CARIBBEAN MARINE RESOURCES

Opportunities for Economic Development and Management

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Washington, D.C.

United States Agency for International Development

United States Department of Commerce
National Oceanic and Atmospheric Administration

PREFACE

The *Caribbean Marine Resources: Opportunities for Economic Development and Management* project is sponsored by the United States Agency for International Development (AID) and produced by the National Oceanic and Atmospheric Administration (NOAA). The report is designed to provide a review of the current status and projection of the potential of marine resource development in the Caribbean region. It is intended primarily to assist AID planners and Mission Directors with their decisions to support marine resource initiatives in the Caribbean Basin. The report also provides background information useful to other groups or individuals interested in the Caribbean marine environment.

The concept and scope of work for the project was originated by Anthony Rock of NOAA's Oceanic and Atmospheric Research (OAR) International Activities Staff in cooperation with the AID Bureau for Latin America and Caribbean, Office of Development Resources. The Office of International Fisheries of NOAA's National Marine Fisheries Service provided technical support and contractual assistance for the project.

Beginning in February 1985, Jill Zucker of the OAR International Activities Staff conducted a literature review and distributed questionnaires to U.S. and foreign experts. The questionnaire, produced both in English and Spanish, was designed to supplement the information obtained from existing literature, with the most current available data from experts of Caribbean marine issues.

A meeting of Washington-based government agencies with interests in the Caribbean was held in December 1985, to discuss issues of the region and to identify authors of background papers for the report. In April 1986 Dr. R. Lawrence Swanson, Chief of the OAR International Activities Staff, replaced Anthony Rock as project director. James Buizer, Director of Latin American and Caribbean Programs for the OAR International Activities Staff coordinated an international workshop which included authors of the background papers and invited experts from the region. The workshop was held at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML), Miami, Florida, September 2-5, 1986. The objective of the workshop was to produce a draft of the final report by synthesizing the background papers with direct input from selected regional experts.

Dr. Melvin Goodwin of the South Carolina Sea Grant Consortium facilitated the synthesis of information at the workshop and was responsible for editing the workshop materials. Meriwether Wilson of the OAR International Activities Staff was responsible for the production of the document, including revisions, layout, design, printing and publication.

Appreciation and gratitude is extended to the many individuals and institutions who supported all phases of the project including contributions of literature, responses to questionnaires, reviewing of background papers, provision of office support and typing. Special appreciation is extended to NOAA's Pacific Marine Environmental Laboratory in Seattle, Washington, NOAA's Ocean Assessment Division in Rockville, Maryland, and Nick Kastelan of OAR in Rockville, for computer support. Completion of the project would not have been possible without such generous contributions of time, information and materials of all those involved.

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CONTENTS

EXECUTIVE SUMMARY

Opportunities for improved economic development and management of Caribbean marine resources are reviewed. Separate chapters are devoted to nearshore marine habitats, fisheries and mariculture, and geological and non-living marine resources. Because any sustained improvement depends upon indigenous human and institutional resources, these are considered in a fourth chapter. Each chapter provides background on the resources, discusses constraints and caveats to development, identifies opportunities for development, defines requirements to realize these opportunities, and offers recommendations to development assistance agencies. Coastal erosion and lack of adequate planning for resource management and economic development are problems affecting all marine resource sectors. Development and management are similarly constrained by the lack of adequate information on the location, extent, and quality of available resources. In brief, the following summarizes some of the existing conditions, major findings and recommendations of this report.

NEARSHORE HABITAT RESOURCES

Nearshore marine habitats include coral reefs, seagrass beds, mangroves, coastal lagoons, salinas, and mud bottoms. These habitats are inextricably linked to fisheries, tourism, and other resources, and are directly related to much of the value of coastal lands. Despite their importance, nearshore marine habitats and species they support are increasingly threatened by poor land-use practices, waste disposal, petrochemicals, pesticides, and overexploitation.

Because of these threats listed above, "development" per se is often viewed as having an inherently negative impact upon nearshore marine resources. Little consideration appears to have been given to the potential for achieving positive impacts on these resources through appropriate economic development. The potential for achieving both economic and resource management objectives centers around activities related to tourism, marine protected areas, threatened species, harbor development, fisheries, and controlled harvesting of certain products as cottage industries.

The primary requirement for pursuing these opportunities is an approach that emphasizes both economic and resource management objectives. This approach should result in detailed coastal zone management plans based upon comprehensive information of the location, extent, development potential and management requirements for available resources. Implementation of such plans requires adequate institutional framework, public education, and trained personnel.

It is recommended that development assistance agencies solicit projects that combine economic development with improved management of nearshore coastal resources. Support should be provided for the inventory and planning activities needed to formulate such projects, and for activities that will provide long-term strengthening for government-based institutions.

FISHERIES RESOURCES

Capture Fisheries

Direct benefits from the development of fisheries resources are likely to be accrued almost entirely by local populations. While the monetary value of such benefits is limited, they can be quite significant within the economic and social context of some Caribbean countries. Potential benefits include increased supply of protein to local populations, increased income and employment, increased value of selected species, and provision of foreign exchange through exports.

These benefits may be achieved through increased landings of oceanic pelagic fishes, increased groundfish production in Central America, small-scale improvements to artisanal fisheries, development of recreational fisheries, and improvements to post-harvest processing and marketing.

Effective development and management of Caribbean fisheries requires that harvest effort and marketing capacity be matched as closely as possible to the potential yields of the specific fishery resources. The central need is for resource-specific plans with country-specific components in which the goals of management and development are set by the socioeconomic conditions of each country. A coordinated regional or subregional approach is needed for oceanic pelagic and many demersal resources that are shared between neighboring Caribbean countries.

Economic development and management of Caribbean fishery resources requires assistance with improved use of underutilized resources, specific improvements to small-scale fisheries, improved marketing and processing, application of techniques for improving the harvest and abundance of fishery stocks, and development of recreational fisheries.

Mariculture Resources

Various forms of mariculture have the potential to reduce imports of fishes, provide foreign exchange, diversify local economies, and rehabilitate some overexploited fisheries. Mariculture can increase the use of resources which are not fully utilized at present, offers opportunities for small-scale farmers and fishermen as well as private entrepreneurs and multinational companies, and has strong potential for producing economically stable systems within a reasonable period of time.

Promising candidates for mariculture development in various parts of the Caribbean, include finfishes, marine shrimp, brine shrimp, lobsters, crabs, conch, and oysters and other molluscs.

There are a variety of constraints that contribute to a high element of risk inherent in most mariculture operations. These include fluctuating costs and returns, lack of biological information, alteration of critical natural systems, potential shortages of seed stock, inadequate food processing and feed manufacturing technology, and scant infrastructure and government policy support for mariculture ventures.

Inherent constraints and risks are cause for caution in pursuing mariculture operations. The potential of mariculture, however, is sufficient to warrant development assistance for pilot projects which meet established economic and ecological criteria. Such pilot projects should provide a more stable basis for subsequent private and public investment, as well as improve access to existing credit facilities for capitalization. The success of individual mariculture ventures depends primarily upon the human, technical, and economic characteristics of each particular project.

GEOLOGICAL and NON-LIVING RESOURCES

Among geological and non-living resources, hard minerals are of major importance because of their high and immediate potential for low-cost development by Caribbean countries. Petroleum resources are well documented, managed by private or national companies. Non-conventional energy is considered an important resource for some countries.

Hard mineral resources with potential for economic development include sand and gravel, placer deposits, phosphate deposits, limestone, and salt. Development of these resources is constrained primarily by absence of sufficiently detailed information on their location, extent and quality.

Uncontrolled sand mining and mineral extraction processes can cause pollution and other serious management problems associated with geological resources. Attention to these problems require specific attention in any development plan.

International organizations and developed nations could provide support to the Caribbean countries for both large-scale and small-scale geologic mapping to provide a basis for economic development and management of hard mineral resources.

HUMAN and INSTITUTIONAL RESOURCES

The written history of most Caribbean countries has not emphasized marine resources, and until recently has had a relatively low priority among governments of the region. As a result, there has been little incentive or opportunity for marine science professionals or institutions. Marine resource developers and managers are caught in a dilemma in which governments are reluctant to commit to a sector which has not previously produced impressive benefits, while such benefits cannot be obtained without serious national commitment.

A variety of skills and techniques are required to achieve long-term benefits from Caribbean marine resources, including resource management, extension service and education, applied research, harvest technology, processing technology, and marketing. There is a diverse assemblage of institutions within the region that offer significant opportunities to meet these needs, but improvement of human and institutional resources does not depend solely upon training and material support. Many training efforts have been undertaken in the past without due regard for how trainees will be able to apply their new skills when training is completed. Improvements to the overall context within which human and institutional resources must operate are also needed. Efforts to improve human and institutional resources must be based upon the economic realities of the nations that are to be served.

It is clear that the key issue of national commitment cannot be solved by external effort alone and it is important to realize that such a commitment has evolved in other areas over a relatively long period of time. The need for improved human and institutional resources to support rational development and management of marine resources is growing faster than are management efforts dedicated to providing such improvements. This represents an important opportunity for development assistance agencies to play an interim supporting role to human and institutional resources in the Caribbean, while simultaneously achieving the tangible benefits needed to build a long-term dedication to the marine sector.

It is recommended that development assistance agencies support the formulation of development and management programs which specify activities needed to achieve program goals and objectives. The cost of the facilities and training required for such activities need to be accounted for.

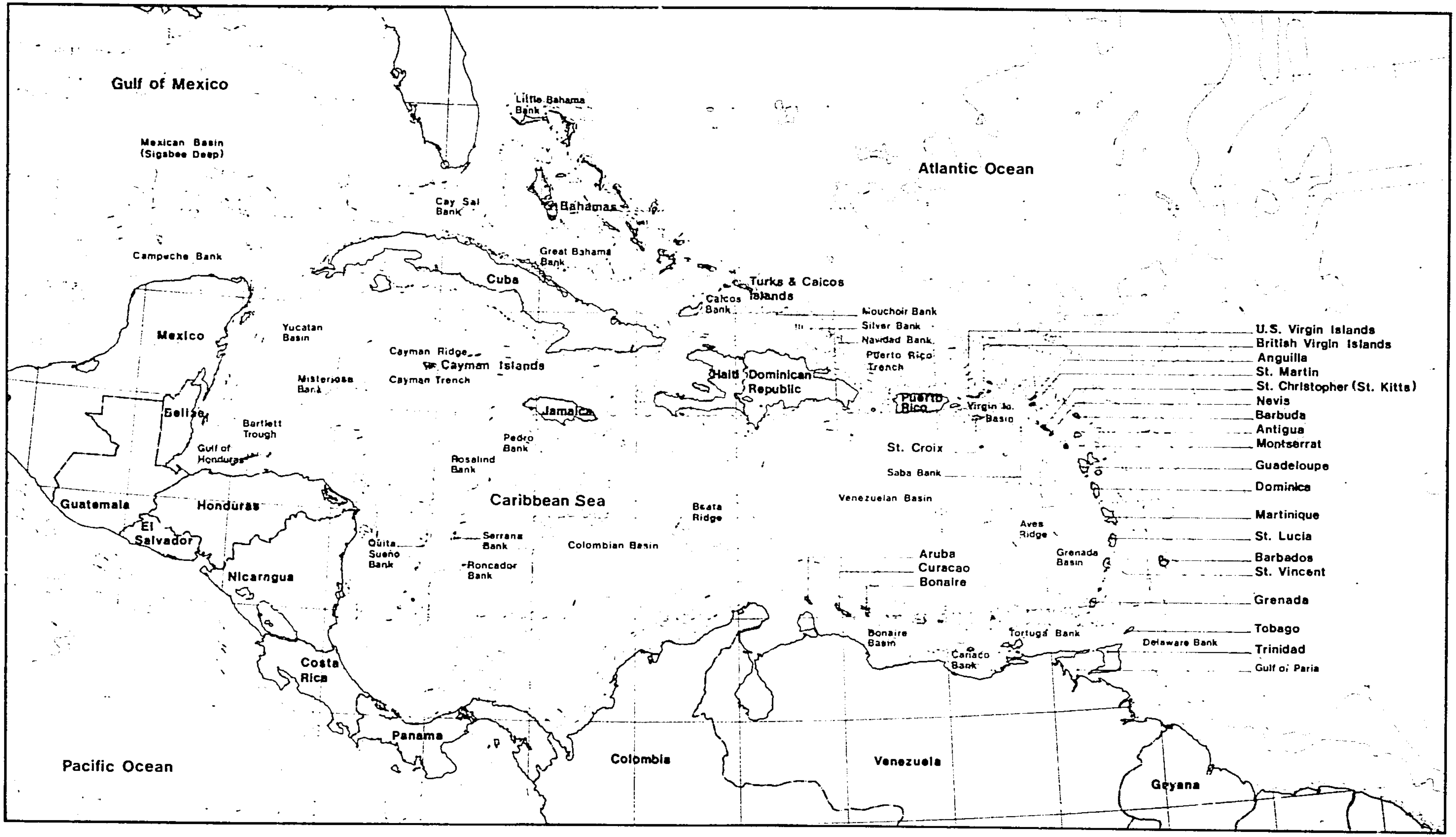
Assistance should be provided for collaborative efforts among regional institutions to provide follow-up support to training that is directed toward the improved use of marine resources. Whenever possible, training should take place in the context of projects related to national programs. Specific provision should be made for public awareness and information concerning the objectives, activities, and results of all projects.

