in Belize by CZMI, can provide high-resolution data on areal cover of all macroscopic benthic organisms, although analysis of tapes is time consuming. Most monitoring of coral cover, such as the protocol used by UCANP in Mexican protected areas, provides less precise data, but at substantially lower cost in equipment and analysis. Many programs also provide some information on other attributes. The AGRRA technique emphasizes the distinction between "recently dead" and "old dead" corals, and quantifies extent of these as well as of living coral. These data can provide crude demographic data for the corals sampled. This technique also quantifies algal abundance as an index of nutrification and grazing pressure (necessarily confounded), and abundances of specific groups of fish species likely to respond to fishing pressure.

The CARICOMP technique is focused on primary productivity in mangrove and seagrass communities, as well as on community composition in reef environments. It is unique in this respect, and appears to be the only form of monitoring of mangrove or seagrass habitats in use in the region. The program is truly regional in scope and includes a central data management office in Jamaica. However, it includes only five sites in the MBRS region, and sampling has been erratic. Extension to more sites in the region would be useful.

Procedures necessary for a full CARICOMP program are straightforward but time-consuming, and many organizations have been unable to find the human resources necessary to sustain this effort. The reef component includes repeated measurements on permanent chain transects along reef faces that yield detailed data on coral species abundances and coverage.

Table 2: Monitoring Programs in the Region (for descriptions of methods, see Table 3)

Monitoring Methods	**Institution**
Environmental Monitoring	
Transect Methods	
Chain Transect	CZMI: commenced 1993, several sites, replaced 1995-6 by video transects Hol Chan Marine Reserve: one of several methods trialed RIMS: 15 transects at each of 4 sites off Roatán, surveyed annually since 1996.

Video Transect	CZMI: 17 sites in Belize, surveyed 1995-6 and once more subsequently RIMS: 17 transects at each of 4 sites off Roatán, surveyed twice: 1997 & 99.
Belt Transect (various widths)	Hol Chan Marine Reserve: one of several methods trialed, fish, lobster, conch CSSMM: 75 sites off Roatán surveyed 3 times at <annual frequency, data not readily available. BICA: 19 permanent transects at dive sites off Roatán, surveyed once in 1997.
Bohnsack Method	Hol Chan Marine Reserve: one of several methods trialed
Photo Quadrats	RIMS: 3 quadrats at each of 20 popular dive sites off Roatán, annually since 1996.
Protocols	
AGGRA Protocol	CEA: sites at Akumal, México surveyed in 1997, 1999. Belize Dept. of Fisheries: protocol trialed at several sites incl. Glovers Reef Hol Chan Marine Reserve: roving diver component only, for conch, lobster, fish Belize Audubon: Lighthouse Reef, 7 sites commenced 1999 HCRF: protocol trialed at Cayos Cochinos RIMS: roving diver only, at four sites off Roatán annually since 1996.
CARICOMP Protocol	UNAM: Puerto Morelos site, Level I, no mangrove site*** UCB: commenced 1995, Calabash Caye, level I, plan Level II commencing 2000 Smithsonian Inst.: Carrie Bow Caye, Hol Chan Marine Reserve: roving diver surveys only CSSMM: Bay Islands, commencing level II, currently have 5 mangrove and 2 seagrass sites
Reef Check Protocol	PROLANSATE & WCS: Surveyed 8 sites off Tela, Honduras, in 1993 and 1997.
Mexican MPA Protocol	UCANP (with Amigos de Sian Ka'an at some sites): Protocol implemented in Sian Ka'an Biosphere Reserve in 1992, extended in 1994-5 to include all Quintana Roo MPAs, at least annually. (Implementation is patchy – 7 years' data in Sian Ka'an, but sites established in 1999 in Cozumel.)
Remote Sensing Methods	
Habitat mapping	Amigos de Sian Ka'an: 1980's base maps for Quintana Roo, from INEGI, updated using LandSat images using ARCINFO GIS, some ground-truthing of shallow marine habitat data. Commencing habitat surveys of Banco Chinchorro now. CZMI: Complete map of Belize coastal ocean on ARCINFO GIS. Using ordinance aerial photos and old LandSat images but no capacity to download or interpret current RS data. Habitat database extensively ground-truthed with some assistance from Coral Caye Conservation, and other NGOs.
Water Quality Methods	
Wet Chemistry	CNA: commenced 1994, monthly monitoring of nitrates, phosphates, BOD and coliforms at 17 sites in Nichupte Lagoon, Cancún. CZMI: commenced 1993, intermittent until 1996, now 50 sites sampled monthly for nitrates, phosphates and chlorophyll. Belize Audubon: Lighthouse Reef, turbidity, temperature, salinity, nitrates, phosphates sediment conc., commenced 1999. CEMA: Shrimp fishery impact study. Nitrates, phosphates, and chlorophyll at 6 sites, 2 near river mouths, Bahia de Manabique, Guatemala. Data not readily available.
Flow Data	CEA: 3.5 yrs data using colorimetry to monitor groundwater flows in aquifers in Akumal region. WRIScS: flow rate in three rivers at Stanns Creek, every 15min, 1998-2000. Belize Dept. of Hydrology: intermittent river gauge data collection.

Other Water Quality	CEA: coliforms and salinity of water in coastal cenotes and lagoons near Akumal. CZMI: since 1996 monthly Hydrolab testing at 50 sites for temperature, salinity, dissolved O2, turbidity, pH. WRIScS: research project monitors turbidity, temperature, conductivity & fine sediment concentration every 15min in three rivers, temperature & conductivity weekly at 40 Belize lagoonal sites, 1998-2000. Sediment traps at three lagoonal sites. CEMA: Shrimp fishery impact study. Standard Hydrolab measurements, plus hydrocarbons, suspended solids, phytoplankton diversity and abundance at 6 sites, 2 near river mouths, in Bahia de Manabique. Data not readily available. RIMS: temperature using HoboTemp dataloggers at 4 site off Roatán.
Meteorological/Oceanographic Influences	
Tide gauges	México Meteorology Department: Belize National Meteorological Service: CPACC project interrupted by Mitch, new instrumentation being installed summer 1999. HCRF: maintains NOAA oceanographic monitoring station at Cayos Cochinos
Current Patterns	TIDE, TNC, U. South Carolina: research project Gulf of Honduras, limited S4 current meter data WRIScS: research project, current velocity (continuous) at three lagoonal Belize sites, 1998-2000.
Fisheries Monitoring	
Catch and Effort Data	All governmental fisheries departments attempt some collection of catch and effort data. Data are incomplete in all cases.
Environmental Impact	CEMA: 5 year study of shrimp industry impact in Bahia de Amatique, Guatemala, including data on stock, catch, and bycatch, 13 sites in bay. Sampling monthly or less frequently. Data not readily available.
Artisanal Fishery	UNEPA, DIGIPESCA & TRIGOH: PRADEPESCA program includes first frame survey of the artisanal fishery in Gulf of Honduras, with numbers of fishermen and types of vessel.
Miscellaneous Methods	
Flagship species	A number of NGOs monitor flagship species in the region although there appears to be no systematic, quantitative collection of data except in specific sites. Marine birds, turtles and manatees are all monitored. NGOs that mentioned these activities to us were Amigos de Sian Ka'an, CEA, Belize Audubon, TIDE, FUNDAECO.
Sociological/Economic	
Registry of tourist enterprises	UCANP: collecting data on nationality, educational level, type of use at Mexican MPA's
Traditional Knowledge	FUNDAECO and PROLANSATE: producing Voice of the Fishermen (TEK for artisanal fishery)
Planned Future Monitoring	
Environmental Monitoring	HCRF: commencing level I CARICOMP at Cayos Cochinos sites
Water Quality Monitoring	TIDE and CZMI will monitor Monkey River impact on water quality in Port Honduras region. CSSMM: will monitor monthly, 8 marine sites at Roatán, plus about 20 assumed terrestrial sources of pollution.
Oceanographic data	INSIVUMEH will shortly install oceanographic monitoring platform for Punta Manabique, Guatemala

3.3.2 Water quality

Despite the widespread expectation that poor water quality is likely to be an important factor in MBRS health, few on-going programs address this issue (Table 3). **The difficulties of monitoring impacts of poor water quality seem unappreciated. Also, there are no attempts to monitor accumulation and possible inputs of persistent organic pollutants that can result from agriculture (pesticides), shipping (hydrocarbons), and municipal effluents (trace metals and organochlorine compounds).**

The largest program in place is the water quality monitoring of Belizean waters by the CZMI. This program analyses a suite of attributes (turbidity, chlorophyll a, dissolved inorganic nutrients, temperature, salinity) using a Hydrolab field multimeter and water samples collected monthly from approximately 50 locations. These locations have been chosen non-randomly to provide representative sites within the waters in the central Belize Barrier Reef lagoon. They are clustered in river mouths and bays as well as on reefs in MPAs. The program commenced in the early 1990s but sampling was erratic until 1996. Sampling has been consistent since then, but the program cannot be expanded without additional equipment and personnel. The goal is to develop a baseline and monitor trends in water quality.

Also in Belize, WRIScS is a research project of Raleigh International and Exeter University UK, designed to assess the effects of three distinct but adjacent watersheds in the Stann Creek District that differ in the extent of agricultural activity. By monitoring flow and sediment transport, and by means of sedimentological "fingerprinting" of samples collected from sediment traps at mid-shelf reefs, WRIScS will assess the effects of land use on sediment transport, and the extent to which transport impinges on mid-shelf reefs. Although a limited-duration research project, WRIScS data are being georeferenced and entered in the CZMI database.

3.3.3 Fishery stocks

Most information on fishery stocks derives from catch statistics, collected to monitor the industry rather than to monitor fish populations. Even when catch statistics are reliably, uniformly, and consistently collected (seldom the case), they document landings, rather than catches at specific locations. As a result, these data cannot be used, except in a very general way, to describe the distribution of fish species in the region. In some cases such as one major Guatemalan study of Gulf of Honduras environmental parameters, the Guatemalan shrimp fishery, and its bycatch, carefully collected fishery data are not available for any purpose because they have not been appropriately shared even within the sponsoring agency.

3.3.4 Oceanography

Meteorological departments in México, Belize, and Guatemala collect very limited data on tidal fluctuations and on currents. As well, the HCRF facility at Cayos Cochinos includes a NOAA oceanographic/meteorological instrumentation package. There is a general lack of suitable instrumentation in the region, and data sets are frequently interrupted by the loss of instruments in storms. These data are not widely perceived as part of environmental monitoring.

3.3.5 Notable gaps and overlaps

Despite dedicated effort by many individuals, current monitoring programs leave many gaps. Water quality is only monitored in Belize, other than for human health concerns, or, on a very local scale by NGOs concerned about water quality at specific sites. Further, as detailed in our recommendations, most of the monitoring of water quality that is being done uses methods that are unlikely to be able to detect changes in quality that will have major effects on reef ecosystems.

Monitoring of reef ecosystems is concerned almost exclusively with species abundances rather than with dynamics and the processes driving these. Except in Belize, monitoring efforts are few and monitoring of reef ecosystems is localized within MPAs, or at sites that are in the process of being declared as MPAs. With the exception of productivity measurements at a few CARICOMP sites, there is no monitoring of mangrove or seagrass ecosystems, despite the recognized value of these systems for fisheries, and for protection from coastal erosion. Instrumentation for monitoring physical conditions (tides, ocean states, weather) is sparsely distributed and frequently not operational. Further, these data do not end up in databases that house other environmental monitoring data. Similarly, most fisheries data are used to monitor the fishery rather than fish stocks, and are not integrated with other environmental monitoring data, even when the same agency is responsible for both.

We did not see any cases of extensive overlap in monitoring effort, except in Roatán where the large, IDB-funded Bay Islands Natural Resources Management Project has generated 54, sometimes duplicative, base-line surveys (none of which appears to exist other than on paper). **More important than overlap was a general lack of integration of effort, both horizontally and vertically, even within countries. Consequently, the collected data from each monitoring site or program were less valuable.**

3.3.6 Existing programs of consistent high quality

The monitoring studies undertaken by the CZMI in Belize appear to come closest to what is needed if these coastal resources are to be adequately managed. Critical points that have made the CZMI program stand out have been:

1) all monitoring data are georeferenced and in a single database,
2) the program has been designed on a regional scale, despite the fact that most component monitoring studies have been local,
3) water quality has been given the priority it deserves, and

4) there has been a clear effort to sustain the program, and to seek more cost-effective methods of monitoring.

The monitoring program developed and implemented by staff of UCANP for MPAs in Quintana Roo, is also of good quality. It is regional in perspective, and has been sustained for several years. It does not include attention to water quality, and currently only includes reef locations under, or in the process of coming under MPA protection.

Other monitoring efforts are usually conscientiously done, but they depend more on the drive of individuals than the commitment of agencies to be sustained, and, as a result, are frequently interrupted or terminated after quite short periods of time. Some are done purely in the context of research projects, with no intention that they become long-term. Nevertheless, these efforts have provided useful data, and the personnel involved have developed skills that will be valuable in the future.

3.3.7 Data management and use

Much of the existing environmental data is not readily accessible. Data resulting from basic research projects are frequently unavailable if they are not published in the primary literature. Data collected in a baseline study or in a monitoring program may be, but are not necessarily, more available. Baseline data will usually be summarized in a report, but the raw data may not be in electronic form, and even if they are, they may not be in a form that makes them readily accessible to others. Monitoring programs frequently start due to the enthusiasm of one or two individuals, and cease when they move to other jobs. In such cases, the data may be filed away and forgotten, even if a subsequent employee continues the monitoring program. Fisheries catch data may be reliably collected over long periods, but also can be relatively inaccessible. The fisheries catch data collected daily for the past seven years by the Inspector de Pesca in Livingston, Guatemala, are recorded on home-made paper forms and sent to UNEPA in Guatemala City where they are used to estimate total monthly catch. The species groupings are crude, there are no effort data, and the catch data are not used in managing the fishery. The data are not on an EIS, nor shared in any systematic way with other agencies or countries.

One of the reasons for the lack of accessible data may be that the governmental agencies in each country responsible for managing environmental data have limited their activities to regions bounded by the coastline. Neither INEGI in México, LIC in Belize, nor IGN in Guatemala maintain any coastal marine data. Monitoring data for coastal marine environments are held instead by smaller agencies that are more closely tied to coastal management. Inevitably, while most current data are in electronic form, they are scattered among the agencies that collected them, maintained with various levels of security and in various not-necessarily-compatible formats. Knowledge about the existence of data is entirely word-of-mouth.