ACRONYMS

ADCP	Aquaculture Development and Coordination Programme (FAO/UNDP)
AID	Agency for International Development, USA
AIMLC	Association of Island Marine Laboratories of the Caribbean
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA), USA
BOSTID	Board on Science and Technology for International Development (NAS), USA
CARIPOL	Caribbean Marine Pollution Research and Monitoring Program (IOC)
CARICOM	Caribbean Community (IOCARIBE)
CARMABI	Foundation Carmabi, Netherlands Antilles
CMRC	Caribbean Marine Research Center, Bahamas
CCA	Caribbean Conservation Association, Barbados
C/CCA	Caribbean/Central American Action, USA
CCML	Centro de Ciencias del Mar y Limnologia, Panama
CCML	Centro de Ciencias del Mar y Limnologia, Mexico
CEHI	Caribbean Environmental Health Institute, Saint Lucia
CEMA	Centro de Estudios del Mar y Acuacultura, Guatemala
CEPAL	Comision Economica para America Latina
CFMC	Caribbean Fishery Management Council, Puerto Rico
CIB	Centro de Investigaciones Biologicas, Venezuela
CIBMA	Centro de Investigaciones de Biologia Marina, Dominican Republic
CIECCA	Centro de Investigacion y Entrenamiento para Control de la Calidad del Agua, Mexico
CIM	Centro de Investigaciones Marinas, Cuba
CIMAR	Centro de Investigaciones en Ciencias del Mar y Limnologia, Costa Rica
CINVESTAV	Centro de Investigaciones y de Estudios Avanzados, Mexico
CIOH	Centro de Investigaciones Oceanograficas e Hidrograficas, Colombia
CIP	Centro de Investigaciones Pesqueras, Cuba
CIP	Centro de Investigaciones Pesqueras, Instituto Nicaraguense de la Pesca, Nicaragua
CMC	Cambridge Monitoring Centre (IUCN), United Kingdom
CTDRC	Caribbean Tourism Research and Development Center, Barbados
DBML	Discovery Bay Marine Laboratory, Jamaica
DCM	Departemento de Ciencias Marinas, Universidad de Puerto Rico, Puerto Rico
DITEPESCA	Direccion Tecnica de Pesca y Acuicultura, Guatemala
DOSP	Dalhousie Ocean Studies Programme, Canada
EDIMAR	Estacion de Investigaciones Marinas de Margarita, Venezuela
EPA	Environmental Protection Agency, USA
FAO	Food and Agriculture Organization, United Nations

GCFI	Gulf and Caribbean Fisheries Institute, USA
GIPME	Global Investigation of Pollution in the Marine Environment (IOC)
IB	Instituto de Biologia, Mexico
ICLAM	Instituto para el Control y la Conservacion de Maracaibo, Venezuela
ICLARM	International Center for Living Aquatic Resources Management, Phillipines
ICMRD	International Center for Marine Resource Development, University of Rhode Island, USA
IFREMER	Institut francais de recherche pour l'exploitation de la mer, Martinique
IMA	Institute of Marine Affairs, Trinidad and Tobago
INDERENA	Instituto Nacional de los Recursos Naturales Renovables y del Ambiente, Colombia
INP	Instituto Nacional de la Pesca, Mexico
INRA	Institut national de la recherche agronomique, Guadeloupe
INVEMAR	Instituto de Investigaciones Marinas de Punta de Betin, Colombia
IO	Instituto de Oceanologia, Cuba
IO	Instituto Oceanografico, Venezuela
IOC	Intergovernmental Oceanographic Commission, United Nations (IOC)
IOCARIBE	Intergovernmental Oceanographic Commission for the Caribbean and Adjacent Regions,
IOS	British Institute of Oceanographic Services, United Kingdom
ITESM	Instituto Tecnologico y de Estudios Superiores de Monterrey, Mexico
IUCN	International Union for the Conservation of Nature and Natural Resources, Switzerland
LAC	Latin America and Caribbean (AID), USA
LIM	Laboratorio de Investigaciones Marinas de Punta Morales, Costa Rica
MARNET	Marine Science Information Network, USA
NAS	National Academy of Sciences, USA
NESDIS	National Environmental Satellite, Data and Information Service (NOAA), USA
NMFS	National Marine Fisheries Service (NOAA), USA
NOAA	National Oceanic and Atmospheric Administration, USA
NOS	National Ocean Service (NOAA), USA
OAR	Oceanic and Atmospheric Research (NOAA), USA
OECS	Organization of Eastern Caribbean States, Saint Lucia
OTA	Office of Technology Assessment, (US Congress), USA
PMEL	Pacific Marine Environmental Laboratory (NOAA), USA
RARE	Rare Animal Relief Effort, USA
RASMUS	Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA
SCSGC	South Carolina Sea Grant Consortium, USA
SCUBA	Self Contained Underwater Breathing Apparatus
STRI	Smithsonian Tropical Research Institute, Panama
TOGA	Tropical Ocean and Global Atmosphere Program, USA
TWI	Trade Wind Industries, Bahamas
UAM	Universidad Autonoma Metropolitana, Mexico
UG	University of Guyana, Guyana
UJTL	Fundacion Universidad de Bogota, Jorge Tadeo Lozano, Colombia
UNAM	Universidad Nacional Autonoma de Mexico
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USGS	United States Geological Survey, USA
UTM	Universidad Tecnologica de Magdalena, Colombia
UWI	University of the West Indies, Jamaica and Barbados
WECAFC	Western Central Atlantic Fisheries Commission (FAO)
WCRP	World Climate Research Program (IOC)
WHOI	Woods Hole Oceanographic Institute, USA
WIL	West Indies Laboratory, Fairleigh Dickinson University, St. Croix, US Virgin Islands
WOCE	World Ocean Circulation Experiment, United Nations

CARIBBEAN BASIN REGION



Source: Ray, C., Dobbin, J., Miller, K., and Putney, A., 1978. Data Atlas (Preliminary), Planning a Marine Conservation Strategy for the Caribbean Region. James Dobbin Associates Incorporated, Alexandria, VA.

INTRODUCTION

BACKGROUND

A need exists to develop marine resources within the Caribbean Region. This development should be accomplished in consideration of the existing cultural, economic and institutional frameworks, and in balance with environmental implications. As part of its commitment to promote environmentally sound development projects, the United States Agency for International Development (AID) and the National Oceanic and Atmospheric Administration (NOAA) agreed to review the current status and to offer a projection of potential marine resource opportunities that could support economic development in the Caribbean region.

The primary purpose of the Caribbean Regional Marine Profile is to assist AID planners and mission representatives in identifying marine resource development needs and opportunities for potential projects within AID countries. NOAA committed assistance with the joint efforts of its National Marine Fisheries Service (NMFS) and Oceanic and Atmospheric Research (OAR) Staff, through their respective international divisions and field offices. Once the need for a regional profile was agreed upon, overall concerns for effective management of marine resources in the region were identified, and the objectives of a study were set forth.

Despite the relatively large water mass associated with the Caribbean Basin, techniques for the effective use of marine resources are underdeveloped in most Caribbean nations. In general, the region lacks an understanding of marine environments and ecological processes. This information is necessary for prudent economic development and policy-making in countries receiving development assistance. Marine research competencies vary extensively throughout the region, from advanced institutional programs to minimally active fisheries departments. Efforts through the United Nations framework, such as the Intergovernmental Oceanographic Commision for the Caribbean and Adjacent Regions (IOCARIBE), and the United Nations Environment Programme's (UNEP) Oceans and Coastal Areas Programme and UNEP's Caribbean Action Plan have largely been unsuccessful in promoting a sustained regional approach to marine research. The United States has not exhibited steady support to these initiatives.

OBJECTIVES

The purpose of this document is to provide a regional overview of marine resource opportunities by using existing information. This overview document is designed to meet the following objectives:

- describe the overall abundance and distribution of marine resources in the region including ecosystems, mineral and non-living resources, and underutilized and endangered species;

- describe the current state of development of these resources including indications of potential trends;

- identify principal marine resource management issues of the region, balancing ecological, economic and social perspectives;

- define economic opportunities for marine resources, and identify requirements needed to realize these opportunities, addressing regional and country-specific issues;

- survey the current state of education, training and institutional mechanisms within the region for marine resource management and development opportunities; and,

- provide recommendations on the above information for regional institutions, assistance agencies and national governments that would foster a balanced approach to economic development through the use of marine resources.

METHODOLOGY

AID and NOAA jointly developed the theoretical framework and methodology used for this study. The study, which began in April 1985, was carried out with an international and integrated resources approach to the Caribbean region. The scope of work carried out by NOAA consisted of the following components:

Information Gathering and Literature Search

The study included a detailed literature search and collection of information on Caribbean marine resources from U. S. and regional researchers, national officials from the region, marine resource program managers, and other individuals interested in these resources. Contacts included 256 non-U. S. representatives, 70 international organizations worldwide with development activities in the region, and 110 U.S. domestic contacts. Nearly 200 published and unpublished reports were reviewed. The literature was organized into subregional study units as follows: Fisheries, Marine Resource Management, Ports and Shipping, Coastal and Marine Ecosystems, Education, Policy and Institutional Structures, Non-Living Resources, Development Assistance, General Background, Tourism, and Country-Specific documents. Some of the documents acquired during this phase of the project are being transferred to the University of Miami, Rosenstiel School for Marine and Atmospheric Sciences (RASMUS). From here it will be made available to the Caribbean marine science community through an electronic network, Marine Science Information Network (MARNET), currently under development.

Questionnaire Distribution

A questionnaire was prepared in English and Spanish and distributed to the above mentioned contacts, including AID missions. The questionnaire was intended to confirm and enhance the comprehensiveness of the information gathered through the literature and information search. It was also designed to provide opportunities for experts to expand on their regional, and country-specific experiences. Institutions and individual representatives from the following countries completed the questionnaire: Barbados, British Virgin Islands, Colombia, Dominican Republic, Grenada, Guatemala, Jamaica, Netherlands Antilles, Nicaragua, Panama, Saint Lucia, Trinidad and Tobago, and Venezuela.

Meetings

NOAA representatives attended the Gulf and Caribbean Fisheries Meeting in Barbados, April 1986, to meet with members of the Caribbean research and marine resource community.

In December 1985 a one-day meeting was held in Washington, D.C. at NMFS to gather individuals of domestic agencies with activities in the Caribbean region. The project development thus far was discussed and findings from the literature review were presented. The meeting provided a forum for a midpoint review of the project and also facilitated inter-agency discussion. A document format was discussed and work groups were created within NOAA to implement these ideas and generate background papers for the final document.

Background Papers

After information from the 1985 Washington meeting was compiled, authors and subjects for a set of background papers were identified. Individals within NOAA having expertise in both marine resources and the Caribbean region agreed to write the papers. Other agencies and consultants were contacted when specific expertise was unavailable through NOAA. The agency or individuals responsible for writing the background sections were encouraged to use the information, literature and questionnaire responses gathered thus far in the project. The authors individually generated the scope, format and size of each paper. The authors are listed in the Project Participants section of this report. The following papers will be forwarded to the RASMUS library, where they will be made available to the scientific community in the Caribbean region: Coastal Area Development, Marine Pollution Problems in the Greater Caribbean, Caribbean Marine Profile: Fisheries Section, Marine Geologic Section of the Caribbean Regional Marine Profile, Education and Training in the Caribbean, and Remote Sensing in the Caribbean.

Regional Workshop

An international workshop was held at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) facility in Miami, Florida, September 2-5, 1986. Attendees included NOAA project staff from Washington, D.C. and AOML, authors of background papers, regional country representatives, and an editorial consultant. During this workshop the experts reviewed the findings from the information collected, presented new ideas and references, formulated a theoretical framework for the drafting of a comprehenive document with the editor, and worked with the authors on rewriting and synthcisizing the background papers into the proposed framework. All workshop participants are listed at the beginning of this document on page 3.

The findings gathered by NOAA staff and confirmed through contact with local and regional experts have been analyzed and assembled into this report to provide recommendations for AID and other parties interested in the development potential of Caribbean marine resources.

The report was drafted by the editor and includes material from the background papers, relevant literature, questionnaires, and additional information obtained during the regional workshop. The draft of this document was reviewed and by the authors, and edited by staff from NOAA and AID that are familiar with Caribbean marine resources.

The report is composed of the following chapters: Nearshore Marine Habitats, Fisheries and Mariculture Resources; Geological and Non-living Resources, and a final chapter on Human Resources focusing on educational and institutional needs. Each chapter provides a background on the status and extent of the resources, addresses constraints particular to specific resources or countries, presents opportunities for development, identifies particular requirements needed to make the realization of these opportunities feasible, and suggests overall recommendations targeted to development assistance agencies.

The reference section lists both the literature cited in the document and provides additional sources that may be useful to the AID Mission Directors, regional planners and the Caribbean marine science community at large.

Annex A, Institutions, presents a brief description and location of institutions in the Caribbean region that are active in both applied and basic research that may be able to assist in the implementation of marine resource development recommendations and projects. Annex B, Country Notes, presents marine resource development information that is country specific regarding ecological, economic or cultural considerations. The information in this annex was drawn largely from the background paper on Coastal Resources and the questionnaires. Annex C, Threatened Taxa, provides a country specific listing of the status, taxon name, and common name for coastal and marine animal species in the Caribbean region.

I

NEARSHORE MARINE HABITATS

Some of the most productive and biologically complex ecosystems in the world are found within the Caribbean coastal zone. These include coral reefs, seagrass beds, mangrove forests, and coastal lagoons. The economic importance of these systems stems primarily from their linkage to other resources, especially fisheries and coastal tourism. These linkages are often ignored or discounted when considering the monetary value of coastal land for commercial development. But the reality is that much of this value is directly related to nearshore marine habitats.

Background

Surface waters of the Caribbean Sea are warm throughout the year, resulting in a relatively stable horizontal layering between surface and deeper waters. This stratification is indicative of a circulation system that prevents the upwelling of nutrient-rich deep water except along the northern coast of South America. Lack of nutrients limits the production of microscopic floating algae (phytoplankton) which are responsible for the high marine productivity in temperate climates; the Caribbean Sea is generally clear because biological productivity is low.

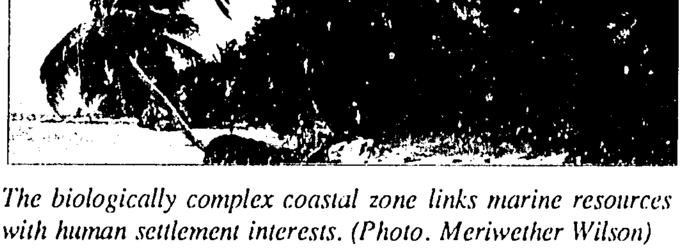
Nutrient limitations are overcome in nearshore marine habitats of the Caribbean through:

- production of nutrients from atmospheric nitrogen by shallow-water, blue-green algae found on coral reefs;

- recycling of certain nutrients within coastal ecosystems, for example, the remineralization of the organic material characteristic of mangroves and seagrass beds; and,

- input of nutrients and organic material derived from terrestrial freshwater runoff into coastal lagoons and mud bottoms.

These mechanisms result in physical, chemical and biological linkages between Caribbean coastal habitats. Changes or disruptions to pathways of interaction will have some effect upon all of these habitats. (Ogden and Gladfelter, 1983). The separation of nearshore resources in the following discussion is for organizational simplicity; such separation does not reflect biological reality. Development and management of these resources must be based upon a perspective of the entire coastal zone rather than on individual components.



The biologically complex coastal zone links marine resources with human settlement interests. (Photo. Meriwether Wilson)

Coral Reefs

There are approximately sixty species of corals in the Caribbean including about six dominant species that are the primary reef builders. Corals are animals, having a thin layer of tissue covering a skeleton of calcium carbonate secreted by the animal tissue during growth. Individual corals grow at rates ranging from 1-30 centimeters per year. Coral reefs, consisting of the consolidated skeletons of corals, accumulate rapidly in geological time. Caribbean coral reefs represent about 10,000 years of coral growth (Goodwin, et al., 1986).

Coral reefs require clear, clean water and relatively high wave energy to grow and flourish. Thus, they are best developed on the windward side of coasts and are absent where sedimentation from terrestrial runoff and rivers is heavy, such as the northern coast of Puerto Rico (Bak, 1983).

Coral reefs are one of the most important coastal resources of the Caribbean region. They are the basis of many coastal fisheries, providing food, shelter, and nursery areas for commercially valuable fishes and crustacean species. Reefs form breakwaters which protect harbors and bays and limit coastal erosion. Coral skeletons are the principal source of sand and gravel resources. The beaches and visual attractions provided by coral reefs are the focus of much of the tourism in the region (Salm and Clark, 1984).

Seagrass Beds

Large meadows of seagrasses of three major species occur in close association with coral reefs in the Caribbean. Seagrasses are true flowering plants with male and female flowers and seeds borne in fruits; yet the most common form of reproduction is asexual via a rhizome (superficially resembling a root) growing through the nutrient-rich sediments.