We found properly georeferenced marine data sets to be extremely rare. The GIS database maintained by Amigos de Sian Ka'an, covering the Quintana Roo coastline of México, and the one maintained by CZMI for the waters of Belize are the only significant ones. In both cases, the database is maintained by one individual, with reasonable familiarity with the software (ARCINFO in both instances). Both databases are recognized as valuable datasets for decision support, and are made use of in this way by outside individuals and agencies.

On the other hand, we would exaggerate if we implied that monitoring data are an important component of the information used in environmental management in either country. In fact, the greatest deficiency in current monitoring programs in this region may be that they are not seen as primarily for the purpose of gathering data essential for future management decisions. Instead, they seem to be viewed by many, including some people directly involved in data collection, as primarily a public relations exercise. The existing data are not used to the extent they could be, particularly if the many local data sets were in a common metadatabase and were reanalyzed in the context of questions posed at the scale of the MBRS.

The lack of importance given to monitoring programs by agencies charged with environmental management, is also indicated by the frequency with which programs are suspended due to lack of funding, and the fact that most were funded from external sources rather than line budgets.

Although data are not maintained in the most accessible way, and there is little formal sharing of data, people we spoke to acknowledged the importance of having reliable access to data, and expressed the view that attitudes to sharing of data were generally good. Inter-individual relationships seem more important than formal agreements among agencies in this regard (TRIGOH has an excellent record in data sharing), and it is probably true that governmental departments may find data-sharing more difficult than NGOs. Data-sharing between countries will be more difficult, particularly if the data involve economic information. Fishery landings data are not readily shared, except in special cases where a trusted individual seeks access in order to make a region-wide assessment (J. Gonzalez Cano is currently doing this for the lobster fishery).

3.3.8 Problems for effective monitoring of environmental condition.

Despite the existence of some excellent monitoring programs, implemented by dedicated people, we have serious concerns about current environmental monitoring in this region. The fundamental problems seem to be:

- a failure of most individuals who monitor to think regionally instead of locally, and
- a failure of most agencies and governments that support monitoring programs to value the process, or the product, sufficiently to ensure it is sustained and the data used and disseminated.

While there is recognition by many of the need for a regionally integrated approach, there is not even an effective integration of effort at the national level in any of the four countries. México and Belize are closer to achieving national integration than are Guatemala and Honduras, but still have a great number of gaps. The focus of monitoring is almost entirely on coral reef systems, to the exclusion of seagrass, mangrove, coastal lagoons, mainland watersheds, and other adjacent ecosystems that impinge directly or indirectly on reef condition. Existing monitoring programs are greatly dependent on the continued presence of particular well-qualified individuals, and can fall into disarray with the departure of a single person for further education or new employment. Only in Belize and México are there geo-referenced databases covering a significant portion of the region under that nation's jurisdiction, and in both of these cases, the database can be accessed and modified by only a couple of people with the necessary skills. As a result, these databases are vulnerable, and less accessible than they could be. Environmental information systems do not exist, even at a national scale.

Monitoring programs, and, indeed, the full range of environmental management and conservation activities, are constrained by limited technical capacity, and nearly all are dependent on external, project-based funding. As a result, most monitoring programs are under a perennial risk of interruption or cancellation. While the situation differs among countries, the contribution to this effort by governmental agencies is less than that of the NGOs in all but México. **Strong governmental will to ensure effective, sustained environmental management is seldom evident, notwithstanding the many dedicated government agency personnel charged with environmental management. Governmental will appears to be growing in México, and perhaps elsewhere, but results achieved to date have been strongly dependent on NGO action, and the international financing they have secured.**

This reliance on NGO action, dependent on external, project funding is not a long-term solution for environmental monitoring. Monitoring programs should be permanent and funded from core resources or of shorter term and designed to answer specific management questions. The NGO sector (which has a valuable continuing role in project initiation) is not the best one to sustain permanent monitoring programs. However, the governmental sector, particularly in Honduras and Guatemala, does not have the capacity to take on a substantial environmental monitoring program at this time.

There is evidence of only limited formal international cooperation on marine environmental management, although there are instances of effective, informal links between individuals across borders. Straddling fishery stocks are managed independently, often using different regulations. There are only scant data on physical oceanography of the region, so that the extent to which impacts of pollution or over-fishing cross national borders is not known. The international programs that do exist (CPACC, PREDEPESCA, CARICOMP) are not comprehensive and none span all four countries. There is little evidence in the management programs of any of these countries of an appreciation that effective environmental management in one area may have beneficial effects at distant locations, and no sense that the four countries are working together to manage this biologically rich and economically valuable shared resource.

4 Recommendations

4.1 Available monitoring methodologies

4.1.1 Traditional, usually low-cost methods

These include diver-based procedures for quantifying reef community composition and habitat structure, classical wet-chemistry methods for assessing water quality, and bioindicator techniques for quantifying contaminant loads and other pollution impacts summarized in Table 3.

Several Diver-based procedures are in use in the region. They differ in the degree of training required, the time invested in field and subsequent laboratory analysis, and the precision and reliability of the results. Because of the substantial natural spatial variation in coral cover and community composition, these methods lack power unless well replicated. In most instances where they are being used, the level of replication being applied limits them to detecting changes in the order of 50% of total coral cover. Video recordings of permanent transects offer the most precise data, but at considerable cost in capital equipment, training, and laboratory analysis of tapes. The adequacy and effectiveness of the sampling design, and the method of data analysis are at least as important as the particular field methodology adopted for any monitoring program.

Diver-based methods for sampling fish rather than benthic organisms suffer additionally because the added complexity of the diver's tasks due to the moving targets reduces precision and increases inter-individual variation in effectiveness (Sale 1997). Many monitoring programs have ignored fish completely, and a smaller range of methods is in use in the region for diver census of fish than for assessment of coral cover. These usually use visual belt transects to count numbers of the target species over defined areas of habitat. Such transects are a component of the AGRRA reef assessment technique, in which a defined set of finfish species, selected because they are most likely to show impacts of fishing pressure, are counted and their sizes estimated on a set of 30 x 2m belt transects. Comparable sampling has been used in a small number of instances, usually in conjunction with monitoring of coral community abundance, for particular species of finfish, for conch and for lobster. The transect dimensions, methods of deploying and counting, and target species tend to vary among programs, and we heard of no such program that was extensive, either among sites or over time. The only notable non-transect method for fishery-independent survey of fish is the Bohnsack method (Bohnsack and Bannerot, 1986), in which a diver remains motionless in the center of, and counts all fish within, a 7.5m radius column. Fish ecologists recognize that there are significant difficulties in comparing data obtained using different transecting methods, and the Bohnsack method does appear to target a different suite of species to the various transect procedures.

Table 3: Methods for monitoring coral reef health	
1. Composition, abundance of reef fauna	
a) Transects:	
Line transect, chain transect. Tape or chain placed across substratum.	Segments of line occupied by each sessile benthic taxon, or substratum type, are proxy for % cover. Also yields species richness, species composition of sessile fauna.
Belt transect. Various dimensions, and various methods for defining width.	Direct counts of individuals within transect boundaries provide abundance and density data for fish and benthic organisms. Percent cover of sessile taxa may be estimated, or measured using superimposed line transect.
Manta tow. Diver is towed for set duration along reef face to create equivalent of a large belt transect.	Direct counts of individual organisms or other environmental features provide abundance or density data. Number of taxa counted must be restricted given the speed of travel and the extent of the area covered.
Photo quadrat. Still photography of defined areas of substratum, with camera fixed distance above substratum and facing directly downwards.	Permanent record of areal extent of each sessile organism or type of substratum. Data on percent cover, abundance, species composition extracted using image analysis.
Photo transect. Video photography with the camera facing directly downwards, a set distance above the substratum, while operator swims a measured path.	Permanent record usually analyzed by extracting "single frame" quadrats, and using image analysis as for photo quadrats
Other defined area or quadrat. Commonly used for census of patch reef fauna, using single patch reefs as the defined sample sites.	Sample area, rectangular, circular or other shape, within which total count of organisms yields abundance, density, species composition as for belt transect.
b) Other diver-based survey methods:	
Bohnsack point-census method. Diver stationary within 7.5m radius sample unit.	Diver enumerates all species of fish seen within 7.5m radius (imaginary) cylinder, and records number of each according to set time protocol. Data yield abundance, density, species composition of fish fauna.

REEF Roving diver census. Diver travels variable path searching for all possible species during fixed time.	Diver records all species seen, and estimates abundance on a five-point scale. Data yield species composition, and crude estimate of relative abundance at the site.
c) Diver-based protocols:	
AGRRA (Atlantic and Gulf Rapid Reef Assessment) Protocol. Line transects and belt transects plus roving diver assessments.	Line transects at two fixed depths to select coral colonies. For each colony, species noted, colony diameter measured, percent living, recently dead, and dead estimated. Also percent cover of algae, evidence of fish bite marks noted. Belt transects 2m wide used to count fish of specified taxa, sizes estimated (5cm categories). Roving diver survey used to build species list of fish at site. Benthic data yield information on mortality rate as well abundance of corals, on algal abundance and intensity of grazing pressure. Fish data yield species composition, abundance estimates for designated species, and size estimates as proxy for fishing pressure.
AIMS (Australian Institute of Marine Science) Monitoring Program	Protocol based on manta tows of reef perimeter, five 1m x 50m belt transects on which a set of fish species are censused, and five superimposed video transects for coral cover and substratum type. Protocol pays particular attention to Acanthaster presence and feeding scars seen during manta tow and on belt transects.
Butterflyfish census as bioindicator of reef health. Line transect, and superimposed belt transect.	Quantify percent cover of coral species (line transect) and abundance of butterflyfishes (belt transect). Also record area of fish territories, frequency of feeding and agonistic behavior. The butterflyfishes are argued to be a sensitive indicator of reef health. Not appropriate for use in Caribbean – butterflyfish fauna depauperate.
GCRMN (Global Coral Reef Monitoring Program) Protocol	Protocol based on manta tow (nine or more 2 min snorkeler tows), line transects for coral cover and substratum type (five 20m transects), and belt transects for fish (three 5m x 50m transects).
UCANP Mexican MPA Protocol	Protocol based on 10 permanent chain transects, and associated 2m x 2m permanent quadrats per site, to sample coral cover, coral diseases, other benthic habitat variables, plus conch, lobster and fish in the quadrats. Plan to integrate water quality measures as part of the protocol.

Reef Check Protocol.	Protocol based on four replicate 20m line transects sampled every m for substratum/coral type, superimposed 5m x 20m belt transects for small defined set of fish species, and of invertebrates. Four transects at ~2-6m and four at ~6-12m depth.
2. Productivity and biomass methods.	
a) Chlorophyll spectrophotometry	Spectrophotometric quantification of Chlorophyll a in water samples, as a proxy for phytoplankton abundance, and therefore as a proxy for water column productivity.
b) CARICOMP Protocol. Full protocol includes permanent chain transects at reef sites, random quadrats at seagrass sites and mangrove sites.	Coral reef transects provide percent cover of coral taxa and other substrata. Assessments in seagrass and mangrove habitats include primary production estimates as well as biomass using quadrat sampling.
3. Water quality methods.	
a) Secchi disk, spectrophotometry	Two measures for turbidity, or light transmissivity in water column.
b) Tube sediment traps. Plastic cylinders, 5cm in diameter, 60cm tall, mounted vertically, open at top, and containing formalin solution.	Tubes are deployed at study sites for several days to weeks. Particles and larval organisms settling into them are trapped within and settle to the bottom. Provide data on relative rates of sedimentation (and also of larval supply). Simple sediment analysis can indicate source (terrigenous or carbonate).
c) Wet chemistry methods for broad range of compounds.	Samples are collected in field, kept refrigerated prior to lab analysis. Nitrates and phosphates in particular can be analyzed this way.
d) Hydrolab field multimeter	The Hydrolab measures temperature, salinity, oxygen concentration, pH, other physico-chemical attributes of the water column.
4. Remote sensing methods.	
a) Satellite sensors	**NOAA-AVHRR**: ocean temperature, 1km pixel size; **CZCS** & **SeaWiffs**: ocean color, 1km pixel size; **RadarSat** & **TOPEX-Poseidon**: surface topography, 10-50m pixel size; **LandSat**, **SPOT** & **IRS**: ocean color, 10-50m pixel size.

b) Airborne sensors	**LIDAR**: surface topography, 0.25-25m pixel size and near real time; **Aerofilm** & **MDV**: ocean color, multispectral and 0.25-25m pixel size; **CASI**: ocean color, hyperspectral and 0.25-25m pixel size.
c) Waterborne, single- and multi-beam acoustic imaging systems	**Sidescan sonar** & **RoxAnn**: seabed topography and composition; **OSSIAN**: water column target detection; **ADCP**: hydrodynamics, all at 0.05-2m pixel size and near real time.
5. Biomonitoring methods.	
a) Bioindicators	These are indicator species that are sensitive to environmental conditions, changing abundance in response to pollution or other change. Assess either by quantifying natural abundances or by deploying and subsequently monitoring survivorship. *E. coli* is bioindicator of sewage contamination.
b) Bioaccumulators	These organisms accumulate contaminants or other substances over time. Abundances or rations of compounds in their tissues are proxy for average level of delivery of these compounds to the site. The ^{15}N:^{14}N ratio in coral tissue is signal for coastal organic inputs to reef.
c) Biorecorders	These organisms incorporate compounds in an interpretable chronology. Various elements trapped in the carbonate structure of scleractinian coral skeletons allow very long-term hindcasting of certain aspects of climate and riverine flow.

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The Reef Environment Education Foundation (REEF), a Florida-based volunteer diving organization has implemented a "roving-diver survey" technique that builds a species list for a dive location. REEF has done an impressive job of building the taxonomic skills of its membership, and of transferring data to an accessible format. Teams from REEF have done these surveys at a number of locations through the Caribbean, and the data are accessible via the internet at http://www.reef.org. Their database can be sorted to access records only from their "expert" divers. It includes surveys of a number of sites within the MBRS region, and could be of value for general assessments of biodiversity. It demonstrates the potential for monitoring programs of data collection by committed amateurs. REEF effort is necessarily focused at sites of significant tourism interest. The "roving-diver" method is also a component of the AGRRA technique.

Fishery species are also monitored through fishery catch statistics. Catch statistics are a poor proxy for population density when effort is not accurately measured, the fishery is continually adopting new methods, there is a sizeable unreported fishery, and catch statistics are not linked to specific habitats, and only intermittently collected or analyzed. These conditions apply generally to fisheries in the region. Particularly in the south, fishery catch statistics seriously underestimate the total catch because of poor monitoring of the artisanal fishery, and neglect of by-catch, particularly from the shrimp fishery. In addition, all routine catch statistics are based on landing site rather than source, and, for finfish, are greatly aggregated across species.