Seagrasses are very productive. Massive amounts of plant material are consumed by grazers (e.g., fishes, green turtles, sea urchins) which feed directly on the plants, or are channeled into a complex community of small organisms and bacteria living among the seagrasses and feeding upon plant detritus.

The seagrasses covering the bottom of coastal bays trap fine sediments and stablize the bottom with interwoven rhizomes beneath the sediment surface. Sediment retention and stabilization is important for adjacent coral reefs because it prevents abrasion or burial of these reefs during storm conditions (Zieman, 1983).

Seagrass blades provide surfaces upon which many organisms attach, including a variety of algae which may produce calcareous sediment or provide food for grazing organisms. Seagrasses serve as nurseries for the juveniles of commercially important species including fishes (snappers, grunts) and invertebrates (lobsters, conchs), (Ross, 1982).

The diversity of coral reef ecosystems are exhibited by the variety of shapes in these soft and hard corals. (Photo: Meriwether Wilson)

The polyps (animals) of these soft octocorals (gorgonians) have tentacles to capture food. (Photo: M. W. Williams)

Mangrove prop roots provide attachment surfaces and shelter for marine organisms. (Photo: Meriwether Wilson)

Mangroves

Mangrove forests are a coastal feature of tropical and subtropical regions. These trees develop in low-lying coastal areas where freshwater is supplied by rivers or terrestrial runoff. Their prop roots provi . : a surface for the attachment of marine organisms and reduce tidal and wave energy, thus promoting deposition of nutrient-rich mud and silt. Mangroves provide habitat and shelter for a variety of animals such as small fishes, crabs, and birds. By breaking storm waves and dampening t'dal currents, mangroves help to maintain the coastline against erosion, and may actually extend coastal lands by trapping and binding sediments. As a result, sediment loads into coastal waters are reduced, and normally there is little, if any, resuspension of sediment through shoreline erosion. Decomposed leaves of the mangroves form the base of a food web that extends to large fishes and birds (Cintron and Schaeffer-Novelli, 1983).

Coastal Lagoons and Salinas

Coastal areas of the Caribbean near major watersheds often contain huge lagoons of fresh or brackish water that provide important sources of organic material and nutrients as well as feeding, nesting and nursery areas for various birds and fishes. Large coastal lagoons are most prominent along the mainland and are often the breeding grounds for nearshore shrimp fisheries. Coastal lagoons are buffers controlling terrestrial runoff and providing natural settling basins for suspended sediments.

Salinas, shallow ponds and lakes with limited or only tidal contact with the sea, are characteristic of many dry Caribbean islands. Traditionally, salinas have been used as salt evaporators and are targeted for mariculture or marina construction in more recent development schemes. These ponds also function as sediment traps, and are important to the protection of nearby coral reefs from excessive sediment loading.

Mud Bottoms

Mud bottoms are extremely productive, supporting commericially important shrimp and groundfish fisheries. Wide bands of relatively flat mud bottom are associated with the coasts of Central and South America. Mud bottoms result from seasonal runoff of fresh water carrying terrestrial sediment and are enriched in organic material by outflow from coastal lagoons.

Present Condition of Coastal Resources and Constraints to Economic Development

Coastal resources of the entire Caribbean region are under increasing impact from human activity. The driving forces for this pressure are unchecked population growth and the need in most countries to generate foreign exchange through export of coastal and agricultural resources, industrialization, and tourism. The following are of particular concern:

Tourism

The Caribbean Tourism Research and Development Center (CTRDC) estimates that tourism accounts for approximately 40 percent of the gross domestic income of Caribbean Island nations. More than 7.7 million overnight tourists (exclusive of 3.7 million cruise ship passengers) spent US $4.6 billion in the region during 1984 (CTRDC, 1985).

Most of the tourist industry is concentrated in coastal areas, where industries depend upon the sea for cooling water, dump sites, and transportation. Tourism, in particular, has caused adverse impacts on marine environments. It has been calculated, for example, that the average tourist uses more than twice as much water as the average island resident; and hotels are prime sources of water contamination (Clark, 1986). Development of marinas and harbor facilities generally adds to problems of pollution such as human waste disposal, destruction of mangroves, coastal siltation, oil leaks from engines, and physical damage to reefs and grass bottoms is caused by extensive yacht anchorings.

Even isolated beaches are fouled by garbage, trash and plastics washed ashore by waves and currents. Every convergent zone including Sargassum wind rows have an accumulation of trash and plastic. The recreational boater contributes approximately 0.5 kilogram per person per boat-day (NOAA, 1977).

Table 1:

Estimated Population and Tourist Arrivals in Representative Caribbean Countries, 1977

	Population	Tourists
Bahamas	218,000	965,000
Belize	139,000	95,000
Colombia	24,977,000	709,000
Cuba	9,604,000	80,000
Dominican Republic	4,980,000	359,000
Haiti	4,749,000	96,000
Honduras	3,039,000	181,000
Jamaica	2,100,000	265,000
Puerto Rico	3,300,000	1,376,000
US Virgin Islands	96,000	718,000

Source: Clark, 1986, p. 179.

Poor Land Use Practices

Because coastal ecosystems of the Caribbean have evolved in clear waters, the major impact from development on land is excessive sedimentation. Uncontrolled sedimentation stresses or smothers corals and seagrasses, cuts light penetration into normally clear waters, and releases pulses of organic material and nutrients. Studies in Guayanilla Bay, a large industrial site on the southern coast of Puerto Rico, have provided evidence of coral reef destruction by sedimentation. Excessive nutrient loading (eutrophication) can result in "blooms" of algae which subsequently die and deplete dissolved oxygen through decay. Shoreline construction, including harbors, groins, channels, and removal of beach sand, interferes with normal coastal sediment transport and can lead to disasterous erosion (Carpenter, 1983).

While shifts to industrialization have sometimes reduced agricultural output, they have more typically led to energy-intensive agricultural practices, including the increased use of fertilizers and chemical pesticides. The sugar industry produces much wastewater with high biochemical oxygen demand as well as solid wastes. As modernization proceeds, the use of agricultural chemicals is likely to increase manyfold. The environmental impact of these chemicals on the tropical ecosystems has not been determined, but it is unlikely to be benign. Such information is critical, as there is little impetus or concern to modify practices that have been satisfactory in the past unless a major economic loss or threat to health can be demonstrated. In most cases this cannot yet be done.

Waste Disposal

Eutrophication from human sewage disposal is a growing problem in the Caribbean, particularly in the vicinity of large coastal cities and harbors. In accordance with long-term practice, the sewage generated by 30 million people is disposed of, more or less, untreated into the Caribbean Sea. Sewage treatment plants if they exist at all, are commonly overloaded and inadequately maintained. Solid waste is placed directly into the sea or into coastal landfills, often within mangrove areas. These landfills are inadequately protected from the sea and the consequent escape of plastics and long-lasting buoyant waste is a growing problem in the region. Undoubtedly toxic wastes are also disposed of in these landfills (legally or illegally) and are possibly leaching into the marine environment. Some disposal sites are near public swimming beaches or waterfronts of luxury hotels and untreated sewage is discharged near adjacent beaches.

The regional extent of the problem is indicated by recent studies, personal communications, and questionnaires provided for the prepartion of this report. In Jamaica, coral reefs exposed to sewage reveal heavy algal overgrowth and dense solid waste litter on the nearby seafloor (Chow, 1985). Since 1981, the Institute of Marine Affairs and Ministry of Health of Trinidad and Tobago have monitored the extent of sewage pollution at several locations around the country. Rivers flowing into the sea recieve fecal wastes from two major sewage treatment plants, some inland treatment plants, farms, and numerous pit latrines of poor construction. Significantly elevated levels of sewage-associated bacteria have been found in several coastal areas including popular beach areas. In Barbados, marine pollution from sewage, fertilizers, industrial effluents and suspended sediment loads is causing stress on the fringing reefs and increasing coastal erosion.

Harbors can concentrate wastes, creating unhealthy conditions and effluents which can have major effects on extensive areas of the coast. At the same time, such water bodies are prime choices for development of ports and industries dependent upon marine transportation facilities. Two cases of particular interest are those of Cartagena (Colombia) and Havana (Cuba) Bays where gross pollution has become apparent. Well-planned, intensive studies of pollution in these bays through international cooperation has provided a wealth of information making these case studies especially useful for planning and implementation of pollution abatement procedures. A priority resulting from the Havana Bay study has been the elimination of anoxic conditions by minimizing organic and nutrient loading.

Hazardous industrial wastes are often placed indiscriminately into rivers or coastal zones. The United Nations Environment Programme has identified the largest industrial concentrations in the region as those along the coasts of Venezuela, Colombia, Mexico, Cuba, Puerto Rico, the U.S. Virgin Islands, Trinidad and Tobago, the Netherlands Antilles, Jamaica, and the U.S. Gulf Coast. Chemical wastes, including many compounds known to be highly toxic, have been dumped in the Gulf of Mexico for many years, primarily from chemical plants in Texas and Louisiana. Two types of industrial chemicals, polychlorinated biphenyls (PCBs) and phthalate ester plasticizers, have been detected in various marine organisms in the Caribbean.

Petroleum and Hydrocarbons

There have been spectacular cases of major oil spills in the Caribbean, and frequent small oil spills associated with most of the region's refineries. During June of 1979 the world's largest oil spill, Itoxc I, occured in the Bahia de Campeche near the Gulf of Mexico. The blown well was not capped until March of 1980. While the local impact is immediate and obvious, there is little information and few quantified studies on the long-term effects of major spills or chronic discharges of oil into the coastal zone (Jernelov and Linden, 1981; Clark, 1986). (See photograph of oil spill from Ixtox I, on page 53.) Oil slicks on the seawater surface constitute a deleterious barrier to the exchange of gases between the atmosphere and the water. In waters with a high biological oxygen demand and minimal surface wave action such as enclosed bays, this barrier may accelerate oxygen depletion and consequent death of resident animal populations.

Studies suggest that corals do not die when oil floats over the reef, but that coral death is from smothering when the oil directly adheres to the coral surfaces (Rogers, 1981). Oil slicks are also known to affect sea birds due to oiling of their feathers. Tar accumulation on beaches is a major impact of oil spills as this reduces the tourism value of coastal areas. An oil spill during 1986 in Panama (at Galeta near Colon) onto a coral reef flat which had been monitored for over ten years may provide a detailed picture of immediate and long-term effects of major oil spills on coral reef environments.

Overexploitation of Harvestable Coastal Resources

Traditional fisheries directly associated with Caribbean coastal habitats (e.g., spiny lobster, conch, reef fishes, sea urchins) are nearly all overexploited. Management techniques (limited entry, size limitations, area closure, etc.) are well known and can lead to dramatic responses within a fishery, but enforcement of such practices remains a problem in traditionally unmanaged and essentially artisanal fisheries. Management plans and practices need to take into account local customs and traditional conservation methods.

Opportunities for Economic Development and Resource Management

"Development" is often viewed as having an essentially negative impact upon nearshore marine resources, and experience to date often supports this view. There apparently has been little consideration of the potential for achieving positive impacts on these resources through appropriate economic development. Planning efforts often are concerned primarily with avoiding undesirable impacts, but it is also possible to actually enhance the inherent values of nearshore marine resources. This potential represents a broad opportunity to achieve both economic and resource management objectives, and to reduce much of the conflict that is often associated with these objectives.

Specific opportunities for benefits from nearshore marine habitats center around six categories of activity:

Tourism

Though typically associated with white sand beaches and neighboring coral reefs, tourism can be developed in association with other coastal environments and activities, particularly where coastal wetlands and swamps provide refuges for wildlife (e.g., the Caroni Swamp in Trinidad and the Black River Swamp in Jamaica). Development of tourism in association with such habitats helps to highlight unique features of each area, as long as hotels are not built in close proximity to these habitats. This benefit is particularly important to countries in which tourism is not well-developed and which must compete with other areas where the industry is better established. At the same time, linking these habitats to economic activity contributes to resource management by providing strong justification for the protection and maintenance of these habitats (e.g., SCUBA diving operations depend upon a clear water environment and are greatly enhanced by close proximity to coral reef communities).

Marine Protected Areas

The management of nearshore marine habitas is linked with tourism, fisheries and other development opportunities. If properly managed, marine protected areas may provide a framework of multiple-use options for entire ecosystems and the species they support. Optimization of the benefits that may be derived from these protected areas depends on: the maintenance of ecological processes, the preservation of genetic diversity, and the sustainable utilization of species and ecosystems associated with these areas (IUCN, 1980). Through maintenance of environmental quality and conservation of the natural resource base, protected marine areas can generate near-term benefits while ensuring the availability of resources for long-term economic growth. Passive use of marine protected areas for underwater tourism and marine recreation could provide substantial short-term gains to many Caribbean nations. Longer-term economic benefits may be derived from the protection of critical habitats and the ecological systems they support for fisheries, coastal mariculture, and coastal stabilization. Marine protected areas can also play a vital role as refugia for threatened and endangered species, whose ecological value may not yet be fully realized. (See Table 2 for a list of marine protected areas in the Caribbean.)

Threatened Species

Overfishing, habitat destruction and marine pollution are threatening the survival of a growing number of marine species. Sea turtles represent the largest group of endangered species in the Caribbean (see Table 3 for a list of threatened and endangered species in the Caribbean, and Annex C for a country by country listing). Of increasing concern to many nations are the number of commercially threatened species, such as conch and lobster, which may have been the mainstay of many Caribbean fishing industries. Both national and regional mangement efforts are required to reverse this decline in species abundance, through a combination of restricted harvesting, marine reserve and rehabilitation programs.

Harbor Development

Caribbean nations have reasonably well-developed port facilities for shipping and tourism. In many countries there is a shortage of marinas for recreational boating and safe harbors offering protection to small craft from severe weather. Salinas, mangrove swamps, and lagoons protected by coral reefs are prime candidates for the latter types of harbor. Construction and operation of marinas has frequently been associated with negative impacts from dredging and pollution, but such impacts are not inevitable. In some cases, marina construction could be coupled with land-based development to minimize negative impacts; for example, salinas converted to marinas lose much of their sediment trapping capabilities, but this loss may be offset by development activities that provide reduced sediment loading through erosion control.

Large scale removal of mangroves for marina construction is undesirable because of the sediment trapping and erosion control functions of these trees. Some clearing is possible, however, and could be combined with floating docks to accommodate recreational vessels. Similar potential may exist in certain coral reef lagoons. Permanent moorings are particularly important in coral areas, as small boat anchors do significant damage to reefs in the vicinity of popular boating sites.

Incorporation of coastal habitats in development plans increases the perceived resource value and offers greater incentive and justification for sound resource management.

Fisheries

Fishery resources are dealt with in detail in the following chapter. In the immediate coastal environment much of the fishing is artisanal and in most cases is already beyond the limits of sustainable yield. Only in a few cases is there opportunity for further development of the nearshore fishery and this is mostly for pelagic fishes such as herring and scad and in mud bottom areas for penaeid shrimp.

Recreational fishing has considerable potential throughout the Caribbean. This potential is not confined to offshore species (e.g., marlin and sailfish), but also includes game fishes such as snook, bone fish or tarpon found in nearshore habitats. Such fishing is often non-extractive (the fishes are released after being caught). By linking benefits directly to resources, significant support can be simultaneously created for resource management and environmental preservation.