While a few direct measurements of physiochemical factors are possible, most of these share the need for on-site collection of water samples, and vary in the nature, complexity, and cost of the subsequent analysis. They include simple and reliable methods such as the use of secchi disk for recording turbidity, or the fluorometric analysis of total chlorophyll (as an index of water column primary production). But many methods are either very sensitive to sample storage procedure and laboratory technique, or measure features which show little variation in reef waters (e.g. PO_4 concentration), or which vary on spatio-temporal scales that are far smaller than those of the sampling regime (e.g. NH_4 concentration). Methods to measure nitrates, other nutrients, or dissolved organics suffer in both these respects, as well as being costly to perform. Compounds carried in the water that are likely to impact growth, reproduction, or survivorship of reef organisms include sediments, nutrients, pesticides, and a broad range of industrial pollutants including metals, PCBs, and hydrocarbons. Whether dissolved or suspended, these materials are usually present in very dilute concentrations by the time the water bearing them reaches a reef. Furthermore, their impact depends upon both flux and concentration, and flux is a function of rate of transport of water over the reef – a process that is non-uniform across sites and through time.

Concentrations close to background levels are difficult to discriminate using routine wet chemistry methods, and concentration data, by themselves are inadequate to measure delivery of compounds to the reef environment. This is particularly the case if monitoring is on a monthly or quarterly schedule that may or may not coincide with major discharges from rivers.

The karst geology characteristic of the Yucatan Peninsula means that non-point-source delivery of terrestrial inputs to coastal waters prevails through a substantial portion of the region. For this reason, it is particularly important that appropriate biomonitoring methods be developed and introduced in order to monitor effects of these non-point source inputs. More detailed studies of the effects on important reef organisms, of specific anthropogenic compounds in realistically low concentrations are needed, and the university sector should be encouraged to undertake these. Empirical studies of groundwater transport, and model development are also needed.

4.1.2 New techniques for monitoring

The methodology of monitoring has advanced rapidly in the past decade, driven by scientific developments and increasing demand from resource managers. New techniques and technologies relevant to the assessment of the MBRS fall into four inter-related categories: sampling design, remote sensing, biomonitoring and modeling. Development and application of these methods has great potential to improve the quantity and quality of data provided for decision support for management. Some are already being implemented (e.g. video transects), and others certainly should be (e.g. nutrient bioaccumulation). All involve a higher level of risk than standard methods because of uncertainties in accuracy and dependability. All involve initial capital costs in training and equipment as well as the continuing commitment required to sustain monitoring. Cost-effectiveness and sustainability are primary factors concerning the applicability and suitability of any new methods in the context of the MBRS project. Capital funds are limited by the project budget, and funds for recurring costs are limited by national budgets. Different countries have different financial and human capacities to implement new techniques. It may be appropriate for those countries with established expertise and pre-existing facilities to develop certain methods (e.g. satellite monitoring of coastal water quality by CINVESTAV in México), which are then extended or shared with others. Some of the methods, while directly relevant and powerful, require capacity and resources that exceed realistic potential of any country in the project (e.g. the use of 3-D hydrodynamic models to monitor effluent and larval dispersion). In these cases it may be appropriate to import technology and expertise for initial model development.

Sampling design: The detection of change in ecological systems is the essence of monitoring. Two major challenges to effective monitoring are up-scaling (extrapolating measurements at small scales and levels of organization to larger scales / higher levels), and statistical power (the probability of detecting a real change or impact). The vast majority of monitoring in marine ecosystems (including coral reefs) to date is locale-specific and has low power. Thus the generality of expensive results is poor, and costly decision errors are common. New approaches to these limitations require increases in the distribution of sampling effort across spatial and temporal scales in order to inform up-scaling, and provision of sufficient replication at scales and levels of organization appropriate to the hypothesis or management option being addressed. A superb recent reference to these techniques is Schmitt & Osenberg (1996). Key tools include:

- nested, multi-scale sampling designs in both space and time that quantify the scale-dependence of monitored variables and avoid spatio-temporal aliasing;

- the use of rapid data acquisition methods and technologies (e.g. manta towing, video transects, remote sensing, data loggers) to increase the number of measurements per unit sampling effort (and thus increase the statistical power of tests); and

- multivariate sampling designs and analysis software that increase the generality and robustness of monitoring results, and establish a benchmark reference condition for reef health.

In order to be able to detect changes in environmental conditions that occur because of pollution or some other stressor, it is necessary to be able to cope with the considerable natural variability that exists across time and space. One useful approach, termed the "reference condition" approach, was developed initially in freshwater systems. It involves the comparison of a site suspected of having deteriorated (the "test" site) with a set of sites characteristic of that habitat. The first step is the selection of a large number of reference sites. The sites are characterized using a broad range of taxonomic, percent cover and other measures, and are then classified by cluster analysis. A variety of geographic and habitat features (depth, exposure) are used in a multiple discriminant (Canonical variates) analysis to create discriminant functions that distinguish the various site groups. The discriminant functions can be used to define the expected characteristics of the test site. Departures from expectation indicate effects of pollution or other stressors. This approach is discussed in Hughes (1995) and Chessman (1999).

Application of these tools and approaches depends on the incorporation of theoretical knowledge in monitoring design at both the managerial and operational levels, and on the availability and informed use of sampling technologies and statistical techniques. These new technologies can be incorporated into regional monitoring in three ways:

- Regionally coordinated education of senior scientists and data managers in sampling theory and statistics,

- Provision and sharing of appropriate new technologies and equipment as required to increase the complementarity of monitoring in the region,

- Regionally coordinated training of field personnel in the use of these technologies.

We recommend a phased approach to implementation, starting with a short training course and regional workshop on sampling design and statistics in the context of designing a regional-scale sampling program for monitoring inter-connections between land and reef, and among reefs.

Remote sensing: Remote sensing of the ambient and excited electromagnetic and acoustic spectra radiated and reflected from the earth's surface is the most relevant technology at the scale of the ecosystems and management challenges of the region. At present it is barely being used (and then in the most rudimentary sense), by any of the agencies involved in monitoring. Marine remote sensing is progressing exponentially on both the technological and theoretical fronts. It encompasses four domains of imagery (Table 4, Section 4.1.1), each with its strengths for application to mapping and interpretation of marine features and processes:

- **Satellite sensors provide data on ocean temperature** (e.g. NOAA-AVHRR) **and color** (e.g. CZCS & SeaWiffs) at 1-10 band spectral resolution, approx. 1km pixel spatial resolution and daily-weekly frequency. They can map meso-to-large scale water masses, major river plumes, suspended sediments, and phytoplankton abundance over $10km^2$ to global areas in depths to 60m. The data can be used to estimate circulation, heat budgets, terrestrial loading and primary production in regional seas.

- **Satellite sensors provide data on surface topography** (e.g. RadarSat, TOPEX-Poseidon) **and ocean color** (e.g. LandSat, SPOT, IRS) at 4-7 band spectral resolution, 10-50m pixel spatial resolution and weekly to monthly frequency. They can map waves, fronts, sea level, river plumes, surface slicks, polluted water masses, suspended sediments, phytoplankton, macroalgae, coral, seagrass and mangrove abundances, coastal and seabed habitats over 1-500 km^2 areas in depths to 30m. The data can be used to estimate sea level change, bathymetry, small-to-large scale circulation, terrestrial loading, environmental impacts, primary production, benthic production, fish production, reef growth and areal change in coastal areas, lagoons and regional seas.

- **Airborne sensors provide data on surface topography** (e.g. LIDAR) **and ocean color** at multispectral (e.g. Aerofilm, MDV) or hyperspectral (CASI) resolution, 0.25-25m pixel spatial resolution and near real time frequency. They can map bathymetry, sea level, local fronts, river plumes, flotsam, surface slicks, polluted water masses, suspended sediments, phytoplankton, macroalgae, coral, seagrass, mangrove, fish and marine mammal abundance, coastal and seabed habitats over 0.01-100km^2 areas in depths to 50m. The data can be used to estimate small-to-meso scale circulation, terrestrial loading, environmental impacts, primary production, benthic production, fish and marine mammal biomass, coral mortality, reef growth and areal change in coastal areas, lagoons, reefs and reef zones.

- **Waterborne, single & multi-beam acoustic imaging** systems provide data on seabed topography and composition (e.g. Side-Scan Sonar, RoxAnn), **water column targets** (e.g. OSSIAN) **and hydrodynamics** (e.g. ADCP) at 0.05-2m spatial resolutions and near real time frequency. They can map 3-D current velocity, bathymetry, sediment characteristics, jetsam, macroalgae, coral, seagrass, fish and marine mammal abundance, coastal and seabed habitats over 0.01-10km^2 areas in depths to 100m. The data can be used to estimate small-to-meso scale circulation, sediment inputs, environmental impacts, invertebrate, fish and marine mammal biomass, reef growth and areal change in seabed habitats.

It may soon be possible to monitor many of the parameters of concern in the region using RS technologies. In many cases, the technologies are still in an experimental stage or are uncalibrated. In others, the costs are simply prohibitive. Green et al (1996) provide an excellent review of most of these in the context of a cost-benefit analysis for coastal zone mapping. The cost of raw data alone ranges from free (e.g. NOAA-AVHRR) to over US$ 5,000 per scene (typically 500 to 3500 km^2 for satellite images). For air and seaborne technologies, the cost per unit area depends on platform costs and economies of scale in area to be covered, but is typically an order of magnitude more costly than satellite imagery. Image processing hardware and software are also expensive (typically US$7-15k per work station). Ground "truthing" (georeferencing, verification and calibration) of marine images is an essential but oft-overlooked component that is also very expensive.

Some RS data and products have already been applied to survey and assessment in the region (e.g. LandSat-TM images used by the CZMI in Belize). Some will continue to be supplied, primarily from external agencies, but it is unlikely that these will support long-term monitoring. The true cost of using RS technologies for monitoring the MBRS must also include the costs of establishing and maintaining the institutional structures and trained professionals required to collect, process and interpret the data.

Judicious selection of new marine RS technologies for monitoring should involve those institutions with RS capacity that already exist in the region (e.g. the various land information agencies, meteorological offices and some military services), as well as the scientists and managers. The focus should first be on affordable satellite imagery covering the entire MBRS and using well-established processing and analysis protocols.

Being listed as a priority location in the NASA LTAP for LandSat-7 data is a major benefit to the region. It should be capitalized upon to establish a baseline water column and seabed habitat map for the region against which future change can be assessed as these subsidized images become available. The new LandSat-7 sensor array, with its added band in the blue end of the spectrum provides the best data yet for the mapping of coastal and marine habitats. A mosaic set of images would provide a superb base layer in a regional GIS. Subsequent overlays generated at annual frequency by regional institutions would provide whole-system monitoring of spatial change in coastal land use, terrestrial inputs, gross geomorphology and water quality that could inform the selection of localized assessments.

At the same time, it would be appropriate for the meteorological offices in each country to develop the capacity to regularly download and interpret NOAA AVHRR data, and also SeaWiffs data, as affordable during high-risk events (e.g. hurricanes, el Nino and red tides).

Cost-effective ground truthing of satellite images should be done according to an agreed protocol on an opportunistic basis using the established network of research stations and other field facilities throughout the MBRS. Finally, detailed surveys of high-value or high-impact areas using high resolution RS technologies (e.g. RoxAnn in WRIScS) should be embedded in the larger scale data set and used to provide another level of calibration.

Virtually all RS products are eminently suitable for the planned data management and environmental information system because they are geo-referenced. A regionally coordinated approach to the acquisition, analysis and sharing of RS data within the MBRS EIS is a priority. A focused workshop could identify priorities and assign responsibilities among participant institutions.

Biomonitoring: The greatest problem in monitoring natural systems (whether emergent rocks or fish stocks) is obtaining an adequate time series of measurements from which to derive statistically defensible conclusions about directions, magnitudes and rates of change. Both the length and the density of the sampling series are relevant. Given the ecological and evolutionary time scales of environmental processes (years to millennia), a decade is about the minimum useful monitoring period. The problem of inadequate sampling duration is acute in the region because there are virtually no established monitoring programs with more than a few years' data (e.g. even commercial fishery landing data rarely meet minimum criteria for use in production models). In contrast, rates of some types of environmental change are fast enough to occur within a modest monitoring program (e.g. a few years), but may still be difficult to detect. The problem here is one of sampling intensity rather than duration. For example, most alterations of water quality are short-lived (hours to days), after which nutrient, pollutant or sediment concentrations return to background levels. Yet it is the cumulative effects of these rare events that drive changes in marine communities.

Sampling programs capable of accurately resolving and integrating such temporal variability must be intense and randomized to avoid aliasing, and hence are expensive. They may be unnecessary for most reef management decisions because all that is required is the net result of the cumulative effects (i.e. the integral). Using biological entities (usually organisms, but also organic and inorganic pools) to integrate measurements and signals over ecologically meaningful time periods (i.e. biomonitoring) can solve both time-scale problems, providing definitive, cost-effective answers to conservation and management questions.

Three types of biomonitors covering progressively longer integration periods have been developed for tropical coastal and coral reef environments (Table 4, Section 4.1.1), and are relevant to the MBRS monitoring initiative:

- **Bioindicators** are the most common form of biomonitoring. Based on the concept of the "indicator species", they are used to infer changes in the microhabitat and local environment that are not obvious from measurements of ambient environmental conditions. Indicator species are usually selected for their sensitivity to small, incremental environmental change that may precede major disruption (e.g. "early warning" or "canary" species that respond to the early stages of eutrophication). The best bioindicator species have a binary response: they are either present or absent (e.g. certain worms, macroalgae and forams) during certain perturbations. Others must be assessed in terms of their relative abundance (e.g. bioeroders, heterotrophic infauna, bacteria). Another approach is to deploy arrays of an organism having well-know ecophysiology (e.g. certain bivalves) and periodically measure mortality (equivalent to a laboratory LD-50 experiment in the field). The application of these approaches to coral reefs is in its infancy, but given their development and acceptance in temperate ecosystems they should have wider use. The main bioindicators for coral reefs are the presence of the bacterium *E. coli* (indicator of human sewage), the abundance of bioeroding organisms (indicator of particulate organic availability), macroalgal abundance (indicator of inorganic nutrient availability) and foram community composition (indicator of nutrient and organic accumulation in sediments).