Other Activities

Apart from fisheries, there are several other artisanal activites with potential for controlled development. These include charcoal production from mangrove trees, the harvesting of land crabs in mangrove forests, and the collection of black coral, sea shells and other curios from coral reefs and seagrass beds. Development of these opportunities requires manipulation of the productive systems rather than simply an increased harvest. Crab production, for example, should be increased through mariculture operations. A limited harvest of precious coral is permissible, but management plans should be developed along the lines used for similar resources in the Pacific, incorporating size, quantity and location restrictions. A similar approach should be used for planned harvest of any ornamental species (such as starfish or helmet shells). Conch shells have established value as tourist souvenirs. Millions of these shells are discarded annually in the Eastern Caribbean, and this certainly represents undeveloped potential.

There is also potential for the culture of aquarium fishes for export trade. It is emphasized that this is the only means by which this market should be pursued; harvest of ornamental fishes from the coral reefs is not an alternative. Artifacts from coral reefs, such as coral skeletons and shells, are attractive to tourists but their collection and sale should only be on a strictly controlled basis to avoid stock depletion (Rogers, 1981). Similarly, the demand for certain reef fishes for the aquarium trade should only be permitted under carefully controlled or cultured conditions.

The economic potential of these activities is not likely to attract large amounts of foreign investment capital, but can be significant on a local scale. For the most part, these activities represent opportunities for small businesses that can contribute to overall economic development of isolated towns and island areas.

Table 2: **Existing Marine Parks and Protected Areas in the Caribbean Region**

Country	Protected Area Name	Estab.	Hectares	(Marine %)
Antigua	Diamond Reef Marine Park	1973	2,000	---
	Palaster Reef Marine Park	1973	500	---
Bahamas	Inagua National Park	1965	74,000	(10)
	Exuma Cays Land and Sea Park	1958	45,000	(80)
	Conception Island Land and Sea Park	---	810	(80)
	Union Creek	1965	1,813	---
Barbados	Barbados Marine Reserve	1980	---	(100)
Belize	Half Moon Caye Natural Monument	1982	4,144	(95)
UK Virgin Islands	Wreck of the Rhone Marine Park	1983	323	(96)
Colombia	Parque Nacional Corales del Rosario	1977	18,700	---
	Parque Nacional Natural Tayrona	1969	15,000	---
	Parque Nacional Natural Isla de Salamanca	1969	21,000	---
	Santuario de Fauna Los Flamencos	1977	7,000	---
Costa Rica	Cahuita National Park	1970	2,000	(35)
	Tortuguero National Park	1970	18,947	(16)
Dominican Republic	Parque Nacional del Este	1975	43,400	---
	Samana Bay - Silver Banks Marine Sanctuary	---	---	---
Honduras	Rio Platano Biosphere Reserve	1980	350,000	---
Jamaica	Montego Bay Marine Park	1959	---	---
	Ocho Rios Marine Park	---	278	---
Martinique	Parc Naturel Regional de la Martinique	1975	---	---
Mexico	Isla Mujeres	---	---	---
	La Blanquilla	---	---	---
	Cancun-Nizuc-Isla Mujeres	---	---	---
	Arrecifes de Cozumel	1980	---	---
	Isla Contony	1960	---	---
	Ria Celestrum	1979	59,000	---
	Rio Lagartos	1918	47,840	---
Netherlands Antilles	Bonaire Underwater Park	1983	---	(100)
	Curacao Underwater Park	1983	---	(100)
Puerto Rico	Jobos Bay / Mar Negro	---	---	---
Saint Lucia	Maria Islands	1985	---	---
	Pigeon Island	1982	---	---
Trinidad and Tobago	Buccoo Reef and Bon Accord Lagoon	1970	---	(100)
	Caroni Swamp	1982	7,900	---
US Virgin Islands	Virgin Islands National Park, St. John	1963	6,073	(33)
	Buck Island Reef, St. Croix	1961	350	(80)
Venezuela	Parque Nacional Archipelago Los Roques	1972	225,143	---
	Parque Nacional Mochima	1973	94,935	---
	Parque Nacional Morrocoy	1974	32,090	---
	Laguna de Tacarigua	1974	18,400	---

Sources: IUCN, 1982; IUCN, 1985; Silva, et al., 1986; Van'T Hoff, 1985.

Table 3: **Distribution and Status of Threatened Caribbean Coastal and Marine Animal Species**

Species **(Common Names)**	**STATUS**	**COUNTRY**
Monachus tropicalis (Caribbean Monk Seal, West Indian Seal)	E	Mexico, Bahamas
Trichechus inunguis (Amazonian Manatee, S. American Manatee)	V	Col., Ven.
Trichechus manatus (Caribbean Manatee, N. American Manatee)	V	Mex., Bah., Cuba, D. Rep., Haiti, Jam., P. Rico,Trin./Tob., Belize, C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Pterdroma hasitata (Black-capped Petrel, Diablotin)	V	Haiti
Caretta caretta (Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana)	V	Mex., Antig./Barbud., Bah., Cuba, D. Rep., Jam., Ne. Ant., P. Rico, Trin./Tob., C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Chelonia mydas (Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Tortuga Blanca)	E	Mex., Antig./Barbud., Bah., Cay. Isl., Dom., D. Rep., Gren., Guad., Haiti, Jam., Mart., Ne. Ant., P. Rico, St. Luc., St. Vin., Trin./Tob., USVI, Belize, C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Eretmochelys imbricata (Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdaderia and de Pente)	E	Mex., Antig./Barbud., Bah., Cay. Isl., Cuba, Dom., D. Rep., Gren., Guad., Haiti, Jam., Ne. Ant., P. Rico, St. Luc., St. Vin., Trin./Tob., USVI, Belize, C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Lepidochleys kempii (Kemp's Ridley, Atl. Ridley Sea Turtle, Tortuga Lora)	E	Mex.
Lepidochelys olivacea (Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama)	E	Mex., Cuba, P. Rico, C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Dermatemys mawii (Central American River Turtle)	V	Mex., Belize, Guat., Hond., Pan., Col., Ven.
Dermochelys coriacea (Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tarataruga)	E	Mex., D. Rep., Grenadines, Guad., P. Rico, Trin./Tob., BVI, USVI, Belize, C. Rica, Nica., Pan., Col., Ven.
Caiman crocodilus crocodilus (Spectacled Caiman)	V	Trin./Tob., Col., Ven.
Caiman crocodilus fuscus (Brown caiman)	V	Mex., Cuba, Nica., Pan., Col., Ven.
Crocodylus acutus (Amer. Crocodile, Crocodilo, Lagarto Negro)	E	Mex., Bah., Cay. Isl., Cuba, D. Rep., Haiti, Jam., Ne. Ant., Belize, C. Rica, Guat., Hond., Nica., Pan., Col., Ven.
Ameiva polops (St. Croix Ground Lizard)	E	USVI
Family *Anthipathidae* (Black Corals)	CT	Caribbean Region
Strombus gigas (Queen Conch)	CT	Caribbean Region
Panilurus argus, P. guttatus (Spotted Spiny Lobster)	CT	Caribbean Region

Status Key: E - Endangered; V - Vulnerable; CT - Commerically Threatened; **Source:** IUCN/CMC, 1987.

Requirements for Economic Development and Resource Management

1. Planning Perspective

The primary requirement for pursuing opportunities for improved economic development and resource management is a plan which emphasizes achieving both objectives rather than making trade-offs between them. Development assistance agencies can provide strong impetus for this perspective by encouraging and favoring projects that can demonstrate both development and management benefits.

2. Information

Planning requires comprehensive information on available resources including location, extent, development potential, and management needs. "Country Environmental Profiles" which have been prepared for some Caribbean countries may meet much of this need, provided the technical quality and level of detail are sufficiently high. To enhance resource development capabilities, each country should acquire and maintain an inventory of its coastal environments and resources. This inventory should provide a balance between long-term goals such as ecosystem preservation and immediate demands such as tourism.

3. Coastal Zone Management Plans

Resource inventory information should be used as the basis for comprehensive coastal zone management plans delineating types of activities and uses appropriate to specific areas, such as the designation of marine protected areas. Implementation of such plans may require legislative action, but the identification of alternative approaches and best uses for resources can provide a valuable guide for developers even before these become law (Kenchington and Hudson, 1984).

4. Pollution Monitoring

Management plans should also include provisions for pollution control such as:

- assessment of the status of pollutants at both the organism and the ecosystem levels; and,

- monitoring in response to assessment results; the need for monitoring would be indicated, for example by relatively high or increasing levels of pollutants, or ecological situations particularly susceptible to detrimental consequences from pollution (e.g. biological accumulation through the food cycle, appropriate levels of domestic and industrial waste treatments).

5. Institutional Framework

The institutional framework for implementing integrated management and development strategies should be government-based. In an ideal situation, universities should be the vehicle for research and should supply government agencies with trained personnel for monitoring and managing coastal resources. In many cases, however, fluctuating political commitments, goals, and budgetary priorities tend to generate instability and erosion of confidence in such agencies. This weakness frequently results in universities carrying out monitoring and management functions on a contract basis. There is a need to ensure long-term stable budgetary support for local agencies so that trained staff can build a career structure within the agencies and develop commitment to the agencies' goals (Sorensen, et al., 1984).

6. Public Education

Means for public education are now available in all parts of the region through television networks and video. Education programs can be used to communicate resource knowledge on many levels, e.g. to train local resource managers or to develop local public awareness of environmental conservation needs. The talent and training needed for preparation of programs and other educational materials exist in the region. The use of video tapes and possibly the use of long distance teaching techniques (e.g., the satellite communications system used by the University of the West Indies) permit wide dissemination of suitable materials.

7. Trained Personnel

Because of financial constraints to individual countries, it may be desirable to undertake large scale activities on a regional or subregional basis, using for example Curacao as a center for the Netherlands Antilles; St. Lucia as a center for the Organization of Eastern Caribbean States (OECS) members; St. Croix as a center for the Virgin Islands; and Jamaica as a center for Jamaica, the Caymans and Belize.

8. Caveats

Most coastal ecosystems are fragile and maintained in delicate balance between the physical and biological environments. Any development activity must take this into account. In particular:

a. Coral reefs absorb wave energy and provide a protective barrier for the beaches and other shoreline structures; any interference with a reefs physical structure is likely to initiate concomitant changes behind the reef.

b. The stability and maintenance of coral reefs is dependent on biological as well as physical forces; removal of grazing organisms, e.g., certain fishes and sea urchins, may encourage algal growth and death of corals, resulting in loss of stability and reef erosion.

c. Excess nutrient input also causes undesirable algal growth; sewage effluents and runoff of fertilizers from agricultural lands must be controlled in reef environments.

d. Excessive sedimentation, as from land drainage, may reduce coral growth either by directly smothering the corals or by reducing illumination; may cause reef degradation and subsequent coastal erosion.

e. Certain forms of solid waste may also have adverse effects on coral reefs if they settle on and smother living coral. Discarded plastic bags are often washed from banana plantations to the sea via rivers and storm gulleys, while pleasure boats and charter yachts frequently dispose garbage in the vicinity of reefs.

f. White sand beaches have their origins in the biological activity of reefs, particularly corals and calcareous algae; damage to reefs may affect the supply of sand to adjacent beaches.

g. Beaches are dynamic coastal features dependent upon physical forces which transport sand; alteration of these forces (e.g., by groins or breakwaters) will alter the physical structure of nearby beaches.

h. Seagrass beds act as shoreline protectors by trapping sediments and restricting their motion; removal or alteration of these beds will alter the dynamics of sediment transport and affect the shoreline accordingly.

i. Mangroves stabilize and extend shorelines and trap excess sediments thus preventing coastal erosion. They help control eutrophication by uptake of excess nutrients, contribute organic matter to the marine ecosystem, and provide nurseries for larval fishes and shrimp. Destruction of mangroves thus interferes with the biological and physical processes which affect the economic value of coastal areas.

Recommendations

1. PROJECTS SHOULD COMBINE ECONOMIC DEVELOPMENT WITH IMPROVED MANAGEMENT OF COASTAL RESOURCES, and preferential support should be given to such projects through development assistance programs. This integrated approach should also be promoted through public education programs that highlight the value and potential of coastal resources and outline effective means for their development and management.

2. SUPPORT SHOULD BE PROVIDED FOR AN INVENTORY OF COASTAL RESOURCES for those countries which do not already have such a data base, and for planning activities that will identify site-specific opportunities for integrated economic development and resource management. One of the most direct approaches is to make low-level aerial photographic imagery available for mapping of resource distribution. For example, existing aerial photography in the United States and Great Britain could be catalogued and lists of available coverage distributed within the Caribbean region. This effort could be augmented with other information such as satellite imagery that might be most appropriate to be developed cooperatively on a regional scale.

3. DEVELOPMENT ASSISTANCE PROJECTS THAT WILL STRENGTHEN GOVERNMENT-BASED INSTITUTIONS ARE NEEDED on a long term basis, so that an on-site project staff can be maintained and can perform effectively.

4. TRAINING INSTITUTIONS SHOULD BE STRENGTHENED as described in Chapter 4 so that an adequate pool of trained personnel becomes available.

5. THE ESTABLISHMENT OF MARINE PROTECTED AREAS SHOULD BE CONSIDERED as part of a Coastal Resources Management Plan integrating marine resource conservation with income generation and long-term growth.

6. NATIONAL AND REGIONAL CAMPAIGNS SHOULD BE MOUNTED TO ENHANCE SURVIVORSHIP OF THREATENED SPECIES through restricted harvesting, protective breeding, habitat enhancement and other management programs.

II

FISHERIES and MARICULTURE RESOURCES

The Caribbean fisheries sector is characterized by wide variations in marine habitat, resource distribution, level of industrial development, consumption patterns, economic conditions, administrative and social organization, and cultural heritage. Because of this diversity, regional development and management plans must be based upon strategies that are appropriate to the specific resources and circumstances of each country.

Fishery resources of the Caribbean are less abundant than those in adjacent waters of the Gulf of Mexico and southeastern coast of the United States. Upper limits of fishery resource abundance (particularly oceanic pelagic species) are set by primary productivity, which is in turn limited by availability of dissolved nutrients. The oceanic climate of the Caribbean limits upwelling of nutrients from deeper water, so that primary productivity is relatively low. In the case of demersal (bottom-dwelling) resources, upper limits are also set by the width of continental shelves and availability of suitable bottom habitat. Because of wider continental shelves and nutrient inputs from major river systems (e.g., Orinoco, Magdalena), demersal and coastal pelagic stocks of South and Central America are more abundant than those of the island archipelagos of the Caribbean. Despite these limitations, the fishery sector has considerable economic importance throughout the Caribbean:

- fishing and related activities are major sources of employment, income, and inexpensive high-quality protein;
- high value marine species (e.g., shrimp, spiny lobster and conch) provide foreign exchange;
- sportsfishing, snorkeling and scuba are an increasingly important part of tourist industries; and,
- mariculture has the potential to partially overcome natural limitations for increased production of fishes and other species for both domestic and export markets.

Because the opportunities and development requirements are distinct and different, capture fisheries and mariculture are discussed separately.