- **Bioaccumulators** may be the same species as bioindicators, but they are used to estimate loading (i.e. delivery integrated over ecological time periods) of organics, nutrients or pollutants. The integration time period depends on the pool turnover time in the organism (usually a fraction of the life span), and ranges from days to a year. Analysis involves the sampling of organisms (or carbonate skeletons, or sediments) and quantitative laboratory analysis of the chemicals of interest. Some assays are well developed for reef organisms, such as the ^{15}N:^{14}N ratio in coral tissue (proportional to terrestrial organic inputs), N:P ratios in seagrass (proportional to sediment nutrient availability), or heavy metal concentrations in bivalve livers (proportional to pollutant inputs). Others are only now being tested (e.g. macroalgal tissue nutrient concentration as a measure of inorganic nutrient inputs). There is great scope for elaboration and calibration of tropical bioaccumulators as monitoring tools.

- **Biorecorders** incorporate accumulated materials in an interpretable chronology, allowing the reconstruction of paleoenvironments and historical time series of anthropogenic impacts. In the tropics, the skeletons of scleractinian corals are the key to the past, allowing accurate hindcasting of ambient temperature, salinity, riverine inputs and nutrient supply, (and hence the interpretation of paleoclimates, bleaching and ENSO events, and human impacts) well beyond the beginning of the industrial revolution. Fairbanks et al (1997) provide a fine introduction to this exciting area of research.

In many cases the technology of biomonitors is still in the developmental stage (e.g. macrophyte nutrient bioaccumulators), and locale-specific research and calibration is always required. A few techniques (e.g. interpretation of sclerochronological records) are sufficiently established to be applied immediately to the MBRS. (Indeed, some have been already.) As with remote sensing, judicious selection of technology must be informed by assessments of true costs and benefits. Some of these techniques are simple and cheap (e.g. bioerosion indices), and all that is required is to train people in their use and interpretation. Others demand expensive, high technology (e.g. ICP mass spectrometers) and highly specialized theoretical and technical expertise.

The nature of biomonitors demands a research and development approach for the MBRS project. This is best done through universities and other public and private sector institutions with a significant investment in and commitment to research. As a first step within the MBRS project a workshop should be convened to select the biomonitoring avenues with the highest relevance to priority problems and the greatest probability of successful implementation, and then to design a coordinated program of progressive development and field trials.

Modeling: Monitoring describes what has happened, models extend monitoring results to predict what is most likely to happen at some specified time in the future. This is of greatest value to resource managers. Models may be conceptual, analytical or numerical, deterministic or stochastic, linear, non-linear or chaotic. They may be designed for explanation, prediction or control, and may operate in simulation, assimilation or optimization modes. For management purposes, they must provide decision makers with comparative evaluations of management options (i.e. they must function as decision support tools). In complex natural systems such as coral reefs, hybrid models are required. Given the dominance of humans as both causes of perturbation and targets of management action, the melding of socio-economic and biophysical models is the priority.

Two types of hybrid models are judged to be of highest priority for the conservation and management of the MBRS at this time:

- coupled bioparticle - ocean circulation models to predict the connections of water borne materials among terrestrial and reef systems (see Black, 1993 for an example), and

- fuzzy-logic bioeconomic models to predict change of habitat quality in response to interventions (see Ruitenbeek et al, 1999 for an example).

The first set of models would predict the direction and magnitudes of delivery of land-based nutrients, organics and pollutants to reef communities, and the degree of metapopulation interconnection and self-seeding amongst reefs in the MBRS. The results would inform the management of land-based activities, and decisions concerning the siting and size of MPAs. The second set of models would inform choices among various options for the management of anthropogenic impacts and stresses.

While the basic components of such models exist "on the shelf" (e.g. Sheng et al, 1998; Ruitenbeek et al, 1999) their adaptation, verification and calibration to this region must be long-term, large-scale regional initiatives for which the MBRS project provides seed money to attract external support for the most expensive component (i.e. intellectual effort). The activity should begin with a modeling workshop that brings experienced modelers together with regional scientists and managers to set priorities and assign tasks. The other costs of modeling are CPU time (especially for numerical models) and *in situ* verification and calibration. The contributions of the MBRS project and the national partners should cover this in the form of funding and logistic support for field measurements. Again, the results of models should be directly imported to the regional EIS.

4.1.3 Data management and Environmental Information Systems

An EIS can range from storage of paper on shelves with the retrieval services of an expert librarian to a completely electronic database-driven system. We are proposing an evolution towards a modern, database-driven system that will be made widely available to participants in the project.

After monitoring data and information are collected, data management is the next barrier to effective and regional application of the materials. Producing large quantities of excellent data and information is not sufficient for success in a project. The data must be converted to useful information for decision-making in the region on an equitable and fair basis, with efficient and effective methods of storage and dissemination. Efficient and cost-effective data management is a non-trivial process under any circumstances, but it will be a particularly important component of the MBRS project due to the multi-national and bilingual nature of the project.

Data management in its most generic form consists of data collection and amalgamation using format translation algorithms where necessary, data storage and backup, and access for use and dissemination of the stored data. In some systems, appropriate decision support and analysis tools such as models and simulations are also stored and made available to the participants in the process.

Due to the different capabilities and equipment available in the four countries, the temptation will be to establish a central database for the MBRS where all data are stored and made available to the participants. This would, in our experience, be a serious mistake if it led to the establishment of an actual central database in one location. We recommend that the "central" database be a meta-database that contains complete descriptions of the data (technical, procedural, legal, format, ownership and availability information, location of each database, georeferenced location for the data, etc.). In other words, the databases should remain with the originators and their descriptions should be made available to as wide a range of participants as can be reasonably and usefully accommodated. One exception to this would be if some participants (nationally, regionally or locally) agreed to combine their data holdings because of economies of scale and effort. This should be encouraged but not mandated.

It is our experience that when databases are held locally, but shared regionally, there are much greater incentives to maintain, upgrade and use the information. Ownership and credit remain with the originators. Anyone using the data and information can access the local databases through the "central" meta-database to discover, examine and obtain any non-proprietary information. If any proprietary, sensitive information is not available for regional use by others, that information could be listed as meta-data but not made generally available. This is also facilitated by the design proposed here. The design is a distributed database system with a commonly held meta-database. It should be emphasized that the meta-database is a "commonly held property" of the groups and countries in the project. Copies of this meta-database could be held at many locations, but should be managed by a group drawn from the participants so that there is a "master" copy that can then be made into "shadow" copies for electronic distribution to others. This is a common feature of many database technologies likely to be used.

To establish such a system, the following stages in evolution are advisable:

- **Data-sharing Agreements**: A set of meetings of all data "generators" such as representatives of government agencies, NGOs, community groups, associations, etc. to negotiate and establish data sharing agreements between the participating countries and their internal and regional representatives. Representatives of actual and potential data "users" should be present at the meeting(s) to ensure that the data and information are appropriate and are made available in an effective manner for decision support functions. This initial series of meetings is crucial to the eventual success of an EIS and may take significant effort to accomplish.

- **Technology, databases and GIS components.** At similar regional meetings held immediately after the Data-Sharing Agreement process, representatives of the designated information technology groups who will be responsible for the physical and information design aspects of the distributed network of databases should be present to ensure that the facilities and capabilities of their components are addressed. As a component of this distributed database Environmental Information System, the GIS community has a role to play in providing and/or producing regional and local maps for use by the participants. These maps should be in an agreed format, scale, datum and accuracy level. Conversion to other GIS formats is possible and may be required, but a key set of maps should be maintained in this agreed format. These maps should also be part of the distributed database in that they should be available from at least one computer system and their characteristics should be detailed in the meta-database.

- **The Legacy Database.** Collection and aggregation of currently available information of all kinds into a "legacy" database and the addition (if not already present) of meta-data to the datasets. As part of this on-going effort, a bibliographic collection should be established using standard library software. This should be made available to all participants through some sharing arrangement or licensing agreement. As this library grows and matures, the bibliographic materials should come to include all "gray" literature, consultant's reports, other reports, maps, articles, references, book citations, etc. As it is collected, efforts should be made to establish a full citation text database where this is feasible or not prohibited by copyright regulations. Searches on the material should eventually be possible by keyword, title, author, location, georeferenced map location, site description, habitat type, etc. Such compete text search capability and technology is now commonly available in the major databases. This "digital" library will grow and will become a valuable research, decision support, community resource and educational tool.

- **The EIS Management Structure.** As these initial meetings proceed, a defined and representative management group should be established to deal with issues and problems as they arise. It is our experience that a smaller committee is preferable to a larger one; a diverse one is preferable to one based solely on scientists, information technology specialists or decision makers in government; national representation is important; a technical advisory group should be accessible; administrative help is very useful; and participant groups can be effectively represented by individuals if they have sufficient influence on the appointment of their representative.

- **Reporting Process.** It is important that the EIS produce useful results as soon as possible. The "legacy" database of bibliographic and other materials is one way of achieving that goal. Another is to widely disseminate reports of activities and progress towards the EIS. Yet another is for the members of the EIS group to become involved in the various meetings and conferences surrounding the project.

- **Capacity Building.** This should be carried out by request of the participants in the EIS. There are many excellent groups in the countries capable of carrying out many of the described activities and they can specify where help and training is required in the information technology areas. Other areas such as setting up data sharing agreements, beginning the legacy database process, incorporating library software, etc. may require some initial assistance and regional training initiatives.

4.2 Recommendations for monitoring approaches appropriate to the region.

4.2.1 The fundamental problem

The general inadequacy of current environmental management, and more particularly, of monitoring efforts in this region can be attributed fundamentally to a general lack of human capacity – scientific, educational, institutional, managerial and political. As in other regions, capacity-building here has traditionally been provided primarily from the developed world, with funding from international development organizations in the context of short-term contracts. Regrettably, most such efforts have failed to create an increase in local capacity that is sustainable without continued infusion of funding and expertise from outside. Reasons lie in design of specific projects and the underlying frailty of economics and governments.

We believe the MBRS initiative, a regional project involving four countries without a long history of cooperation in environmental management, will be at considerable risk without careful attention to this problem. **There is urgent need for a new paradigm, one of integrated, sustainable, demand-driven capacity development based on community-level participation and greater equity in the North-South partnership. We also believe, there is a good possibility of building such a paradigm into the MBRS project, using development of monitoring and EIS as a central activity in two of four key components.**

These key components are:

1) **To build the capacity to educate and train**, including community education, adult training and formal education, so as to provide sufficient numbers of competent human resources to develop and implement environmental management, and to provide the societal support for sustaining this management,

2) **To build the capacity to measure and understand** coastal marine systems, through monitoring, research, technology development and forecasting, so that reliable data are available, and used for analysis and decision-making, leading to sound decisions,

3) **To build the capacity to legislate, regulate and achieve compliance** through effective governmental, non-governmental and private sector institutions and through effective enforcement and community acceptance,

4) **To build the capacity to provide appropriate, affordable environmental management** through effective, sustained investment and management by public agencies and private sector enterprises.

This easily understood framework is an effective tool for organizing truly integrated plans of action, for building consensus and for improving equity in the assignment of roles, responsibilities and costs among stakeholders. Implementation requires an equally integrated approach in the provision of project-based capacity-building services. To the extent possible, actions we recommend to address environmental monitoring and EIS development are designed to include:

- training, community awareness, advanced education and/or associated institutional capacity development as integral parts of each component
- monitoring activities, applied research to develop better monitoring and data management tools, and associated institutional capacity building, all in the context of building a regional perspective
- development of a regional Environmental Information System, including modeling and expert systems, as a demonstration of its value for assessment, prediction and planning

These address the first two of the four actions. Other portions of the MBRS project must include capacity development for policy and regulatory institutions, and institutional capacity development for public sector and private sector service providers.

4.2.2 Goals for environmental monitoring

Monitoring programs may be effectively permanent components of management, or limited term efforts designed to test hypotheses in an experimental context. In either case, environmental monitoring is a waste of resources if the results are not used. **A well-designed, and sustained monitoring of environmental condition achieves one or all of three separate goals. It provides data with which to judge the effectiveness of management actions, it provides early warning of environmental degradation, and it offers a significant opportunity for effective public education. All three are important in this region.**

A long term monitoring program will provide repeated measures of environmental condition at a number of sites in a region, and may detect degradation before that deterioration becomes obvious. This leads to quicker identification of causes, and more prompt remediation if human impacts are responsible. Therefore, it is theoretically possible and tempting to establish a comprehensive monitoring program throughout the region, recording a broad range of data at frequent intervals. However, such programs become very expensive, and we do not recommend this.

The Australian Institute of Marine Science (AIMS) long-term reef monitoring program samples abundance of Crown-of-Thorns starfish (*Acanthaster*), coral cover, and fish abundances annually on 50 reefs distributed along the 1500km length of the Great Barrier Reef Marine Park, at an annual cost of AU$ 3M. This program is large, but not fully comprehensive (it has not tracked water quality, for example). It is unclear whether this program has monitored the most important features, or at the correct spatial scales. Even for wealthy nations such as Australia, the expense of maintaining such programs is sizable and may be difficult to justify over the long term, especially if environmental quality remains good, or if it deteriorates in ways not detected by the monitoring being done.

In less wealthy countries, financial constraints make it necessary to compromise even further, maintaining an affordable level of overall assessment, while focusing more detailed assessments at times and places where changes in environmental condition are anticipated. These places may be sites subject to effects of planned new or changed human activities, or sites that are expected, due to the nature of their biology or particular geography, to be particularly sensitive to disturbances. Designed this way, the monitoring effort is focused primarily at fulfilling our first goal – decision support. Properly planned monitoring can measure the effect of a management decision, and such evaluation of effect should be a usual and important part of environmental management. It also provides the justification for management actions that may be needed in the political or legal arena.

An environmental monitoring program, can also be a most effective tool for educating about environmental issues. This is particularly the case if its data are analyzed and reported, and if the program engages or directly involves the public. In all four countries, there is a pressing need to enhance the appreciation of the multiple values of the Mesoamerican barrier reef, of its vital linkages to other coastal marine habitats and the terrestrial environment, and of the need to manage its use sustainably if a thriving tourist industry, sustainable fisheries, and growing quality of life are to be maintained. Enhanced public education, including education of governmental officials and the tourist industry as well as the general population must be a vital part of the MBRS project. A participatory monitoring program with results readily available for public view is one possible component of this because publicly accessible, reliable, environmental data have power to persuade and to strengthen political will.

Commensurate with our recommendations on integrated, sustainable capacity building, and with reference to the direct management and public education benefits of well-designed environmental monitoring programs, we now propose the following three objectives to strengthen the environmental monitoring effort in this region. We follow with a set of four regionally coordinated Actions to be implemented as part of the MBRS project.

Objective 1: Build a regional perspective for MBRS management. Coral reef ecosystems are intrinsically ecologically open, with substantial exchanges of nutrients, pollutants, and reproductive products among reefs and between reefs and other systems, including the coastal watersheds. Because of this, effective environmental management requires a regional perspective, unconstrained by MPA borders, or national boundaries. Individuals and agencies, even if responsible for particular, perhaps quite local, monitoring programs, should view their data as part of a whole. They should anticipate that decision support, even within the local area that is their primary concern, will require use of monitoring data from the wider region. To build this regional perspective requires 1) a significant reorientation of those engaged in monitoring, 2) a new appreciation of the benefits of cooperation and data sharing, and 3) installation of data processing and management structures and protocols that foster a regional viewpoint.

Objective 2: Build a management framework based on ecosystem function. Local patches of coral reef habitat are connected to other reef patches and neighboring ecosystems, including adjacent watersheds and the open sea, by the movement of individual organisms, nutrients, and pollutants. Complex patterns of passive transport by currents, directed swimming by organisms, and the complex geographic relationships among neighboring habitat patches together ensure that these interconnections will be complex. They will establish a set of source and sink locations for recruitment of organisms, and a set of higher and lower risk locations for impacts of pollution, storms, and other disturbances. Effective management of coral reef ecosystems, as well as requiring a regional perspective, requires recognition that nearby patches may differ substantially in their ability to export reproductive products or to receive recruits from other patches, and may also differ substantially in their risk of impact from pollution or other disturbances. Management will be more effective if it makes use of these differences in dynamics and risk among different local examples of the reef ecosystem.

Objective 3: Build national capacity to manage sustainably. Throughout the region there is a serious lack of human, financial, and institutional capacity for environmental management. There is a need for the development, introduction and refinement of monitoring techniques that directly and explicitly support adaptive management that will be cost effective, and appropriate to the culture and ecology of the region. Achieving this will require capital equipment, and non-project-tied operating funds, so that monitoring programs can be sustained by permanent institutions with management responsibility. There is also a pressing need for more and technically better trained staff, in order to do the required monitoring. Finally, there is a need for introduction and refinement of monitoring techniques that will be cost-effective, appropriate to the capacity available, and tuned to the specific ecology of the region. It is appropriate that some of these needs be achieved by a redirection of existing governmental resources, in the process demonstrating national commitment to sustainable management and use of their marine resources. However, training and capital equipment, and the research for development and refinement of monitoring methods are appropriately part of this project.

4.2.3 A monitoring program and EIS for the MBRS.

The following four Actions will achieve the three Objectives we have set out: to build a regional perspective for MBRS management, to build a management framework based on ecosystem processes, and to build national capacity for marine resource management. **These Actions include training, advanced education, and public education where appropriate to the context; specific monitoring activities, and research to develop more effective monitoring procedures; and the building of a regional EIS with important decision support and public education roles. These Actions are also designed to lever sustained commitment and financial support for environmental monitoring from the governments of the four countries. Implementation will require substantial capacity enhancement, and capacity building is an integral part of each Action. In these ways, they conform to the paradigm for effective capacity-building programs that we have articulated in Sections 4.2.1 and 4.2.2.**

These Actions will encourage a regional perspective, and regional collaboration among managers in the four countries, while preserving national autonomy and freedom to manage for nationally perceived objectives. They offer a combination of support for existing, quality, local programs, for existing participation in Caribbean-basin and other regional programs, and for new regional initiatives. We think it vital that current involvement in CPACC, CARICOMP, CFRAMP, MBC, and PROARCA/Costas programs, as well as possible future participation in GOOS, LOICZ, WOCE, and ICRI-GCRMN or other global or regional projects must be encouraged.

In order to ensure the most effective use of funds, it will be wise to disburse them for specific, defined projects, and on defined schedules that depend on achieving specific performance milestones. Several of our recommendations assume that regional and national advisory committees will make these funding decisions as the program unfolds. Our recommendations also assume that components of the program will be executed by a variety of governmental and non-governmental groups. Indeed, particularly in Guatemala and Honduras there is currently substantially more capacity within the NGO sector than exists in the relevant government agencies. While this may change, it will be most effective to strongly support the NGO sector, given the overall lack of highly qualified personnel in the region.

4.2.3.1 Action 1

Action 1: Implement a distributed, web-based Environmental Information System available to all participants, to include basic environmental data for all reefs and adjacent waters in the region, data on watershed outflows, and all available local and regional monitoring data, including data that form part of broader-scale programs such as CARICOMP and CPACC.

Maximizing access to environmental data from throughout the region is core to building a more regional perspective. A regional EIS is the mechanism for data management and decision support. However, this EIS will also play a significant role in public education about the reefs and adjacent waters of this region.

This EIS is to be a major product of the MBRS project, but must be viewed as an organic, growing entity. It should be implemented early, but will grow in complexity and value as new data become accessible to it. It will be two-tiered, with an upper level designed principally as a public education component, and a deeper level designed for decision-support for managers. It will be bilingual throughout, and designed using the latest display technology. This EIS must not be a centralized database supported by a cumbersome bureaucracy that makes it difficult to access data. Instead data will be maintained within the government department, NGO, or other agency that has generated them, but each such agency will be a node within the EIS. There will be at least one node in each country, and a regional office that will maintain a central metadata catalog, with links to all nodes. This office will be small (perhaps 3 people). Because of anticipated complexities in building regionally complimentary fisheries management, fishery catch statistics and other data used for fishery stock assessment and management decisions need not be included in the EIS initially, although they should become included subsequently.

Important features of this EIS are:

- Ownership of all data stays with originators
- Geo-referenced metadata catalog is maintained at small regional office (metadata are data describing the data – where, when collected, by what methods, in what format, held where, how accessed)
- Access rules and data sharing agreements will be established by participants, but direct links from the metadata catalog to node servers are possible and preferred
- Each country will identify at least one node agency, but all agencies wishing to participate may apply to become nodes, and have access to information or data through the network as agreed
- Regional office will also hold legacy and synoptic data that might otherwise be unavailable (e.g., historical environmental data and remotely sensed data not claimed as the "property" of any agency)
- Training workshops in database management, GIS, analysis of remotely-sensed marine data, and data evaluation will be an integral part of EIS implementation, as will technical support and some equipment
- While most of the EIS will be accessible only through node agencies, an upper layer will be available to the public via the Internet, will provide information, and some interactivity, concerning the reefs and adjacent marine environments in this region, and will be linked to a broad range of other relevant sites. This facility should become part of a school-based educational program in coral reef conservation.

There are six components required to implement this Action. These include the several steps in EIS development outlined in Section 4.1.3, plus steps to develop physical systems and data, and additional components of capacity building:

1) **Building management structure.** It is vital that data access rules and procedures, and preferred data formats be developed by the participants rather than imposed by others. It will be desirable that policies and procedures be developed that are a) likely to work, and b) likely to facilitate linking to data from outside the EIS. A consultant experienced in the development of distributed systems, and knowledgeable regarding the problems that can arise in data sharing will be necessary to facilitate this process.

2) **Building infrastructure.** Establishment of the EIS will require additional computer and communication equipment in most participant node agencies. The provision of equipment and training will be conditional on a commitment by each node agency to participate fully in the EIS over the long term by providing staff resources to maintain data and links to the EIS, and by making data available through the EIS according to agreed procedures.

3) **Building technical capacity for GIS and database management.** Although INEGI in México, and to a lesser degree, LIC in Belize have significant capabilities in database management, neither agency has expertise in interpretation of remotely sensed marine data, and their databases exclude all subtidal regions. The geo-referenced coastal marine databases maintained by Amigos de Sian Ka'an in México,

and by the Belize Coastal Zone Management Institute are the only substantial ones for the region. Neither of these agencies has adequate technical capacity (one individual in each with necessary GIS skills). A coordinated training program will be implemented as part of the initial planning stage for the EIS, to ensure that the regional office and each node agency have GIS and database management expertise.

4) **Building technical capacity for sampling program design and data analysis.** While there is a small cadre of trained people able to implement the various monitoring methods in use, there is a lack of technical expertise in the design of monitoring programs, and in data analysis. A coordinated program of training workshops and secondments will be implemented to build node agency skills a) in the design of monitoring programs that will be adequate for decision support, b) in the interpretation of remotely sensed data, and c) in the statistical analysis of monitoring data. We recommend implementation of the "reference condition" approach to evaluation of data (see Section 4.1.2) as a particularly powerful tool for evaluating environmental condition, when data available are of different type, unbalanced, strongly non-normal, inadequately replicated, or in other ways violate the assumptions of BACI or other parametric analyses. It will be vital that the participant agencies identify the aspects of program design and data analysis most needed to be taught, and have a role in the development of this training program.

5) **Building regional data.** At minimum, geo-referenced maps, and first-cut distributions of major watersheds, coastal water masses, and broad habitat types in shallow waters should be available from the regional EIS. Much of these data will have to be generated because, with the notable exception of Belize, monitoring efforts have largely focused on specific local sites (usually MPAs). Node agencies appropriate to generate these baseline data will be identified by the EIS partners, and will be funded to acquire and interpret remotely sensed data, and to make these data available as part of their contribution to the EIS.

6) **Building effective interfaces.** The effectiveness of the EIS will be compromised if it is not designed in ways that will facilitate transfer of data among its databases and other databases in the region. Seamless communication with databases maintained by INEGI, LIC, and IGN, and by regional or global entities such as CPACC, GOOS and WOCE are all desirable. Facilitated by an informed consultant, decisions on, and implementation of appropriate interfaces must be achieved by mutual agreement among participants.

Implementation of the various components of this Action must be integrated effectively into a substantial capacity-building effort. We recommend that this Action be implemented under the guidance of a consultant, skilled and experienced in the design and implementation of distributed EIS, knowledgeable regarding special requirements of coastal marine data, sensitive to the need for client-driven decision-making, particularly on sensitive issues such as data-sharing protocols, and well-equipped to provide advanced training in database management, program design, and data analysis appropriate to environmental management. We also recommend that the Belize CZMI be invited to house the regional office and assume a leadership role in the EIS.

All governmental agencies, NGOs, and academic units engaged in environmental monitoring should be encouraged to become participants in the EIS. However, it is vital that each agency commits to be a long-term participant in order that a sustainable EIS will be built. For this reason, it may be appropriate for each National Committee (N-STAC) to formally approve applications to join. **Each government must commit to sustained support of the EIS, and to sustained provision of staff time in government agency nodes to maintain data and EIS links. NGOs and academic units wishing to be nodes must also commit to sustained provision of staff time to maintain data and links. All node agencies should also budget for replacement/upgrading of computer equipment that provides their link to the EIS. A long-term commitment to data sharing under agreed rules is also expected of all nodes.** In return for these commitments, MBRS Project funds will provide training, and initial capital equipment as well as funds for specific products, such as baseline, remotely-sensed environmental data, conversion of legacy data to electronically accessible formats, and development of the upper-layer, publicly accessible EIS.

4.2.3.2 Action 2

Action 2: Implement an interdisciplinary regional project (ECONAR) for collection of synoptic data on physical oceanography and ecological connections among reefs, and between reefs and adjacent ecosystems, including coastal watersheds. Identify locations that are biodiversity hot-spots, sources or sinks for recruitment of corals, fish, or other important community components, or sites at special risk for pollution due to onshore activities.

The MBRS is comprised of numerous local reefal structures scattered in a surrounding sea, and embedded in a mosaic of interlinked ecosystems. There are important linkages between reefs, other marine environments, and coastal watersheds, all mediated, partially or entirely, by water flow. Despite the importance of water currents in transporting nutrients, pollutants, and reproductive products across ecosystem and national boundaries, and throughout the region, there is a grave lack of information on these. Nor is there much attention to the potentially complex patterns of reproduction, larval dispersal, and recruitment of corals, fish, and other important reef components. These dispersal and recruitment patterns depend on the complex interaction of water flow and larval behavior. **Characterization and modeling of these features will provide important data to the EIS for future use in management decisions, including decisions on the siting of coastal development and future MPAs. Modern hydrographic, ecological, genetic, analytical and modeling techniques assure that the scientific goals can be attained. Active involvement by scientists and managers in a five-year program to obtain this information will build a regional perspective based on ecosystem function and dynamics, and a tradition of collaborative research and monitoring among the participants from the region. This tradition will be of long-term benefit for the conservation and sustainable use of the reefs and other ecosystems of the region.**

While existing MPAs have been established for a variety of reasons, and by a variety of means, and have been sited without any particular reference to one another, they do constitute a distributed set of locations, most with some degree of management. As such, they are well suited to become the sites for a regional scale experimental study of ocean currents, pollutant transport, and recruitment dynamics. By using them as the sites, the results obtained will be directly relevant to their future management. The experimental monitoring necessary to do the study will enhance presence of management agency staff, and help convey the idea that these are managed places.

ECONAR (Ecological CONnections Among Reefs) will be a sharply focused set of experiments, not a general collection of baseline data. It will include building of a regional-scale numerical model of shallow (upper 50m) flows, empirical testing of that model in two or three critical locations, exploration of delivery dynamics for pollutants from specified coastal sources, monitoring of fish and coral recruitment at a set of comparable locations across the region, and application of genetic, chemical, and other techniques to collected recruits of selected species in order to establish sources of the recruitment to specific sites. Ancillary studies to characterize the local communities, and to explore possibilities for enhancing fish recruitment (as a fisheries management or mariculture method) may be included, but are not central.

ECONAR will be structured as a multidisciplinary, multi-organizational, and international program that will bring scientists and managers of the region together in a truly regional 5-year research effort. ECONAR will make use of many of the actively managed reef locations in the region, and must directly involve the managers. Interested members of the university sector in the region will also be involved. While it might be efficient to structure ECONAR as four national components, or to focus effort in locations where transboundary effects occur, it is essential that the work is contemporaneous, that the methods adopted are compatible, that mechanisms are put in place to ensure continuing communication among groups, and that adequate effort is made to ensure a truly regional approach in all phases. The advantages of a regional approach include the greater statistical power of a larger scale study as well as the long-term benefits of the international collaboration this will force. Worldwide, this study will be the first attempt to monitor coral reef dynamics on a truly regional scale. That it will be an international effort will enhance its stature as an example of science for management. The results will provide guidance for future management decisions locally, nationally and regionally.