Fishermen casting a seine net for coastal pelagic fishes. (Photo: Meriwether Wilson)

CAPTURE FISHERIES

Background and Condition of the Resources

Definitive assessments of numbers and sustainable yields for the various Caribbean fishery resources are not available. Throughout the region there is a lack of reliable information on catch-per-unit effort which is compounded by the lack of standardized data on fishing power of different gears (e.g., traps, handlines, longlines, trawls, seines). Estimation of artisanal landings is even more difficult, as most of the catch landed is in remote areas and distributed locally. Formal statistics are rarely kept and there has been no comprehensive effort to estimate the extent of the catch using statistically valid sampling methods. During 1984 the reported landings were estimated to be 484,000 tons (1984, FAO), yet actual landings may be 2-10 times higher than those reported (1981, FAO). Seasonal and annual variations of the abundance and availability of living marine resources in the Caribbean region contribute to the lack of reliable and definitive data on these resources.

Fishing for reef fishes with a handmade net at sunset. (Photo: Meriwether Wilson)

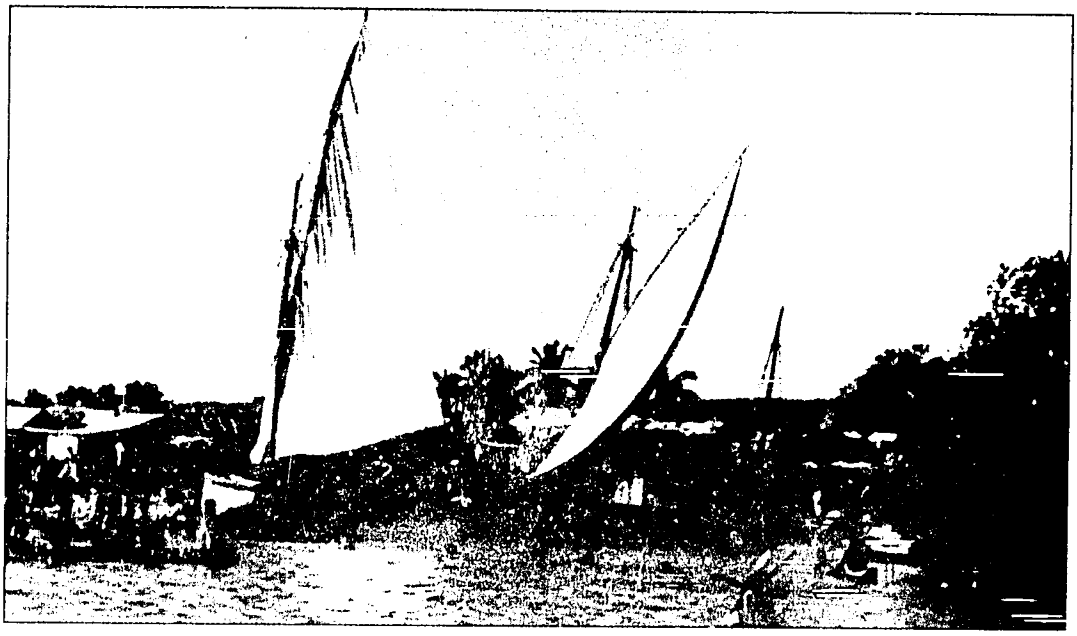
Reef Fishes

There are more than 30 species of commercially important reef fishes throughout the Caribbean. These fishes inhabit areas of hard bottom on continental and island shelves and oceanic banks, usually in depths less than 250 meters. Population size is often limited by the extent of available habitat.

Shallow-water reef fish species include grunts, parrotfish, squirrel fish, small snappers, and groupers. In deeper water near the shelf edge the catch is primarily silk snapper, blackfin snapper, vermillion snapper, and groupers belonging to the genera *Mycteroperca* and *Epinephelus*. Most reef fish species are long-lived with slow growth rates; characteristics that make these stocks particularly vulnerable to overexploitation. Management is complicated by the fact that most reef fishes have planktonic eggs and larvae, making stock delineation difficult.

The harvest of shallow-water reef fishes is done primarily with fish traps, while hand lines and occasionally traps are the primary capture techniques for deep-water reef fishes. The fishermen usually use small vessels which range from canoes to wooden boats of 7 to 10 meters in length, typically powered by outboard motors. Fisheries based on these resources are among the most economically important in Caribbean island states; they employ the majority of fishermen, and land more than 50% of the fishes consumed in eastern Caribbean islands. Overexploitation of the shallow-water reef species in specific sites has resulted in low catches, changes in species composition, and reduced mean sizes. Similar trends have been observed for some deep-water snapper stocks. On the other hand, fishing surveys have demonstrated the presence of underutilized, deep-water snapper and grouper resources on the outer portions of continental and island shelves and offshore banks in areas of the Caribbean where traditional fishing activity has been limited.

Fishermen in dugout canoes inspecting morning catch. (Photo: Craig McLean)



Sail-powered fishing boats docked in mangrove area. (Photo: Craig McLean)

Groundfishes

Groundfish species in the Caribbean include croaker, sea trout, catfish and porgy. Most require a broad, muddy bottom and depend upon estuaries during part of their life cycle. The primary Caribbean fishing grounds for these stocks are on the Campeche Bank off the Yucatan Peninsula, and in the river deltas of the Magdalena and Orinoco River systems off the coasts of Colombia and Venezuela, respectively. Significant groundfish stocks are also found along most of the northeast coast of South America, the islands of Cuba, Hispanola, and, to a lesser extent, Jamaica. Stocks are limited in the smaller islands of the eastern Greater Antilles, the entire Lesser Antilles archipelago, and the coast of Central America because of the narrow shelves and hard, rough bottoms that characterize these areas. These species share the same habitat as penaeid shrimp. Nearly 80% of the groundfishes harvested in the Caribbean are unintentionally taken in shrimp nets as bycatch and discarded at sea by commercial shrimp trawlers.

Coastal Pelagics

Pelagic fishes refers to fishes that primarily live in open ocean environments. This group includes pelagic species inhabiting the coastal waters of continental or island shelves. Most school in surface or near-surface water, and are found in areas of high plankton concentration along continental shelves and near areas of upwelling and riverine discharge.

Coastal pelagics can be subdivided into two groups. The clupeoids include various species of herrings, anchovies, and sardines, which are small, planktivorous and have a short life span. These species comprise the largest single group of fishes landed in the western central Atlantic. This resource is considered by many to be underutilized, though the actual potential yield has not been determined.

Large-scale commercial fisheries for clupeoids exist in Cuba, Colombia, and Venezuela, with most of the catch being reduced to fish meal and oil. The largest fishery for clupeoids in the Caribbean is for Spanish sardine off northeastern Venezuela. Artisanal fishing for these species also occurs throughout the region using beach seines, lift nets, and cast nets. However, clupeoid abundance in the Lesser Antilles is limited by the smaller shelf and lower plankton concentration.

The second group of coastal pelagics includes the larger, longer-lived predators such as scads, butterfish, halfbeaks, jacks and bluefish. Scads, halfbeaks, and butterfish are found throughout, but are most abundant in the same areas as the clupeoids. They form dense schools and are attracted to strong light sources at night. In contrast, jacks do not school densely, are often solitary, and their abundance varies seasonally. These behavioral patterns affect fisheries development potential as it is easier to catch large numbers of schooling fish than individual fish. No large, directed fishery for these species exists in the Caribbean but many are taken incidentally by the purse seine clupeoid fisheries of Cuba, Venezuela, and Colombia.

Oceanic Pelagics

This category includes numerous large species such as tunas, billfishes, dolphinfish, kingfish, sharks, and flyingfish which are predominatly found away from coastal areas, preferring open ocean environments. The important aspects of their biology are that they are widely distributed, migratory and seasonal, though there is a great deal of interspecific variability in these characteristics. For example, yellowfin tuna are distributed and fished throughout the western Atlantic, while flyingfish stocks and fisheries appear to be localized within the Lesser Antilles region. These differences have major implications for exploitation and management.

These pelagic fishes are usually exploited by boats ranging from canoes with outboard engines to large launches used for longlining with ice storage facilities. Although the composition of the catch varies between islands, dolphin, yellowfin tuna and kingfish are the most important large pelagics, and flyingfish the most important small pelagics.

The current state of exploitation and potential for expansion is unknown for most species. This potential varies between species. For example, yellowfin tuna are exploited throughout the western Atlantic by large commercial fleets, and the harvest may approach or exceed their potential sustainable yield. The catches taken by Caribbean countries are probably insignificant in relation to total catches worldwide. Sharks are wide ranging and little exploited, except as bycatch in the tuna fisheries. Flyingfish are primarily exploited by eastern Caribbean countries which may share a common stock.

Crustaceans and Molluscs

Shrimp are the most valuable crustacean resource in the Caribbean region. More than 90% of the shrimp captured belong to the genus *Penaeus*. All of the penaeid shrimp species share similar life histories, the most significant characteristics of which are the migration of juvenile shrimp from inshore estuaries to offshore spawning grounds, a short life-span (12 to 18 months), and high rates of growth, fecundity, and natural mortality.

Shrimp are abundant along the continental coast of Central and South America from Mexico to Brazil, and on the Cuban shelf. With the exception of Cuba, and to a lesser extent, the Dominican Republic, the Caribbean islands generally do not have sufficient estuarine habitat or shelf area to support shrimp populations. Trawl fisheries have developed in virtually all areas where shrimp are present in large quantities, including Mexico, Honduras, Nicaragua, Colombia, and Venezuela. Almost every country along the continental Caribbean from Mexico to Surinam has at least a modest trawl fleet for shrimp. In Costa Rica, Guatemala, and Panama, the shrimp fleets are concentrated in the Pacific, with limited activity along their Caribbean coastlines. Most, if not all, shrimp resources in the Caribbean are exploited at maximum sustainable levels. An undetermined amount of artisanal fishing for juveniles occurs in estuaries and lagoons using cast nets and beach seines from boats and canoes, while mature adults are usually caught offshore.

Spiny lobster (*Panulirus argus*) are found throughout the region. These animals are harvested primarily by divers with SCUBA and snorkeling equipment. Despite the simple harvest technology, a growing demand from both the United States and intraregional markets is stimulating fishing to the point that overexploitation of lobster stocks is becoming a problem of regional importance. There is little harvest from deeper waters, and lobsters in these habitats may constitute a

Queen Conch, a traditional native and popular tourist food, is becoming overexploited. (Photo: Marea Hatziolos)

"breeding reserve" that sustains the heavily exploited cohorts in shallow water. The size of spiny lobster populations, particularly in the juvenile stages, appears to be limited by the availability of suitable habitat. Assessment of lobster stocks is complicated by the possibility that planktonic lobster larvae, like those of most fisheries resources, are carried long distances by prevailing currents. Thus, heavy fishing in one area may affect stocks over a much larger area, making the effect of that fishing effort difficult to evaluate. Little is known about lobster stock delineations in the region (for further discussion on spiny lobster and conch management, see DuBois, 1985).

Crabs with commercial potential in the region include the blue crab *(Callinectes sapidus)*, "siri" crabs *(Callinectes danae)*, the stone crab *(Menippe mercenaria)*, and a large species of spider crab *(Mithrax spinosissimus)*, known as the Caribbean King Crab. Few assessments of crab resources have been attempted. There are pilot projects for culture of the Caribbean King Crab in the Dominican Republic, the Turks and Caicos, Grenada, and Antigua.

The most significant mollusc in the Caribbean is the Queen Conch (*Strombus gigas*) which has been harvested as a traditional food throughout the region. In the past, the location of conch grounds were often kept as family secrets. The conch has recently gained popularity in the tourist markets of the Caribbean and southeast United States. Like spiny lobster, conch are harvested primarily by divers, and concern is growing over the possibility of overexploitation.

Other molluscs with commercial potential are the mangrove oyster, and various species of squid, octopus, and clam. Assessment of stocks is difficult because the majority of mollusks taken in the region are harvested by artisanal fishermen and not reported. Currently underutilized squid species found throughout the region hold the greatest potential for increased mollusc production.

Characteristics of the Fishing Industry

Commercial Fisheries

Large-scale commercial fisheries are highly capital intensive operations, usually centered in urban areas. They provide most canned and frozen fishes as well as fishes reduced to fish meal and oil. They use large mechanized vessels, such as trawlers and purse seiners, and are directed at specific species, such as shrimp, tuna, or clupeoids. They also require extensive support facilities for processing and marketing. Commercial fisheries are not common in the Caribbean. Notable exceptions are Cuba, Mexico, and Venezuela which have large fleets capturing shrimp, sardines, anchovy, and tuna. Apart from Cuba, commercial fisheries are not found in the islands of the Greater and Lesser Antilles.

Artisanal Fisheries

Artisanal fisheries are labor intensive, usually located in rural and coastal areas, and use low-level technology to produce fishes primarily for local consumption. Extremes of boat-type range from predominantly sail-powered in Haiti, to the "ice-boats" of the Barbados fishing fleet. The latter vary from 12-18 meters in length with 5000-10,000 kilogram capacity ice-holds. They remain at sea for 4-14 days, targeting primarily flyingfish and dolphinfish (Goodwin et al., 1985).

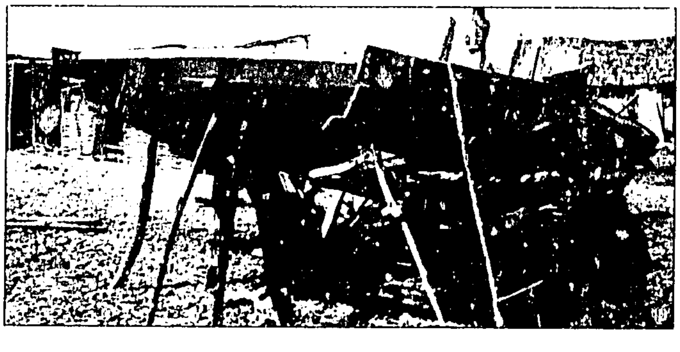
Many artisanal fishermen fish only part-time and supplement their incomes with other types of labor. Little information is available on the incomes of artisanal fishermen, but they are consistently ranked among the lowest socioeconomic groups in the Caribbean. Much artisanal fishing is conducted for subsistence purposes, i.e., to directly meet the nutritional needs of the fisherman and his family. Artisanal fisheries are present in every country in the Caribbean region and are the only form of commercial fisheries in the islands of the Greater and Lesser Antilles (with the exception of Cuba).

Recreational Fisheries

Recreational fishing includes all fishing conducted for sport and relaxation. Typically, sport-caught fishes are not sold in the Caribbean, though they are frequently bartered. At present, recreational fishing is not a major component of marine fisheries in the Caribbean even though a potential exists for including marine recreational fishing as an integral part of tourism and fisheries development strategies. However, marine recreational fishing is growing in importance, particularly in the Bahamas, the Cayman Islands, Turks and Caicos Islands, Jamaica, Puerto Rico, the United States and British Virgin Islands, Mexico, Belize and Venezuela.

Olson and Wood (1983) provide one of the few characterizations of Caribbean marine recreational fishing, contending that such fishing in the U.S. Virgin Islands is representative of sportsfishing in other Caribbean island nations. They conclude that marine recreational fishing is composed of subactivities which account for the following general percentages of total sportsfishing effort: trolling (18.3%), bottom fishing (4.9%), spear fishing (12.7%), lobster diving (17.3%), conch diving (7.3%), whelk diving (7.3%), fish and marine life observation via snorkeling (23.5%), fish and marine life photography (6.4%), and other activities (2.3%). These authors report that total recreational landings are generally comprised of oceanic pelagics (12.2%), coastal pelagics (15.9%), shallow water reef fishes (67.3%), lobster (2.0%), conch (1.3%), and whelk (1.3%). These exact percentages will not apply to other areas, but may identify the importance of various activities and target species groups.