Important features of ECONAR:

- As well as delineating patterns of water flow and pathways of larval transport, ECONAR will identify several features of management importance:
  - ✓ biodiversity hot spots
  - ✓ sources and sinks for recruitment
  - ✓ sites at special risk for pollution
- This international, interdisciplinary project will involve managers and scientists from the four countries, and some from other countries, working collaboratively for shared goals

- ECONAR will use a set of reef locations with existing management or research infrastructure, and vessel(s), in an integrated, contemporaneous, regionally-focused study
- It provides opportunities to build collaboration across sectors/levels, and among countries
- Participation will be by an open, but competitive process, and may require provision of matching funds by wealthier institutions/countries. Participants must agree to make data accessible through the EIS.
- ECONAR has implicit capacity building potential because the university sector will participate and a number of graduate students will complete advanced degrees working on aspects of an interdisciplinary, international project. Management personnel also will benefit from direct participation in a regional-scale, interdisciplinary research program.

This Action will be implemented in the following components:

1) **A planning workshop** will be convened, including managers and scientists with appropriate skills and interests from throughout the region, as well as others from other countries but with past experience in the region, to develop a detailed proposal for a major, regional study of surface current patterns and reef community dynamics, and to identify likely participants. **The workshop will select a Scientific Steering Committee charged with coordinating and implementing ECONAR.**

2) **Academic scientists interested in participating will be encouraged to secure matching research funds.** The extent of match will be graduated from highest for scientists from developed countries, to very low for scientists based at Universities in Belize, Guatemala or Honduras. This process will help select participants on the basis of research excellence, and will ensure that some component of each country's research support is directed towards coastal marine systems. There are significant opportunities to leverage funds from national and international sources to help fund ECONAR.

3) **Managers of MPAs, research stations, and other facilities located with easy access to coral reef environments will be invited to participate.** They will be expected to provide logistic support to the field operations, and will be encouraged to also provide field personnel to support the project. Added costs of these forms of support will be covered from MBRS project funds. Manager participants will be encouraged to take an active role as co-investigators in the research project.

4) **The research done will fall into 7 categories:** hydrodynamic modeling, field testing of physical models, monitoring of fish recruitment, monitoring of coral recruitment, ancillary field studies to characterize the biotic communities, monitoring of physical and biological features at each field site, laboratory studies directed at identifying sources of recruited larval fish. The Scientific Steering Committee will manage the project budget, and partition it among components and field locations. Major outputs are summarized below.

5) **Coordination of ECONAR** will require, at minimum, annual workshops that bring participants together to discuss and refine their work. Reports on the project will appear in technical journals and at major international conferences. The Scientific Steering Committee will protect the multidisciplinary and regional nature of the project by encouraging use of the name ECONAR to define the project in all publications and presentations, and by promoting coordinated publishing of results. All data generated will be available on the regional EIS, as will a publicly available description of the project and summaries of results.

Primary scientific outputs of ECONAR are: 1) a functional, customized, 3-D, fully non-linear hydrodynamic model of the MBRS with approximately 3km grid size, and the capacity for Lagrangian transforms; 2) data to document pathways for pollutants arriving at reef locations from specified coastal sources; 3) an extensive database over four years detailing spatio-temporal patterns in recruitment of juvenile fishes, corals and certain other reef organisms at a number of locations throughout the regions; and 4) data obtained using ecological, genetic and micro-chemical approaches that will identify the source areas for fish recruiting to different locations.

These primary outputs will be integrated to produce a clear understanding of the linkages within the region, the important mechanisms governing exchange of nutrients, pollutants and organisms, and the dynamics that drive the system. The data obtained will provide valuable layers for the EIS, and will guide siting of new MPAs and other management decisions. The data, and hydrodynamic model will also be critical in informing the study of water quality issues being undertaken in Action 3.

The Scientific Steering Committee to be formed to manage ECONAR has major responsibility for all phases of implementation, and will report regularly to the Project Coordination Unit from which it will receive MBRS Project funds. Fully successful implementation requires 1) the generation and entry into the regional EIS of new physical and biological data that together discriminate among study sites in terms of surface flows, biodiversity, and recruitment sources and sinks, 2) the production of high profile technical articles and conference presentations reporting these results to the world scientific and management community, 3) the promotion of the project as a well-integrated, multidisciplinary and international research project to further sustainable marine environmental management**. The three most important products of ECONAR will be the new data, the successful completion, by academic scientists and environmental managers in the region, of a regional-scale, multidisciplinary research project of management relevance, and the production of a number of M.Sc. and Ph.D. students from the region who received their training in the context of this project.**

4.2.3.3 Action 3

Action 3: Develop and employ time-integrated measures of temporally variable impacts to augment existing water quality monitoring by measuring fluxes of groundwater and major rivers to the MBRS, and by using biomonitoring to evaluate effects of nutrients and contaminants in reef communities.

Water quality impacts are widely perceived as important influences on reef health in the MBRS region, yet few programs to monitor these are in place. In the southern portion of the region, freshwater inputs are principally from rivers, many supporting substantial agricultural development and population centers. To the north of Belize City, non-point source inputs become progressively more important. The monitoring of non-point source inputs is less straightforward, but adequate monitoring of water quality is technically difficult in either case. Measurement of nutrient and contaminant loading requires knowledge of flux as well as concentration. Concentrations of most nutrients or contaminants are so dilute by the time water arrives at reef environments that direct assay of water samples is too imprecise to discriminate impacts from background levels. For this reason, **routine monitoring of water samples from sites within the region should be limited to total chlorophyll, temperature, salinity, and transparency/turbidity. We recommend the use of bioindicator techniques that integrate the effects of chemicals over ecological periods (hours to years) to assess impacts of poor quality water on coral reef health, and direct flow rate and chemical analysis of water at sources, such as river mouths or sewer outfalls, to ascertain the quantities of potential pollutants being delivered to the system.** Direct chemical analyses will also be appropriate in an experimental context, and studies to determine the effects of compounds likely to occur in the region are clearly needed. These effects on reef health may be severe – causing a rapid overgrowth of corals by algae, or the quick death of organisms exposed to a compound. However, they may be as subtle as inhibition of reproduction in otherwise healthy corals, or inhibition of settlement in mature coral larvae (Richmond et al. 1999). It will be necessary to develop biomonitors appropriate to the local region.

The experience of managers in Australia and the Florida Keys may be particularly helpful in identifying the chemicals to monitor, and the best techniques to use. An attempt should be made to characterize flood conditions in major rivers, mapping plumes to establish locations most at risk of impact, and sampling at the river mouth through a flood cycle to see variation in the chemical composition of the water.

There are three components to this Action. First is an effort to gauge and assay water chemistry in all significant rivers in the south, and to establish "zones of impact" on reef environments. Second is to explore techniques for assessing pattern and extent of non-point source influx of groundwater in the north. Finally, a program will be undertaken to develop and implement appropriate biomonitoring for nutrient and contaminant impacts on reef ecosystems.

River outfalls: Implementation of the first component will be straightforward. In Belize, the Departments of Environment and/or Hydrology should implement gauging and monthly water quality monitoring at mouths of rivers, as outlined in NARMAP, the environmental water quality monitoring program developed for the Belize government in 1995. In Guatemala and Honduras, comparable programs should be developed by the appropriate agencies (CONAMA and SERNA) for each major river entering the region. The MBRS Project will provide needed equipment contingent on the government departments providing sustained staff support to do the monitoring.

Using satellite imagery of river flood plumes, and/or analysis of off-shore sediments for terrigenous materials, a risk analysis will identify those reef communities that are most at risk from pollutants that may be input via rivers. A consultant with the necessary technical skills should be recruited to do this study, in close cooperation with the hydrodynamic modelers working on ECONAR. Attention should be paid to those compounds, such as pesticides, that are likely to be a product of agriculture, and that are not routinely monitored in water quality studies. The task should be to identify those bioactive compounds that are present in the water exiting each major river, and that find their way to the reefs. Given that flood plumes are unlikely to respect national boundaries, it will be useful to implement these studies using a multi-national team approach. The Tri-national Council of NGOs in Belize, Guatemala and Honduras (TRIGOH) may be an appropriate organization to coordinate this work.

Groundwater flows: Groundwater outflows to the marine environment will need monitoring to assess the water quality and quantity entering the marine environment. This should be integrated with oceanographic work (in ECONAR) to establish or confirm the currents that will affect the fate of such groundwater inflows. From the field-testing, models should be produced to predict the likely impact on the reef of these diffuse groundwater inflows. Evaluation of groundwater flux is not as straightforward as surface water flux, since the former cannot be directly measured. Consequently, a baseline characterization is first required to better define the properties of the regional groundwater flow system, followed by interpretive computer modeling to refine the understanding of spatial and temporal variations in groundwater and pollutant fluxes to the MBSR. Modeling results should be used to refine a monitoring program to assess the regional geology, regional hydrogeology, and pollutant sources and migration pathways. The computer modeling and field monitoring should permit a risk analysis, to identify those reef communities that are most at risk from pollutants that may be input via groundwater. Some information for the northern Yucatan may be available from CNA. Because development of a fully operational model for groundwater outflows in the Yucatan is a major undertaking, we recommend a modest initial investment in projects focused on monitoring flows in proximity to coastal locations likely to be impacted by pollution due to residential development or industry.

Biomonitoring techniques: The third component, and the one with potential for significant breakthroughs, is a research project to identify and develop one or more simple, inexpensive biomonitors for water quality that could be applied routinely in coral reef habitat throughout the region. A number of simple biomonitors have been tried in coral reef systems, but none has yet gained widespread acceptance and use. Water quality issues are likely to be monitored more effectively, particularly in the northern portion of the region, if a simple but reliable set of biomonitors can be adopted. Growth rate of selected organisms, including growth rate of organisms that colonize clean surfaces, is likely to prove the simplest proxy of overall water quality. Concentration of humics or ^{15}N ratios in corals clearly documents riverine influence and sewage input respectively. It should be possible to use known variation in water quality at selected sites in the region in an experiment designed to evaluate the precision and reliability of different biomonitor techniques.

Since the need for biomonitoring is greater in México than further south, because of the largely non-point source delivery of water, it may be appropriate to base this study in that country. Several universities in the Yucatan Peninsula have expertise needed in such a project, however it will be advantageous to ensure the participation of representatives from Belize, Guatemala and Honduras as well. To implement this component, we recommend that:

- A regional planning workshop will be convened, including environmental managers, water quality experts, and interested members of the academic community. The workshop will consider alternatives, encourage collaboration, and extend a call for research proposals.

- The PCU, with appropriate expert advice will award research grants to the two to four most promising proposals for up to three years funding.

- Field trials included in research projects may benefit by being integrated into the field component of ECONAR.

- Investigators funded to develop biomonitors should meet annually, perhaps in conjunction with the annual meetings scheduled for ECONAR.

- A final workshop convened by the PCU and including funded investigators, environmental managers, and regional and international water quality and biomonitoring experts will report research findings, and recommend adoption of the most effective biomonitoring techniques developed.

The primary goal of this component is to develop one or more simple, reliable biomonitoring assays for nutrification. A secondary goal will be to develop biomonitoring assays for other prevalent kinds of contaminants.

The three components of this Action can proceed independently, and should be managed by the PCU. Funding to government departments for the gauging and monitoring of rivers should be limited to provision of equipment and training. The river plume studies, the groundwater tracer and modeling study, and the development of biomonitors should be managed as research projects with funding scheduled according to agreed deliverables. The expectation is that biomonitoring methods will be developed that will be easily incorporated into on-going monitoring programs through the region, and at minimal additional cost. All funding should be conditional on data being available on the regional EIS. The groundwater modeling and biomonitoring components both include significant capacity building. Both involve the application of expertise to develop new knowledge and new techniques. They will involve the academic community, and graduate students are expected to be a part of the effort. However, consultants with expertise in groundwater modeling, as well as groundwater training, and in biomonitoring techniques would facilitate these components.

4.2.3.4 Action 4

Action 4: Foster co-operation among Departments of Fisheries, the fishing industry, and with appropriate NGOs on collection of fishery data; to strengthen the ability to make ecosystem-based estimates of total fishing mortality.

The most important fishery product in the region is spiny lobster, followed by shrimp, conch and finfish. As well as a commercial fleet, there exists an artisanal fishery of variable importance, but of greater importance in the southern portion of the region. The fishery stocks straddle national borders, and there is some, sometimes legal, cross-border fishing. Internationally, Marine Stewardship Councils are implementing the certification of fishery product derived from sustainably managed fisheries using environmentally sound methods. Uncertified production will command lower prices, so it is within the interest of the commercial fleets to improve management. While each government maintains a Department of Fisheries with management responsibilities, the reality is that management, in most cases, consists of approximately documenting the annual catch. Fisheries managers expressed concern to us about over-fishing and the need to reduce effort. The MBRS project will have failed if it does not ensure modest improvements in this situation.

Current assessments of fishery catch are incomplete, inaccurate, and aggregated (especially for the artisanal fisheries that dominate landings from reefs). Further, the data come chiefly from sampled landings, and do not identify the geographic source of the catch. To properly assess the impact of fishing activity within the region, there is a need for region-wide, georeferenced, habitat-based data on total catch.

Such data, with estimates of ecologically sustainable yield, could permit a more effective management of these multi-species fisheries. Because other active programs are working to improve the management of trans-boundary fishery stocks, and because a separate consultant is reporting on trans-boundary issues for the MBRS project, our recommendation is for provision of limited additional funds to facilitate coordination among agencies, and introduction of habitat-based assessments of total fishing mortality for comparison with fishery-independent estimates of potential yield. Data obtained would be accessible through the EIS.

Since the shift from landings-based to habitat-based assessment requires a substantial reorientation within Fisheries Departments, we recommend that this Action should only be funded in conjunction with a set of compatible activities all seeking to move fisheries management in a similar direction. Such activities fall outside our purview, although habitat-based assessment is clearly one category of environmental monitoring.

5 Capacity building for regional environmental management

5.1 Existing institutional, technical and human capacity.

Throughout the region, but particularly in the south, there is a pervasive shortage of needed skills and equipment. There are scarcely any people trained adequately in physical oceanography, in management of GIS data, or in assessment of water quality, and the situation is not much better in fisheries assessment or ecological assessment. No agency seems adequately funded for the responsibilities it should be fulfilling, and the result is that the few skilled staff are underpaid, and poorly equipped. Turnover of staff is rapid, and we heard of many instances of staff being recruited, trained, and lost shortly after to higher paying jobs in the private sector, or to opportunities outside the region. **In this project, it will be essential to maximize the use of existing talent and facilities, while building capacity to do more. In our view, capacity building must be intimately linked to other project activities.**

5.1.1 México

México is in the best position, yet it is handicapped by its overly centralized administrative tradition that fails to deliver resources to field offices where they are needed. Despite the large size of SEMARNAP, and the importance attached by the present government to improved environmental management, the staff available, and the budgets provided to each MPA are limited. While PROFEPA enforces park regulations, the number of staff available within UCANP for all other aspects of park management is very small. Consequently, the extent of current environmental monitoring has been limited. UCANP relies on Amigos de Sian Ka'an for provision/management of geo-referenced data, and Amigos has just one technician with modest GIS capability.

The Mexican higher education sector is large, but also poorly set up for advanced training and research relevant to marine environmental management along the coast of Quintana Roo. It is strongly centralized in México City, and most of the regional campuses concentrate on undergraduate teaching to the detriment of research activity by their faculty. Exceptions in the Yucatan are CINVESTAV, ECOSUR, and the Puerto Morelos campus of UNAM. Even in institutions that offer advanced degrees, only a minority of faculty have been interested in research of direct relevance to the needs of environmental managers. The result is that the few advanced students are often not well equipped for positions in environmental management when they complete their studies.

Despite these negative aspects, it is encouraging that México's MPAs have Directors and management staffs, have stable (if small) budgets, and have management plans now available at the INE web site. The MPA Directors in Quintana Roo have pioneered the development of a uniform, Mexican, reef monitoring protocol that is being applied in the MPAs. Some University faculty are well aware of the need to share more fully in the effort to enhance México's marine environmental management, and COCCYTAC, the Mexican N-STAC, includes a preponderance of university faculty.

5.1.2 Belize

Belize is far smaller, and poorer than México, and its considerable achievements to date in marine environmental management are a testament to the dedication of a small cadre of personnel. The very impressive achievements of the Coastal Zone Management Institute have depended almost entirely on external (chiefly UNEP-GEF) funds. CZMI currently has one skilled water quality chemist, and one GIS technician. The only other GIS capability appears to be at the Land Information Centre (Department of Environment) in Belmopan (total staff of 5 people). The Fisheries Department has few staff with limited training, in poor buildings and with very limited facilities. The Manager of Bacalar Chico Marine Reserve described eloquently his use of volunteers from the UK to provide an educational component at the interpretive center, his inability to continue the monitoring he had commenced because of a lack of staff (1.5 staff, plus Manager), and a boat with an unreliable motor. When we met (April, 1999) his reserve had been without a budget since December 31. Apparently, it is the government (and Fisheries Department) view that marine reserves will be fully self-supporting based on fees paid by visitors, yet even the Hol Chan reserve, with a sizeable visitor base, raises only half its funding this way. The University College of Belize offering a 2-year undergraduate program, is the only tertiary institution in the country. A Peace Corps Volunteer from the U.S., now entering the second of his two-year placement, manages its Marine Center, including a field facility on Calabash Caye. This (capable) individual sits on the Belize Barrier Reef Committee (the Belize N-STAC), on behalf of UCB. NGOs based in Belize are typically small, and with few technically skilled people. International agencies like WWF and TNC have contributed by working closely in support of the activities of internal NGOs.

5.1.3 Guatemala and Honduras

The already grim situation in Guatemala has been worsened by the impact of Hurricane Mitch on that country's economy. The Ministerio de Agricultura, Ganadería y Alimentación (MAGA) has jurisdiction over fisheries, and all other exploited or unexploited marine resources. Within MAGA, Unidad Ejecución Pesquera y Acuicola (UNEPA) has an Atlantic Section including just two professional and one technical staff in Guatemala City, and two field staff (in Puerto Barrios and Livingston). No marine environmental monitoring is being done, and fisheries data provide catch estimates, but not effort, and only on the commercial catch. The NGO community plays an important role in Guatemalan environmental conservation, and comprises a number of small, locally focused NGOs, and a few sizeable institutions that play an important facilitating and coordinating role. FUNDAECO is the largest of these with ca 250 staff nation-wide including 10-20 professionals. Its Puerto Barrios office, which manages several local protected areas, has about 150 staff, but only 4 with university degrees including one biologist. (Four of the 150 have marine responsibilities.) The emphasis among NGOs has been on terrestrial environments, or on charismatic species such as turtles and manatee. No coral reef monitoring is being done, and little attention is paid to problems of coastal pollution from rivers. Guatemalan NGOs lack technically skilled personnel, work mainly in public education and on sociological issues, and tend to have a local focus. TRIGOH, the Tri-national Alliance for the Gulf of Honduras, is doing an effective job of strengthening the NGO sector in this region. With the exception of CEMA (Centro de Estudios del Mar y Acuicultura, of the Universidad de San Carlos (USAC), which shows some promise although it offers only an undergraduate program, the university sector is not engaged in research that would contribute directly to the needs for coastal marine environmental management.

The situation in Honduras is comparable to that in Guatemala. SERNA, the Environment Ministry, is strongly oriented to terrestrial questions, and DIGEPESCA conducts limited estimation of the commercial catch. While the NGO community is strong in Honduras, it lacks technically trained people and has few with a marine orientation. BICA is an exception, with a focus on management of coastal marine sites. Universidad Nacional de Honduras includes one or two faculty with marine research interests, but their opportunities are limited by lack of research funding. The HCRF facility at Cayos Cochinos is a superior field research facility, but is currently under-used.

5.1.4 Intra-regional Capacity Sharing

Capacity sharing within the region is limited. Cultural differences and different governmental structures add to a tendency to work independently that is strongly encouraged by the lack of resources to do more. We were told repeatedly that there are instances of good person-to-person collaboration, but that institutional links were absent. This was true even within countries. Many individuals seemed unaware of parallel efforts across national borders, but expressed willingness to explore cooperative ventures. An AGRRA training workshop we visited in Akumal included participants from all parts of the region, as well as from further afield.

It may be more difficult to improve regional cooperation in fisheries management. There is evident distrust among these countries regarding fishery management and cross-border poaching is claimed to be common. Fishery management is also more exclusively an activity of government departments, and involves substantial foreign revenue.

5.2 Steps to build capacity

Each of the four Actions we have proposed includes important capacity building elements. Provision of computing and other infrastructure is a component of three Actions, and all four include training, advanced education, and/or public education as central components.

The building of a regional EIS, based on monitoring data collected throughout the region both requires, and will facilitate a progressive improvement in capacity. Establishment of the infrastructure to support the EIS will require new computing equipment, better Internet access, and a greater number of individuals skilled in handling GIS data. These will be provided under Action 1 in return for commitments by node agencies to provide personnel and operational costs to sustain a functioning EIS beyond the term of the MBRS project. The training workshops on monitoring program design and analysis planned as part of Action 1 will build the skills of people currently employed in environmental management, and should be made open to academic and other interested people as well. **The inclusion of a publicly accessible upper tier to the EIS will facilitate dissemination of information about the reefs and other marine environments of the region. A schools curriculum on sustainable marine environmental management should be developed to use this resource in effective community education.**

ECONAR, the region-wide research project on ecological connectedness and community dynamics (Action 2) will require, and will provide resources to obtain increased capability to deploy workers in the field, and to access remotely sensed data. Its multidisciplinary, collaborative nature ensures significant augmentation of the skills and knowledge of the individuals involved. In addition, a number of graduate students will be supported to receive education through participation in this project. The experience of participating in a large-scale multi-investigator project will also change perceptions of how to do important marine science, and will strengthen the relationships between academic and management personnel both within and among these countries.

Action 3 similarly includes two components with significant research elements that provide educational opportunities for students. The other component, on improved monitoring of river outflows includes provision of some equipment. Action 4 is intended to bring about changes in methods and perspectives in the fishery management community.

We believe it imperative that educational capacity building be integrated into activities seen as directly relevant to management, as we have recommended. We believe sufficient opportunities for overseas advanced education already exist. What is needed (and built into the Actions we propose) is project-based training of technical personnel and university students who will have a high likelihood of continuing to work in environmental management in the region.

5.3 Budget needs

The following budget assumes that GEF funds will be used to leverage significant funding from three other sources: governmental core funding to agencies with responsibility for environmental management, national research agency funds to support research projects of academic and other scientific personnel, international agency funds to support research and development projects in coastal marine resource management. Action 2 (ECONAR) in particular will require substantial leveraged additional funding. The budget also assumes that an experienced consultant will manage Action 1, that the Scientific Steering Committee formed for Action 2 will provide its financial management, reporting to the PCU, and that the components of Actions 3 and 4 will be managed directly from the PCU.

Action 1 includes significant workshop and training costs, and substantial computing equipment costs. Actions 2 and 3 have modest or no explicit training costs, but have significant travel and research implementation costs. For Action 3, these are mostly included in the grants program funds.

Categories	Year 1	Year 2	Year 3	Year 4	Year 5
Training					
Action 1 (EIS)	**150000**	**200000**	**175000**	**100000**	**50000**
Action 3 (Water quality)	**80000**				
Action 4 (Fisheries data)	**50000**				
Grants (Action 3)		**250000**	**250000**	**250000**	**175000**
EIS policy development	**50000**				
Equipment & Implementation					
Action 1	**283000**	**148000**	**108000**	**68000**	**68000**
Action 2	**255000**	**335000**	**340000**	**275000**	**210000**
Action 3	**75000**	**75000**			
Direct meeting costs					
Action 1	**100000**	**90000**	**90000**	**85000**	**85000**
Action 2	**50000**	**50000**	**50000**	**50000**	**50000**
Action 3	**50000**				
Action 4	**40000**	**40000**	**40000**		
Travel					
Action 1	**100000**	**100000**	**80000**	**80000**	**80000**
Action 2	**145000**	**145000**	**160000**	**160000**	**155000**
Action 3	**50000**				
Action 4	**40000**	**40000**	**40000**		
Project Management	**170000**	**168000**	**168000**	**155000**	**145000**
Total budget by year	**1688000**	**1656000**	**1501000**	**1223000**	**1018000**
Total, EIS & monitoring					**7086000**

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7 Appendices

7.1 Terms and Definitions

ADCP:	Acoustic Doppler Current Profiler: remote sensing instrument
Aerofilm:	Kodak's industry standard film for aerial photography
AFE:	Administración Forestal del Estado: Honduras
AGRRA:	Atlantic and Gulf Rapid Reef Assessment: monitoring protocol
AIMS:	Australian Institute of Marine Science
ALIDES:	Alianza Centroamericana Para el Desarrollo Sostenible: part of CCAD
ARCINFO:	Major GIS computer program
ASOREMA:	Alliance of NGOs responsible for managing protected areas in Guatemala
BICA:	Bay Islands Conservation Association: Honduran NGO
BAS:	Belize Audubon Society: manages several National Parks
CARICOMP:	Caribbean Coastal Marine Productivity Program: monitoring protocol
CASI:	Compact Airborne Spectrographic Imager: remote sensing instrument
CCAD:	Comisión Centroamericana de Ambiente y Desarrollo: Guatemala
CCC:	Coral Caye Conservation: United Kingdom NGO
CEA:	Centro Ecológico de Akumal: Mexican NGO
CECON:	Centro de Estudios Conservacióniosta de la Universidad de San Carlos: Guatemala
CEDS:	Conservation and Environmental Data System: Belize Ministry of Natural Resources and Environment, LIC
CEMA:	Centro de Estudios del Mar y Acuicultura Conservacióniosta de la Universidad de San Carlos: Guatemala
CFRAMP:	CARICOM Fisheries Resourse Assessment and Management Program: Belize
CHAMP:	Coral Health and Monitoring Program: NOAA
CICIMAR:	El Centro Interdisciplinario de Ciencias Marinas: México
CINESTAV:	Centro de Investigación y de Estudios Avanzados: México
COCCYTAC:	Comite Consultor Científico y Tecnico de los Arrecifes Coralinos de México
COHDEFOR:	Comisión Hondureña de Desarrollo Forestal: sub-unit of SERNA, Honduras
CONAB:	Comisión Nacional de la Biodiversidad: Guatemala
CONADES:	Consejo Nacional de Desarrollo Sostenible: Honduras
CONAMA:	Comisión Nacional del Medio Ambiente: Guatemala
CONAP:	Consejo Nacional de Areas Protegidas: Guatemala
CONCYT:	Consejo Nacional de Ciencia y Tecnología: Guatemalan research funding agency
CNA:	Comisión Nacional del Agua: México
CPACC:	Caribbean: Planning for Adaptation to Climate Change: support organization funded by GEF/World Bank and executed by OAS
CRIP:	Centro Regional de Investigación Pesquera: INP, México
CSSMM:	Consorcio Safege-Sogreah-Moncada y Moncada: Consortium of two large Honduran NGOs funded by the IDB
CZCS:	Coastal Zone Color Scanner: remote sensing instrument
CZMA:	Coastal Zone Management Authority: Belize
CZMI:	Coastal Zone Management Institute: Belize
CZMU:	Coastal Zone Management Unit: Belize
DAPVS:	Deparmento de Areas Protegidas y Vide Silvestre: Honduras
DiBio:	Dirección de Biodiversidad: SERNA, Honduras
DIGEPESCA:	Dirección General de Pesca y Acuicultura: Honduras

DOF:	Department of Fisheries
EIS:	Environmental Information System
ECONAR:	Ecological Connections Among Reefs: proposed component of MBRS project
ECOSUR:	El Colegio de la Frontera Sur: México
FAO:	Fisheries & Agriculture Organization: United Nations
FUNDAECO:	Fundación para el Ecodesarrollo y la Conservación: Guatemalan NGO
FUNDARY:	Fundación para la Conservación del Medio Ambiente y los Recursos Naturales, Mario Dary Rivera: Guatemalan NGO
GEF:	Global Environment Facility: United Nations funding program, UNDP
GIS:	Geographical Information System
GCRMN:	Global Coral Reef Monitoring Network
GOOS:	Global Ocean Observing System: global system for observations, modeling and analysis of marine and ocean variables coordinated by IOC, WMO, UNEP, and ICSU.
HCRF:	Honduran Coral Reef Foundation: Honduran NGO
ICLARM:	International Center for Living Aquatic Resources Management: international NGO based in the Philippines
ICRI:	International Coral Reef Initiative
ICSU:	International Council for Science
IDB:	Inter-American Development Bank
IGN:	Instituto Geográphico Nacional: Guatemala
INE:	Instituto Nacional de Ecología: SEMARNAP, México
INEGI:	Instituto Nacional de Estadística, Geografia y Infomática: México
INGAUT:	Instituto Guatemalteco de Turismo: Guatemala
INSIVUMEH:	Instituto Nacional de Sismología Vulcanología Meteorología e Hidrología: Guatemala
INP:	Instituto Nacional de Pesca: SEMARNAP, México
IOC:	Intergovernmental Oceanographic Commission
IRS-RESURS:	Indian Remote Sensing satellites
ISRS:	International Society for Reef Studies
IUCN:	International Union for the Conservation of Nature: The World Conservation Union of governments, government agencies, and NGO's from 138 countries, based in Switzerland
LIC:	Land Information Centre: Belize Ministry of Natural Resources and Environment
LiDAR:	Light Detection And Ranging bathymeter
LOICZ:	Land-Ocean Interactions in the Coastal Zone: part of the International Geosphere-Biosphere Programme (IGBP), a study of Global Change of the International Council of Scientific Unions (ICSU).
LTAP:	Long Term data Acquisition Program: NASA
MAGA:	Ministerio de Agricultura, Ganadería y Alimentación: Guatemala
MBC:	Mesoamerican Biological Corridor: World Bank-GEF project
MBRS:	Mesoamerican Barrier Reef System: World Bank-GEF project
MDV:	Multiple camera Digital Video: remote sensing instrument
MPA:	Marine Protected Area
NARMAP:	Natural Resource Management and Protection Project: USAID, Belize
NASA:	National Aeronautics and Space Administration: U.S.
NCRI:	National Coral Reef Institute: Nova Southeastern Univ. Fort Lauderdale, FL.
NGO:	Non Governmental Organization
NOAA-AVHRR:	National Oceanic and Atmospheric Administration- Advanced Very-High Resolution Radiometer: U.S. remote sensing satellite
NMS:	National Meteorological Service, Ministry of Energy, Science, Technology & Transportation: Belize
N-STAC:	National Science and Technology Advisory Committee
OAS:	Organization of American States
OCRET:	Oficino de Reservas Territoriales: Guatemala
OSSIAN:	French multichannel acoustic fish survey sonar
PCRF:	Planetary Coral Reef Research: project launched through Scripps Institution of Oceanography, NASA/AMES, and Boston University, to establish a means to study coral reefs, using, satellite imagery.