There is growing recognition of the potential of recreational fishing in the Caribbean. The fourth session of the Western Central Atlantic Fisheries Commission recommended in 1983 that recreational fishing statistics for the Caribbean be collected and that the role of recreational fisheries in Caribbean tourism development be examined. A series of presentations on development of marine recreational fisheries at the 38th Gulf and Caribbean Fisheries Institute pointed out that sportsfishing could be developed as a tourist attraction to maintain the appeal of the Caribbean to tourists, as well as to help increase the supply of seafood to local markets, stimulate growth of support industries (bait and tackle, charter boat businesses, etc.). It would also help generate additional support for improved management and conservation of fishery resources and associated habitats. Similar conclusions are presented in a number of Caribbean marine resource development studies (DOSP, 1985).



Construction of wooden fishing boat. (Photo: Craig McLean)

Constraints to Economic Development and Management

Technical Constraints

Limited Knowledge of Available Resources

Stock structure and potential yield are not adequately known for any marine fisheries resource in the Caribbean. The lack of reliable information on the extent of fisheries stocks makes it difficult to determine the appropriate scale for harvest and post-harvest facilities. The same deficiency coupled with inadequate understanding of the life history of these stocks complicates attempts to manage these resources for optimum benefit.

Inadequate Gear and Technology

The efficiency of artisanal fisheries in many areas is limited by the equipment and methods used in capture. These same limitations are constraints to development of under-utilized resources.

Lack of Marketing and Processing Infrastructure

Much of the catch is sold at the landing site, either directly to consumers or to middlemen who distribute the catch to a limited local area. The absence of cold storage, processing facilities (e.g., drying, salting, smoking), and an organized distribution system prevents the supply of fishes to inland areas and inhibit the harvest of seasonally abundant fishes; therefore, catch is limited to what can be sold immediately.

Institutional Constraints

Lack of Trained Staff

Fisheries administrations are generally hampered by a shortage of qualified personnel, and responsibilities are often divided between several governmental agencies. These problems hinder efforts to collect reliable information and slow or prevent the establishment of extension programs that can provide needed services to artisanal fishermen. Funds for on-site training or hiring of additional trained staff are scarce.

Low Priority of the Fisheries Sector

Fisheries development in many third world countries has been constrained by a legacy that favors agricultural production. This is reflected in:

The catch is usually sold at landing sites as marketing and processing systems are inadequate for shipment elsewhere. (Photo: Craig McLean)

- low priority of fisheries development efforts by national country governments and donor agencies alike;
- a lack of country-specific fisheries development plans with clearly defined objectives; and,
- inadequate fisheries legislation.

Questionable Economic Potential of Fishing

Uncertainties as to size of fishery stocks and probable effects of increased fishing efforts result in the oft-stated problem of inadequate financing and credit. This prevents fishermen from purchasing equipment and gear needed to increase their catch, and hampers development of simple processing and marketing systems.

Other Constraints

Ciguatera

Certain fishes caught in various parts of the Caribbean are contaminated with a potent toxin. Human ingestion of this toxin causes a poisoning syndrome known as ciguatera that affects the central nervous system causing sensory reversal and hallucinations that can last for months. Gastrointestinal disorders have also been reported. The treatment is symptomatic and varies with location as no antidote is currently known. (Tacket, 1981). The toxin thought to be responsible for the human poisoning is named ciguatoxin (CTX) and is believed to be produced by marine dinoflagellates that are found in the fishes (Scheuer, et al., 1967). The toxin is most prevalent in snappers, groupers, and other bottom-dwelling species and is only rarely found in pelagic fishes.

It has been proposed that the benthic dinoflagellate *Gambierdiscus toxicus* is directly related to the abundance and occurance of ciguatoxic fishes in the Pacific (Yasumoto, et al., 1979). This species has been reported in the coastal waters of Florida and the U. S. Virgin Islands, but there has been no direct evidence linking this dinoflagellate with ciguatoxic fishes in the Caribbean (McMillan, et al., 1980).

The incidence of poisoning has reached ten cases per thousand residents per year in St. Thomas and Puerto Rico (Tacket, 1981). It may be occuring in the wider Caribbean and the risk of ciguatera reduces the domestic and export market potential for fishes from many areas. Tourists consuming affected species in restaurants and aboard cruise ships have experienced the poisoning. The Sea Grant extension office of NOAA has received various proposals to reduce or eliminate ciguatera poisoning through research to characterize the toxin and to develop a dockside test, based on comparative color changes in fish scales (Attaway, D., pers. comm.). There have been two conferences on ciguatera, in Puerto Rico during 1980 and 1985, to expand the knowledge and to discuss the need for solutions of this health problem in the Caribbean.

Conflicts between Fisheries Sectors

Development of recreational fisheries may create conflicts between commercial and recreational fishermen for the limited resources (e.g., lobster, conch, reef fishes), and may contribute to deterioration of reef habitats due to collecting activities. These conflicts are less likely where pe gic species (e.g., billfish, tuna, wahoo, dolphinfish) are the target of recreational fishing.

The need to protect vital marine habitats often appears to conflict with other economic activities such as tourism and industry, but such conflicts can be reduced or eliminated through comprehensive management and development planning (see Chapter I, Nearshore Marine Habitats).

Marine Pollution

Nearshore fishery resources and some offshore stocks are dependent upon coastal habitats for food, shelter, and breeding grounds. These habitats are increasingly jeopardized by human activity as discussed in the first chapter on nearshore marine resources and habitats. Pollution problems affecting fisheries resources include:

(1) **Fish Kills:** There are increasing reports of relatively large-scale fish kills in some Caribbean countries, although the causes in most cases remain obscure. Many appear to be due to natural causes such as, subtle shifts in plankton ecology, but some cases attributed to chemical pollution have been documented in semienclosed water bodies in Trinidad (Atwood, 1982).

(2) **Plastic Refuse in the Sea:** Death of fishes, marine mammals, turtles and birds is caused by drowning and strangulation through trapping in plastic boxes, plastic bags and nylon fishing gear. Ingestion of undigestible plastics leads to illness and undernourishment, eventually with fatal results. Plastics in the sea are a result of disposal of trash from ships, loss of fishing gear, runoff containing land-based litter and inadquate land-based disposal technologies of countries in the Caribbean and worldwide (Paine, R., Corredor, J., and Richardson, Q., pers. comm.).

(3) **Petroleum Pollution:** Animals of at least one protected species, the Hawksbill Turtle, feed on floating tar from tanker ballast washings, causing illness and death. Data on turtle strandings from the Florida Department of Natural Resources show that strandings are highest along coasts with the most serious tar contamination.

(4) **Domestic Sewage:** A study of the harbor of Kingston, Jamaica, showed high bacterial levels along the entire northern shore of the harbor, possibly associated with fish kills in the area (Chow, 1985). In 1974, fewer than 10% of sewage systems in the Caribbean region had any treatment facilities. There is no indication that the situation has improved in the intervening years, nor that treatment capacity is keeping pace with growth of resident and transient populations. With the exception of Panama, less than 50% of the population of Caribbean countries is served with sewage systems. In the eastern Caribbean the figure is less than 15%.

(5) **Toxic Metal Pollution:** Concentrations of mercury above the EPA-approved limit have been documented in fishes at Guayanilla Bay, Puerto Rico. The closing of a soda plant at Cartagena, Colombia resulted from concerns regarding rising levels of the same toxic metal in the marine environment.

(6) **Agricultural Runoff:** Surplus nutrients provided by fertilizers favor rapid growth (blooms) of algae. The algae subsequently die and decay causing a shortage of oxygen which may result in fish kills. While there have been no substantiated cases of such events in the Caribbean, there is some evidence that it may have happened. Pesticides, including DDT and DDE, have been found in the tissues of reef-dwelling groupers in the Gulf of Mexico and Grand Bahamas. Analyses of shrimp and fishes from the Gulf and northern Caribbean have shown these pesticides to be widely distributed but at very low levels.

Opportunities for Improved Management and Development

Direct benefits from development within the fishery sector are likely to accrue almost entirely to local populations. Because of the resource limitations described above, the dollar value of such benefits are modest relative to other activities and to fisheries in temperate climates. But even at a modest scale, these benefits can be significant within the economic and social context of Caribbean countries. The Eastern Caribbean islands are characterized by high population densities along the coast. As a result, artisanal fisheries are especially significant in the numbers of people employed and the production of high protein food. These fisheries are estimated to supply 50% of the effective demand for fishes in the eight English speaking islands of the eastern Caribbean.

In addition, indirect impacts on other sectors can produce benefits beyond the individual countries. Tourism, for example, may be enhanced by the availability of a diverse array of local seafood and the opportunity to engage in fishery-related activities. Such enhancement benefits foreign investors in the Caribbean tourist industry and increases the retention of tourist dollars in local economies. Perhaps even more significant are the indirect international benefits from improved local nutrition, employment, and income. These benefits help increase local political stability, thus improving the environment for international investors and general economic growth. Conversely, loss of these benefits through poor fisheries management or inappropriate development can have negative impacts far beyond those within the immediate fishery sector.

Five general benefits may be realized through application of appropriate management and economic development strategies:

- increased fisheries output to meet the protein needs of local populations and to reduce imports;

- increased income and employment in the fishery sector;

- improvement of processing and marketing of selected species, thereby increasing value-added from the industry as well as providing employment;

- provision of a source of foreign currencies by exporting surpluses of high priced fish species; and,

- servicing tourist population through restaurant trade.

It should be appreciated that these benefits are attainable in an overall context but not for each specific fishery. For example, development of overexploited resources requires a reduced harvest in the short-term to allow an increase in stock sizes that will permit higher sustainable yields. In contrast, development of underutilized fisheries requires increased fishing and marketing capacity. In both cases, development must be accompanied by a management system that ensures the economic health of the fishery and is not threatened by overexploitation and stock collapse. Specific opportunities to achieve these benefits include:

Increased Landings of Oceanic Pelagic Fishes

These are generally considered to hold the greatest potential for development in the eastern Caribbean. The larger oceanic pelagic species are of value to sports fishermen, and have considerable potential for the development of recreational fisheries and tourism.

Increased Groundfish Production in Fisheries of the Campeche Bank, Colombian and Venezuelan Coasts

Increased production can be achieved by more complete use of bycatch from shrimp trawlers; a development which depends on an improved market demand for discarded groundfishes. Mexico, Cuba, and Guyana have been attempting, with varying degrees of success, to efficiently use this bycatch for both human consumption and nonedible fish products such as fertilizer.

Small-Scale Improvements to Artisanal Fisheries

Improvements to Fishing Efficiency

Because the majority of artisanal fishermen are employed in other occupations (e.g. agriculture), an increase in the efficiency of existing fishing technologies can provide a greater catch-per-unit-effort, allowing more time for other remunerative activities. The use of fish aggregating (FADs) devices is an example of such an improvement.

Improvements to Vessel Safety

In the Caribbean region fishermen are lost at sea every year partially due to poorly equipped and maintained vessels. These losses could be reduced through provision of basic safety equipment and survival knowledge that are generally lacking in artisanal fleets.

Improved Capabilities for Harvesting Underutilized Coastal Resources

Deepwater bottom stocks, squid, octopus, and coastal pelagic fishes may have significant potential for artisanal-scale harvest, though the location and extent of these resources have not been precisely determined.

Development of Recreational Fisheries

Few statistical data exist on the nature and extent of marine recreational fisheries in the Caribbean, but the potential for development is suggested by the British Virgin Islands where recreational landings (93 metric tons) accounted for an estimated 12% of the total marine fish landings in 1982. This represents a fourfold increase between 1975 and 1982 which can be largely attributed to expansion of the local charter fishing fleet, increasing popularity and number of sport fishing tournaments, increasing popularity of sport diving (snorkeling and SCUBA), and the general growth of the tourism industry.

Improvements in Post-Harvest Processing and Marketing

Most Eastern Caribbean countries experience alternating periods of shortage and glut in local fish markets coinciding with seasonal availability of oceanic pelagic fishes. Fishermen cannot get high prices for fishes that do not have market outlets or which spoil due to poor processing and preserving technologies. These conditions reflect the inadequacy of existing processing and marketing facilities, and in many cases are a disincentive for increased landings.

Improvements in landing and processing facilities are needed to increase fishing efficiency. (Photo: Craig McLean)

Requirements for Economic Development and Resource Management

Effective management and development of Caribbean fisheries requires that harvest efforts and marketing capacity be matched as closely as possible to the potential yields of the specific fishery resources. There is need for country-specific resource plans in which the goals of management and development are set by the socioeconomic conditions of each country. For example, there is a trade-off between maximum economic profitability, total catch and employment. Such plans improve linkages between sectors, for example, between recreational fisheries, tourism, commercial fisheries, and private business (Schmeid, 1985).

Because oceanic pelagic resources and many demersal resources have planktonic (free-floating) larval stages, stocks are shared between neighboring Caribbean countries. Ultimately a coordinated subregional or regional approach will be necessary for effective development and management of these fisheries. The potential for developing recreational fisheries and the importance of migratory coastal and oceanic pelagic species to these fisheries argues for development of cooperative interjurisdictional management programs. To meet these requirements, development assistance is needed in four areas:

1. Improved Information for Development Planning

Three major issues must be addressed: (1) the extent to which stocks are shared among Caribbean states; (2) the abundance, life history and potential yield of fishery stocks; (3) trends in abundance of the stocks in relation to exploitation. Basic information on catch and effort can be used to detect trends in abundance, to analyze stock changes, and to model fisheries production. Local fisheries personnel may require assistance with species identification, basic protocols for recording catch and effort data, and standardization of effort units in fisheries which use several different types of gear to exploit the same resource.

Support for fishery-related research should be targeted toward projects with clearly defined and tangible objectives, particularly if they are addressing the questions of stock delineation or potential yield. Projects assessing potential yield that warrant further attention include: estimates of the area of suitable habitat for demersal stocks, investigations of the distribution and real abundance, and information on life histories of pelagic stocks. Development of recreational fisheries requires country-specific evaluations of the present status of sportsfisheries, and the availability of goods and services essential to the sport.

2. Improved Resource
Management Capabilities

The managerial capacity of most national fishery agencies needs to be strengthened through:

- administrative training for senior personnel;
- broader technical training for mid-level staff;
- generation of comprehensive, resource-specific development and management plans;
- appropriate legislative framework for management;
- effective surveillance and enforcement capability;
- establishment of a licensing system for fishermen; and,
- mechanisms to develop and enforce limited entry.

3. Improved Fishing Capability

Development of underutilized resources requires pilot scale fishing projects for specific stocks discussed above. Because such resources are likely to be limited, pilot operations should employ technology that ultimately may be applicable on a sustained basis for artisanal and commercial fisheries. Further development of these resources will require capital and training to improve gear and boat capabilities in local fleets.