PCU: Project Coordination Unit
PRADEPESCA: Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano: European Union funded regional fisheries programme.
PROARCA/Costas: Programa Ambiental Regional para Centroamerica Componente de Manejo de la Zona Costera: consortium of TNC, WWF, Univ. Of Rhode Island, and local NGOs, supported by USAID-G/CAP
PROFEPA: Procuraduría Federal de Protección al Ambiente: SEMARNAP, México
PROLANSATE: Fundación para la Protección de Lancetilla, Punta Sal, y Texigaut: Honduran NGO
RARE: RARE Center for Tropical Conservation: U.S. NGO
RECOSMO: Region de Conservación y Desarrollo Sostenible Sarstun-Motagua: an official government agency of CONAP, governed by a board of four members (UNDP, CONAP, CONAMA, MAGA), and managed by the UNDP
REEF: Reef Environment Education Foundation: based in Miami Florida, U.S.
REHDES: Red Ecológista Hondureña Para el Desarrollo Sostenible: Honduran NGO
RIMS: Roatán Institute for Marine Science
RoxAnn: Marine Microsystem's multibeam acoustic seabed classification system
SEMARNAP: Secretaría de Medio Ambiente, Recursos Naturales y Pesca: México
SERNA: Secretaría de Estado en el Despacho de Recursos Naturales y Ambiente: Honduras
SeaWiFS: Sea-viewing Wide Field-of-view Sensor: remote sensing instrument…provides CZCS data
SPOT: Satellite Pour l'Observation de la Terre: French remote sensing satellites
TEK: Traditional Ecological Knowledge
TIDE: Toledo Institute for Development and Environment: Belize NGO
TNC: The Nature Conservancy: international environmental conservation agency based in U.S.
TOPEX-Poseidon: The Ocean Topography Experiment-Poseidon: remote sensing protocol
TRIGOH: Tri-national Alliance for the Gulf of Honduras: international consortium of NGOs, Belize, Guatemala and Honduras
UCANP: Unidad Coordinadora de Areas Naturales Protegidas: INE, México
UCB: University College of Belize
UNAM: Universidad Nacional Autónoma de México
UNDP: United Nations Development Programme
UNEP: United Nations Environment Programme
UNEPA: Unidad de Ejecución Pesquera y Acuicola: Fisheries Division of MAGA, Guatemala
USAC: Universidad de San Carlos de Guatemala
USAID: United States Agency for International Development
WCS: Wildlife Conservation Society: international wildlife conservation society based in New York, U.S.
WOCE: World Ocean Circulation Experiment: international project studying ocean circulation
WMO: World Meteorological Organization: United Nations agency
WRIScS: Watershed-Reef Interconnectivity Scientific Study: conducted by Raleigh International, Ambios Environmental Consultants, and University of Exiter
WWF: World Wildlife Fund: International wildlife conservation organization

7.2 List of Persons Contacted

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7.3 Record of interviews

Belize: April 18 - 22, 1999. Drs. Sale, Chavez, Hatcher, Mayfield		
19 April		
1.	Caribbean Fisheries Resource Assessment & Management Program Offices	Mr. Hugh Saul, CFRAMP Project Manager, Dr. Milton Haughton, Director
2.	CFRAMP Offices	Dr. Milton Haughton, Director, Mr. Noel Jacobs, Aquaculture, Mr. Dwight Neal, Fisheries & Biodiversity Management
3.	Coastal Zone Management Institute	Dr. Vincent Gillett, Executive Director, Dr. Janet Gibson, National Project Advisor, Mr. Eugene Ariola, Water quality technician.
4.	Coastal Zone Management Institute (Hatcher only)	Mr. Barry Dawson, GIS technician.
5.	Radisson Fort George Hotel	Mr. Noel Jacobs, MBRS Project Coordinator
20 April		
6.	Fisheries Department Offices	Mr. George Myvette, Director, Mr. James Azueta, Mr. Jose Perez
7.	University College of Belize (Mayfield only)	Mr. Jonathan Kelsey, Marine Research Center, staff of Information Technology Dept.
8.	National Meteorological Service Offices (Hatcher only)	Mr. Carlos Fuller, Director, Mr. Francisco J. Salazar
9.	Raleigh International Offices (Hatcher only)	Ms. Delia Tillet, Deputy Project Manager, WRIScS
21 April		
10.	Radisson Fort George	Mr. Jonathan Kelsey, UCB, Dr. Tom Bright, Director, Glovers Reef Research Station, Mr. Dylan Gomez, Manager, Bacalar Chico Marine Reserve, Mr. Miguel Alamilla, Hol Chan Marine Reserve
11.	Ministry of Natural Resources, Belmopan (Sale and Mayfield)	Mr. Oswaldo Sabido, Chief Forestry Officer
12.	Ministry of Natural Resources (Sale and Mayfield)	Mr. Ishmail Fabro, Director, Dept. of Environment
13.	CARICOM Offices (Hatcher only)	Dr. David Brown, Sociologist, CFRAMP
14.	Radisson Fort George	Dr. Peter J. Mumby, University of Newcastle, UK
22 April		
15.	Radisson Fort George (Sale, Hatcher and Mayfield)	Mr. Wil Maheia, Director, TIDE
México: May 16 - 20, 1999, Drs. Sale, Chavez, Ciborowski and Hatcher		
16 May		
1.	Holiday Inn Hotel, Cancún	Mr. Ricardo Munoz, CINVESTAV
17 May		
2.	Holiday Inn Hotel, Cancún	Mr. Manuel Puerto, Director, Mr. Francisco Aguilar, CRIP, Puerto Morelos, INP
3.	CNA Office, Cancún	Ing. Fro Javier Vargas, Manager, Northern Coordination Zone, Quintana Roo
4.	Amigos de Sian Ka'an Offices	Ms. Carelia Rodriguez, Mr. Angel Loreto

18 May		
5.	INP CRIP facility, Puerto Morelos	All scientific staff away at meeting, brief tour of facility
6.	CEA Offices, Akumal	Mr. Michael Mulgrew, Director, CEA, Dr. Charles Shaw, Ms. Kate Robinhawk, Ms. Shauna Slingsby, and Ms. Patricia Beddows, student, McMaster University (Canada).
7.	Akumal Club Caribe Hotel	Dr. Carlos Garcia, Director, Honduras Coral Reef Foundation, Cayos Cochinos, and Mr. Adonis Cubas, Assistant Director.
19 May		
8.	Akumal Club Caribe Hotel (Drs. Hatcher and Ciborowski)	Dr. Tomas Camarena, Director, Banco Chinchorro Biosphere Reserve, Ing. Francisco Ursua, Director, Parque Nacional Costa Occidental de Islas Mujeres, Punta Cancún y Punta Nizuc, Dr. Mario Lara, Director, Parque Nacional Isla Contoy, Sna. Elvira Carvajal, Directora, Parque Nacional Arrecifes de Cozumel, M.C. Alfredo Arellano, Director, Sian Ka'an Biosphere Reserve, M.C. Barbara Reveles, Amigos de Sian Ka'an, Dr. Ernesto Arias, CINVESTAV, Merida, Dr. Carlos Garcia, Director, HCRF, Cayos Cochinos.
9.	Akumal Club Caribe Hotel (Drs. Sale and Chavez)	Ing. Gerardo Garcia, Director Parque Nacional Punta Cancún y Punta Nizuc, Juan Carlos Huitran, Sub-director, Parque Nacional Punta Cancún y Punta Nizuc, Dr. Eloy Sosa, ECOSUR, Chetumal, M.C. Roberto Ibarra, ECOSUR, Chetumal.
10.	Akumal Club Caribe Hotel	Dr. Ernesto Arias, CINVESTAV, Merida, Dr. Eloy Sosa, ECOSUR, Chetumal, M.C. Juan Manuel Vargas, Universite de Veracruz, M.C. Patricia Arceo, Progreso CRIP, INP (all members of COCCYTAC), and M.C. Juan Carlos Huitran, Parque Nacional Punta Cancún y Punta Nizuc, M.C. Aurora Beltran, Amigos de Sian Ka'an, Oscar Beltran Amigos de Sian Ka'an, M.C. Barbara Reveles, Amigos de Sian Ka'an
Guatemala & Honduras: 31May – 10 June 1999, Drs. Hatcher, Chavez & Mayfield.		
1 June		
1.	CEMA, Universidad de San Carlos de Guatemala	M.C. Luis Francisco Franco, Director, CEMA, Sr. Sergio Guzman, Sra. Sonia Vetor
2.	MAGA Offices, Guatemala City	Sr. Luis Alberto Castaneda, Vice-Minister MAGA, Sr. Antonia Rodas, CODEFOR
3.	Canadian Embassy, Guatemala City	Mr. Wayne Mackenzie, Commercial Consul
4.	Hotel Santa Clara, Guatemala City	Sr. Luis Sandoval, Sub-Director, Atlantic Fisheries, UNEPA
5.	Hotel Santa Clara, Guatemala City	Ms. Megan Hill, Regional Coordinator, National Fish and Wildlife Foundation, Washington, DC USA
2 June		
6.	CONAMA Offices, Guatemala City	Dr. Juan de Dias, Sub-Coordinador, CONAMA
7.	PROARCA/Costas Offices, Guatemala City	Mr. Nestor Windevoxhel, Project Director
8.	FUNDAECO Offices, Guatemala City	Sras. Martha Ayala, Gabriel Valle, Amilia Baechli, FUNDAECO
9.	INSIVUMEH Offices, Guatemala City	Dr. Eddie Sanchez, Director General, INSIVUMEH

3 June		
10.	Canadian Consular Offices, Tegucigalpa, Honduras	Mr. Neil Mussell, Consul General
11.	Private home near University of Honduras	Lic. Carla Suarez, Wildlife Conservation Society, project manager.
12.	CONADES Offices, Tegucigalpa	Dr. Mario Rietti, Executive Secretary, CONADES
13.	Instituto Hondureno de Turismo Offices, Tegucigalpa	Ing. Norman Garcia, Minister, Secretario de Estado en el Despacho de Turismo, Lc. Erasmus Sosa, Gerente de Ecoturismo, Sra. Jackeline Fogila, Sub-Secretaría de Estado, Sr. Jose G. Flores, Executive Director, Bay Islands Natural Resources Management Project, Lc. Enoc Burgos, Coordinator, Natural Resources, Bay Islands Natural Resources Management Project.
14.	By telephone at hotel (Hatcher only)	Mr. Don Hawkins, Consultant, World Bank Sustainable Coastal Tourism Project.
4 June		
15.	At hotel, Tegucigalpa	Sr. Martin Ochoa, Environmental Specialist, World Bank, Mr. Steven Maber, Regional Representative, World Bank.
16.	DiBio Offices, Tegucigalpa	Sr. Jose Antonia Fuentes, Director, DiBio, and others.
17.	Secretaría de Estado en el Despacho de Agricultura y Ganadería Offices, Tegucigalpa	Ing. Guillermo Alverado, Minister, Dr. Marco Polo Sub-Secretario de Ganadería, Ing. Pedro Sevilla, Secretario
18.	DIGEPESCA Offices, La Ceiba	Sra. Mida Mehea, Regional Fisheries Officer
5 June and 6 June		
19.	Honduras Coral Reef Foundation facilities, Cayos Cochinos	Dr. Carlos Garcia, Director, Lc. Adoni Cubas, Sub-Director HCRF
7 June		
20.	Roatán Institute of Marine Science, Roatán	Sr. Julio Galindo, Sra. Samir Galindo, owner/managers, Anthony's Key Resort, Sr. Eldon Bolten, Director, RIMS, Ms. Jennifer Keck, Education Officer, RIMS.
21.	Consorcio Safege-Sogreah-Moncada y Moncada, Roatán	Ing. Claude Buffet, Project Director, Bay Islands Natural Resources Management Project, Sr. Mario Villeda, Co-team Leader, M. Vincent Salbert, Oceanographer.
22.	Bay Islands Natural Resources Management Project Offices, Roatán	Lic. Enoch Burgos, Natural Resources Coordinator, Lc. Ana Maria Obando, Admin. & Finance Coordinator.
23.	Bay Islands Conservation Association Offices, Roatán	Ms. Irma Brady, Executive Director, BICA
24.	At Hotel, Roatán	Ms. Jennifer Keck, Education Director, RIMS
25.	CRIPCA Offices, Roatán	Ing. Cesar Salinas, Fisheries Officer
8 June		
26.	HCRF Offices, La Ceiba	Mr. Jerry Haylock, Immediate Past Director, REHDES
27.	HCRF Offices, La Ceiba	Dr. Rafael Sambula, PROLANSATE
9 June		
28.	FUNDAECO Offices, Puerto Barrios	Sr. Giovanni Zamorra, FUNDAECO
29.	UNEPA Field Office, Livingston, Guatemala	Sr. James Hernandez, Fisheries Officer
30.	UNDP Offices, Puerto Barrios	Sr. Francisco Olivet, Director Nacional, RECOSMO