Improved fishing capability may also be desirable even if the resource is near maximum sustainable yield if the objective is to improve cost-effectiveness of catch rather than total catch. Improving fishing capability may sometimes be achieved simply by facilitating the exchange of existing fishing techniques between Caribbean countries.

Options for improving the harvest (e.g., fish aggregating devices for oceanic pelagic fishes) and abundance (e.g., artificial reefs for nearshore demersal fishes) have been explored on a trial basis in the Caribbean with positive results. These techniques need to be refined for optimal application to artisanal and recreational fisheries.

Training given to fishermen often is not well-suited to local conditions. One reason for this is that local fishermen usually are not consulted prior to the training. Training is often designed by uninformed outside "experts" according to their idea of what is appropriate. Artisanal fishermen tend to be highly individualistic. Because they generally know their trade quite well within the limits of their technical knowledge, these fishermen are frequently skeptical of outside offers of assistance. Training must be done by individuals who can:

- work in the fisherman's environment,
- win his confidence by demonstrating equal or superior skill, and
- apply the most appropriate technology according to local conditions.

The need to understand established fishery systems also extends to better understanding the role of women in the

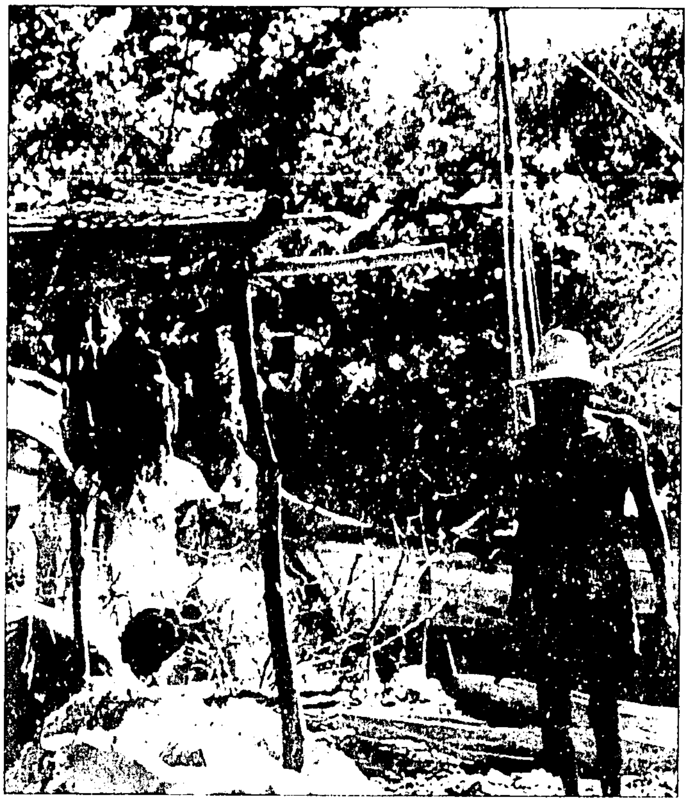
In many rural areas women play an important role in the marketing and distribution processes of fisheries resources. (Photo: Craig McLean)

marketing and distribution process. Most efforts to develop these sectors have been directed at men. In many rural, traditional economies women play an important role, often, but not always, behind the scenes. The extent to which this is true in the Caribbean will vary from area to area and should be considered.

Caution is needed in regard to further development of capital intensive fisheries in the Caribbean. Most species presently targeted by large-scale fisheries are already fully exploited. In addition, the abundance of species which are reportedly underutilized, such as squid and certain clupeoids, has not been assessed but appears to show strong seasonal variation. There is a high risk factor inherent in the capital intensive nature of commercial fisheries. Development of this sector can create severe financial problems if actual production falls short of projections. Such problems can be difficult for large countries with a broad economic base; they can be disastrous for the fragile economies of small island nations. From harvest vessel to processing, large-scale fisheries require highly trained personnel at all levels; a resource in short supply in most Caribbean countries.

4. Improvement of Marketing
and Distribution

Landing gluts and large post-harvest losses are often



Long-term storage and preservation facilities do not exist in many rural areas. Hanging fish to dry on racks in the sun is a common local preservation method. (Photo: Craig McLean)

characteristic of small-scale fisheries in the Caribbean. Development of simple, low-cost techniques for post-harvest handling, utilization, and marketing could increase supply of fishes as well as incomes of fishermen and intermediaries. These improvements are indicative of those with the greatest potential to contribute to growth and expansion of the Caribbean fisheries sector.

Recommendations for Development Assistance

The opportunities, constraints, and requirements discussed above suggest that rational economic development of Caribbean fisheries depends upon a sound basis for resource management, but it is also true that such management can be justified and achieved only if increased economic benefits are realized from the fisheries sector. Assistance should focus on long-term programs with well defined goals rather than "quick-fix" solutions to complex problems. These programs should be implemented through existing regional institutions using regional expertise whenever appropriate. For these reasons, it is suggested that the needs for resource management be met in the context of the following economic development activities:

1. DEVELOPMENT OF UNDERUTILIZED RESOURCES

Exploratory operations to harvest underutilized stocks, which are identified in previous sections, should be supported. In addition to locating stocks and evaluating harvest techniques, these pilot operations should be used to obtain estimates of abundance needed to determine the level of capitalization appropriate for optimum sustained use. (Munro, 1983, suggests that this is often the most effective means for obtaining such information.) These operations should be undertaken at the local level, using a small number of vessels suited to local conditions. An incremental approach to the development of new resources is needed. The level of capitalization should be adjusted to the best information available to determine the capacity of the resources required to support the harvest. These same operations provide an opportunity to address research needs and improve resource management capabilities through attention to requirements discussed earlier.

Satellite technology can be applied to fisheries development. By using present satellite remote sensing technology, delination of the three dimensional circulation of the Caribbean can be improved. This is best achieved with high resolution sensors in narrow visible and infrared wavelength bands. A Coastal Zone Color Scanner (CZCS) can be used to detect chlorophyll concentrations while an Advanced Very High Resolution Radiometer (AVHRR) can be used primarily to estimate sea surface temperatures.

2. IMPROVEMENTS TO SMALL-SCALE FISHERIES

The potential for economic development in the fisheries sector depends largely upon small-scale fishermen. Necessary improvements to artisanal fisheries are discussed in the requirements section, and depend in some degree upon the development of underutilized resources as described above. All improvements require effective mechanisms for extension of information and technology to artisanal fishermen, and such mechanisms should be developed immediately.

Projects to establish credit opportunities are often needed to support effective local extension services. The issue of vessel safety, in particular, provides an opportunity to build extension capabilities necessary for economic development as well as to meet a serious current need. Fishermen usually do not have the immediate financial means to maintain, upgrade or expand equipment needs. Assistance agencies can provide credit opportunities, yet incentives such as local involvement and project success are often needed to repay loans.

Contact with local fishermen developed through extension services also provides an opportunity to acquire critical information needed for management and development planning. Catch and effort information is fundamental to addressing the issues described in the "Requirements" section of this chapter. Coupling acquisition of such information with extension activities will encourage cooperation and provide an opportunity to involve fishermen in the resource management process. Information on the status and biology of exploited stocks is essential to optimum use of these stocks in small-scale fisheries, and directed research to meet this need should be supported where information from local catch is insufficient.

Support should also be provided for projects directed toward establishing appropriate legislative frameworks for management. There is a strong need to obtain effective surveillance and enforcement capabilities of fisheries harvest efforts, coupled with the development of incentives to comply with laws.

3. PROCESSING IMPROVEMENTS

Support should be provided for activities to reduce gluts and post-harvest losses through such activities as:

- promotion of improved handling techniques (e.g., gutting, icing) at sea and on shore to reduce the amount of time that fishes are out of water and exposed to the sun;

- provision of short-term cold storage facilities at local landing sites;

- promotion of simple processing methods (drying, salting, smoking, etc.) which could be carried out at the landing sites using inexpensive low-level technology with sophisticated processing methods where appropriate; and,

- promotion and recognition of projects that involve women and fishermen's family members.

4. MARKETING IMPROVEMENTS

Projects to improve the distribution and marketing of Caribbean fishery resources should be supported. Development mechanisms to supply inland markets with fish protein, and external markets with high value or exotic fishery products are needed. Promising activities for such support include regional or subregional information centers and projects to develop simple marketing and distribution systems which could help alleviate the geographical and seasonal supply and demand variations.

5. APPLICATION FOR TECHNIQUES FOR IMPROVING ABUNDANCE AND HARVEST

Support should be provided for a systematic expansion of the use of artificial habitats and fish aggregating devices. In addition to meeting immediate local needs, such projects should be designed to improve this technology by answering such relevant questions as optimal deployment strategy, efficiency in design, and species selectivity.

6. DEVELOPMENT OF RECREATIONAL FISHERIES

Establishment of recreational fishing enterprises should be encouraged. Capital financing for recreational fishing vessels should be available through existing lending institutions. The primary development need is for reliable site-specific information on the economic potential of such enterprises. Support should be extended to projects which will provide such information, ideally through pilot-scale operations as described for underutilized resources. These operations can generate an economic development context for international cooperation for use in acquiring the information needed on oceanic pelagic stocks described in the preceding sections.

Activities such as spearfishing and diving for lobster or conch are often featured in sportsfisheries development, but are clearly inappropriate in most Caribbean countries as they target stocks that are already heavily exploited. It is imperative that development of recreational fisheries be undertaken within a regulatory framework which assures protection of critical habitats and fishery resources. A useful starting point might be exchange of information on the development of fishery management plans for billfishes in the Atlantic, Gulf of Mexico and Caribbean areas.

Table 4:

FISHING VESSELS AND GEAR COMMONLY USED IN THE CARIBBEAN

BOATS

- Traditional canoes, outboard powered.
- Carved and built wooden dinghies, 4-5 m, sail powered.
- Double-ended whalers, 6-10 m, outboard powered.
- Small decked sloops, 8-10 m, diesel powered.

FISHING GEAR

- Trolling lines, used while boat is underway or drifting.
- Bottom hand lines, in depths of 20-200 meters.
- "Z" shaped traps, wooden stakes reinforcing chicken wire.
- Gillnet, used primarily for the capture of flying fish.
- Beach seines, most traditional gear for organized fishing.
- Diving, often with SCUBA equipment, for conch and lobster.
- FADs, growing interest in fish aggregating devices of all types; research shows that catch rates have been increasing with the use of benthic FADs such as artificial reefs, as well as open water, sub-surface devices.

Source: National Marine Fisheries Service, Foreign Fisheries Analysis Branch

MARICULTURE

Background

Aquaculture is an overall term, referring to farming activities involving the culture and husbandry of aquatic organisms in fresh, brackish, and marine waters. Mariculture is specific to culture of marine organisms and is the focus of this section. Caribbean mariculture was first initiated by the United Nations Food and Agriculture Organization (FAO) with brackish water tilapia and carp culture in the 1950s. This has generated substantial interest in the last few years. Limitations of capture fisheries, efforts to reduce imports and expand exports, and the need for economic diversification have contributed to public and private sector interest in the culture of high-valued marine species for export and less expensive species for local consumption.

The Western Central Atlantic Fisheries Commission, at its November 1980 session in Havana, identified mariculture as one of the priority areas for development of fisheries in the Caribbean Region. Two missions were fielded in the early 1980s to examine freshwater and marine aquaculture possibilities in Antigua, Bahamas, Barbados, British Virgin Islands, Cayman Islands, Grenada, Montserrat, St. Lucia, and Turks and Caicos. As follow up to these missions, a working group was convened in October 1981, which concluded that adequate justification existed for attempting to develop mariculture throughout the region. This position was reiterated in August 1986 at the 19th Regional FAO Conference for Latin America and the Caribbean.

The physical characteristics and resources of the region indicate considerable potential for coastal mariculture. Many Caribbean countries are endowed with long coastlines dotted with protected bays, coves, harbors, and lagoons; relatively fertile brackish water estuaries, mangrove swamps and other wetlands; large areas of coastal land with marginal agricultural potential; and a tropical climate favoring year-round growth. The presence of edible or commercially valuable species of crustaceans, mollusks, fishes, seaweeds, etc., also favors the development of coastal mariculture systems.

Early attempts at mariculture development were restricted primarily to the larger islands and the mainland of South and Central America. These efforts centered around species of shrimp, mangrove oysters, and both native and exotic fish species which could serve as a source of income and protein to coastal and inland populations. This experience was not readily transferable to smaller islands of the eastern Caribbean, because of environmental and economic differences.

Recently, considerable research has been undertaken to determine which species are best suited and appropriate for mariculture development in the island countries. The UNDP/FAO Aquaculture Development and Coordination Programme (ADCP) reviewed a number of species and determined that those with the best short-term outlook for development are snapper, grouper, dolphinfish, mussels, and mangrove oysters. These species were chosen based on existing demand for the product, and because they can be cultured using existing technology with low capital requirements. Other species suggested by various experts include eels, pompano, mullet, Caribbean King Crab, shrimp, algae, and brine shrimp. In the long run, coastal mariculture development is seen as the area of greatest potential using the extensive coastal environment to produce large quantities of native and exotic species.

Considerable interest has been generated in development of culture systems for species of mollusks and crustaceans that could be exported to generate foreign exchange. Although local species are obviously preferable, from the standpoint of seed availability, disease resistance and environmental considerations, much of the available technology in the field is for species that are not native to the region. Rapid growth and favorable behavioral traits have made culture of these species more desirable, at least in the short-term. More emphasis should be placed on identifying appropriate technologies for native species culture. The relative costs and benefits of local vs. exotic species must be carefully evaluated on a case-by-case basis before investing in long-term programs.

As noted above, mariculture can be a very complex operation, requiring a high level of investment and a certain degree of technology. Disease and predation can be major problems. Commercially successful mariculture operations therefore require careful planning and good business judgment as well as in-country support for associated industries, e.g., feed and fertilizer production, electricity, and transportation. For a more detailed review of mariculture issues and operations in the Caribbean, see Goodwin, et al., (1985).

Constraints to Mariculture Development

Weidner (1985) describes a number of factors constraining the development of shrimp culture. Many of these are also relevant to other mariculture activities and have been adapted in the following discussion.

Economic Constraints

a. Risk: This is a major constraint to Caribbean mariculture. The high level of risk and uncertainty inherent in mariculture operations often makes it difficult to justify investing large amounts of human and financial capital into activities that have yet to prove commercially successful (exceptions are penaeid shrimp culture in the Dominican Republic, Panama, Honduras, Belize, and Guadeloupe). Most countries of the region lack capital for investment in mariculture, especially at the rural level.

b. Fluctuating costs and returns: The economic health of mariculture operations can be rapidly altered by a variety of factors which are largely beyond control of the culturist, including world prices for the product, demand in international markets, fluctuating interest and exchange rates, and production costs.

Technical Constraints

a. Lack of biological information: Much of the biological information relevant to mariculture (particularly of indigenous species) is not available.

b. Availability of seed stock: Progress in development of hatchery technology has been slow for many species, necessitating a reliable natural source of eggs, larvae, or juveniles.

c. Lack of technology: The culture of many native species is dependent upon technologies that are more appropriate for particular exotic species. This can have a negative impact on projects especially when culturing penaid shrimp, for which the technology is best known for Pacific species, e.g. *Penaeus vannamei*, *P. stylirostris*, and *P. monadon*.

d. Availability of suitable culture sites: Many types of mariculture have requirements related to specific site characteristics such as soil type, vegetation, and water quality. The culture of clams, oysters, or mussels, for example, generally requires a source of water rich in microscopic algae; such waters are not common in many parts of the Caribbean. For shrimp culture, sites with tidal flushing or access to clean sea- water in non-acid, compact soils are required. Improper siting of mariculture operations result in the alteration of biologically productive areas and ecological support systems. Examples include the destruction of mangroves for shrimp ponds, nutrient loading of nearshore waters, and salinization of adjacent agricultural lands.

e. Disease: This is a problem especially in hatchery reared juveniles due to contamination in monoculture situations.

f. Food processing and feed manufacturing technology: These may not be developed in areas suitable for mariculture. Importation of feeds may be a financial disincentive.

g. Hurricane susceptibility, droughts, and water quality shifts: Cultured organisms may be more vulnerable to environmental variations.

Institutional Constraints

a. Lack of supporting infrastructure: Many Caribbean countries lack the facilities needed for research to carry out local adaptation of existing technology. There is a similar shortage of trained and experienced mariculturists, technicians, extension workers and managers.

b. Government policy: There is a general lack of policies and legislation to provide continuing support for successful mariculture development, demonstration, and extension.

c. Competiton for coastal land from other sectors: Development options with more immediate economic returns such as tourism and real estate may use sites that would be feasible for mariculture.

d. Domestic, foreign, import and export regulations: There may be restrictions against the introduction of exotic species in some countries. Experts of cultured shellfish must meet rigorous U.S. Food and Drug Administration requirements for quality control prior to admission to U.S. markets.

Opportunities for Economic Development

The 1981 FAO Working Group identified several factors that illustrate overall goals and needs that can be met through mariculture development. These include:

- diversification of the narrowly based regional economies and increase in foreign exchange earnings;

- improvements in balance of trade through fisheries imports; and

- rehabilitation of fisheries where overfishing may be occurring.

Potential for addressing these needs through mariculture is indicated by:

- increase in the use of underutilized marine resources;

- the variety of culture opportunities and income generation for small holders, fishermen, private entrepreneurs and multinational companies; and,

- the probability that economically stable and appropriate mariculture systems can be developed within a reasonable period of time.

Review of past and current mariculture projects suggests that a number of opportunities for mariculture development exist. Opportunities will vary from country-to-country depending on the local physical and economic environment and the available resource base. Although opportunities for freshwater aquaculture do exist in the Caribbean and have proved to be commercially successful, the following discussion is confined primarily to the culture of marine species. It is based primarily on UNDP/FAO (1981) and Goodwin, et al., (1985).

Finfish Culture

At present, finfish culture in the Caribbean is limited to projects in Martinique, the Bahamas and Jamaica. Although these are in the experimental stage, results appear promising and pilot studies should be supported. Finfish culture can help to reduce the region's dependency on fisheries imports and provide opportunities for selective harvest of fishes without ciguatera. Under optimal conditions it is best to have local hatcheries for cultured species to sustain commercial production, though it may be possible for culture operations in many locations to be supplied from a single hatchery.

Technology for cage culture of snapper and grouper is well developed in certain parts of Asia and may be adaptable to local Caribbean species. European sea bass *(Dicentrarchus)* have been cultured commercially in Martinique for several years, and exported to France, using relatively simple technology. Experimental culture of indigenous Caribbean species, particularly jacks, has shown promising results. Redfish (*Sciaenops ocellata*) and hybrid striped bass (*Morone saxatilis* hybrids) have similar culture requirements. Culture of redfish has been tried in the Bahamas and is proposed for Martinique. Technologies for fingerling production ponds and grow-out have been developed in the United States, and may be applicable in the Caribbean.

Culture of the freshwater species of tilapia is well developed worldwide, but is primarily for local consumption. The Caribbean Marine Research Center in the Bahamas is experimenting with mariculture of two species of tilapia *(Tilapia aurea and T. mossambica)*. About 2500 tilapia have been successfully raised in saltwater cages and shipped to needy families in Haiti (Finkle, E., pers. comm.).

Crustacean Culture

Marine Shrimp

There has been considerable interest expressed throughout the Caribbean and Central America in the culture of marine shrimp. Success has varied depending upon site-specific ecological and economic conditions. The success of projects in Ecuador and Panama have been due to large land areas adjacent to estuaries, that provide ideal culture conditions and post-larvae stock. A local supply of broodstock can reduce problems due to transportation and quarantines. At present, culture technology is more developed for the exotic Pacific species, *Penaeus stylirostris* and *P. vannamei*, than the native, slower growing Caribbean species, *Penaeus schmitti*, which is found along the coast of South America. Marine shrimp culture is still being developed, and there are currently demonstration projects, including some for native species, in the Caribbean which merit continued support. The major islands have recently shown marked progress in penaeid shrimp culture.

There have been successful *P. schmitti* pond culture operations in Brazil and Colombia. In Cuba there are government sponsored experiments, and in the Dominican Republic one farm exists and there are plans for additional larger farms. There were pilot hatchery and grow-out operations to rear the Caribbean species *P. schmitti and P. duorarum* in Antigua, but these were not commercially successful. Projects using the exotic species *P. stylirostris* and *P. vannamei* include: research projects between the Maritek Corporation and the Morton Salt Company in the Bahamas, and a commercial hatchery and grow-out enterprise for *P. vannamei* , which has been in operation for three years on St. Kitts.

Brine Shrimp

There is extensive demand for eggs of brine shrimp *(Artemia)*. The larvae hatched from these eggs are widely used as larval feed for shrimps in commercial mariculture, aquarium fishes in the pet store trade, and as livestock feed. There is also a market for brine shrimp in the adult form. The culture technology is not complicated and pilot scale culture operations have been recommended for the Caribbean islands (Goodwin, et al., 1984). Findings of a study sponsored by AID of the mariculture potential of the native Eastern Caribbean brine shrimp indicate that these shrimp have good nutritional characteristics when reared on phytoplankton naturally occurring in salt ponds. Pilot projects targeted towards commercial production have been recommended.

Freshwater Prawns *(Macrobrachium)*

Although freshwater prawns are not marine their culture is similar in many ways to that of marine shrimp and a number of prawn culture projects that exist in the Caribbean. These species include the native *Macrobrachium acanthurus* and *M. carcinus*, and the imported *M. rosenbergii*. While prawn culture technology is not fully developed, even with ten years of industrial research in the Pacific and Asia, it is adequate for commercial use. Marketing problems rather than technological constraints have been the primary cause of prawn industry failures in the Pacific. In the Caribbean, prawn culture is limited by the availability of freshwater, seed supply sources and reliable tourist markets. Current freshwater projects in the Caribbean involving the culture of the native species *M. acanthurus* include: a 50 hectare farm in Puerto

Rico, two farms in Jamaica, a 90 hectare farm in Martinique, and smaller projects in the Bahamas, Dominica, Dominican Republic, Grenada, Guadeloupe and Haiti.

Spiny Lobster

Culture of the spiny lobster *(Panulirus argus)* is often proposed because of the high market prices and the rapidly declining populations in the Caribbean. The complex larval history, behavior and food requirements of this species have made closed cycle culture a distant prospect. Although small-scale grow-out of wild caught juveniles may be feasible in conjunction with other mariculture activities, enhancement of this fishery is dependent on habitat production and harvesting regulations of existing stocks rather than on culture efforts.

Caribbean King Crab

While some crabs form the basis for commercial capture fisheries, e.g., the blue crab in the United States, few Caribbean crab species are harvested commercially and fewer still are suitable for mariculture due to aggresive behavior characteristics, slow growth rates and low-meat yields. An exception to these conditions is the recently discovered mariculture candidate of a native spider crab, commonly known as the Caribbean King Crab *(Mithrax spinosissimus)*.

This crab has shown considerable promise in pilot culture operations throughout the Caribbean for development of an appropriate mariculture technology for artisanal fishermen. Hatchery and grow-out systems are being developed in Turks and Caicos (Adey, 1986), Antigua (Creswell, 1986; Ryther, et al., 1987), the Dominican Republic (Adey, 1986), Martinique (Bobin, 1986). The first commercial pilot operation was initiated recently in Carriacou, Grenada (Adey, 1986). The methodology for *Mithrax* culture, introduced by the Smithsonian Institution, is based on the conversion of algal turfs, cultured concurrently as a food source for these crabs, into high quality protein for tourist and export markets. Efforts are currently focusing on refining the technology for commercial scale development.

Brood stock for Mithrax spinosissimus culture.
(Photo: Marea Hatziolos)

MOLLUSCAN CULTURE

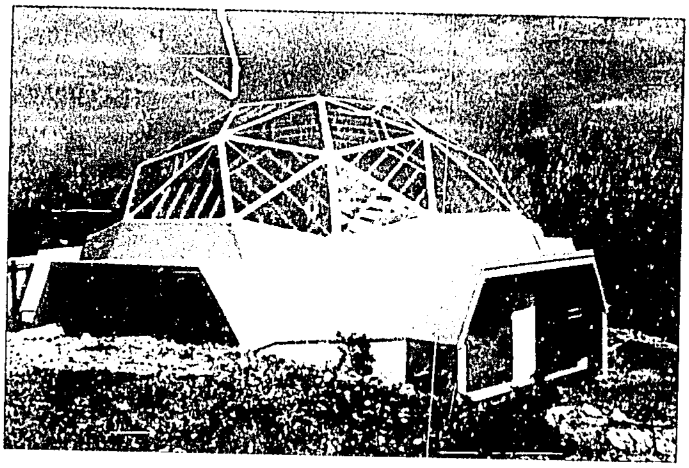
Molluscan culture in the Caribbean is in a pioneering phase relative to the status of crusteacean culture in the region and of bivalve culture, e.g., oysters and clams, in the Pacific and many parts of Europe. The low productivity of Caribbean waters has inhibited widespread cultivation of suspension feeding molluscs, which require nutrient-rich environments such as estuaries and mangrove wetlands for optimum growth. The contamination of bays and estuaries with human sewage and agricultual runoff further limit the availability of suitable sites for mollusc culture in the region.

Despite these limitations, efforts are underway to develop mollusc mariculture as a fisheries enhancement technique for the Caribbean. Jory and Iversen (1985) divide current molluscan culture in the Caribbean into three categories: semi-intensive, involving spat collection and grow-out of bivalves on rafts or suspension systems; extensive culture, which allows hatchery-reared juveniles to graze in open systems or penned enclosures; and research on a variety of promising species and culture methods. Much of the following information is drawn from Jory and Iversen's (1985) comprehensive review of these efforts in the Caribbean.

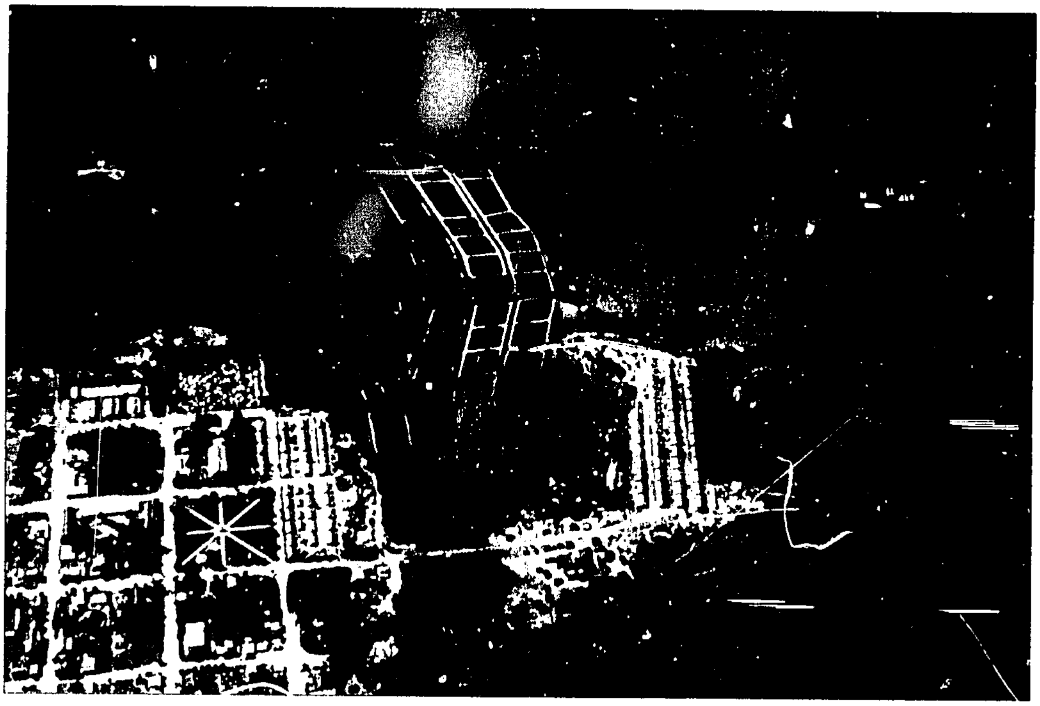
Queen Conch

Queen Conch *(Strombus gigas)* has long been a staple of Caribbean fishing communities and a chief source of income for artisanal fishermen in the Caribbean. Its rapid depletion from traditional fishing grounds, with increased demand from tourist and U.S. markets, has led to efforts to culture juveniles for mass release in reef reseeding operations. Years of research have resulted in the large-scale production of seed stock at a number of government sponsored hatcheries (e.g., Bonaire, Netherlands Antilles and Quintanna Roo, Mexico) and in the region's first commercial conch hatchery in the Turks and Caicos.

While juvenile conch production has entered a commercial phase, grow-out of adults remains largely experimental. Trade



Commercial conch hatchery in the Turks and Caicos islands.
(Photo: Leroy Creswell)



Coastal aquaculture ponds in the Greater Antilles. (Photo: Marea Hatziolos)

Wind Industries in the Turks and Caicos Islands represents the first attempt to rear Queen Conch from egg to sexual maturity (three years) on a commercial scale. Plans to release several hundred thousand juveniles in a five square kilometer underwater enclosure are now underway (Hess, C., pers. comm.). Results of this final stage in the culture of conch to harvestable size will determine the feasibility of extensive closed culture systems for Queen Conch and other grazing molluscs of high market value.

Oysters

Both Mangrove Oysters *(Crassostrea rhizophorae)* and American Oysters *(C. virginica)* are reared in semi-intensive culture in the Caribbean. The greatest success has been achieved in Cuba where production of Mangrove Oysters may reach one million kilograms (unshucked weight) annually. In Jamaica, an "Oyster Culture Unit" was set up in the Ministry of Agriculture in 1980, to promote cultivation of Mangrove Oysters through pilot demonstrations and extension services.

Disease, fouling and contamination problems have limited production thus far. In the Gulf of Mexico, culture of American Oysters has met with considerable success in the coastal lagoons of Tabasco and Vera Cruz. Production is currently on the order of 40,000 tons per year with the potential for expansion, into 100 million hectares of suitable habitat, barring future contamination of these waters. Research is being conducted on the ecology and mariculture of Mangrove Oysters in the Boca del Toro region of Panama and in the Cienaga Grande de Santa Marta in Colombia. The culture of pearl oysters has been proposed adapting Japanese culture techniques to the native Caribbean species, *Pinctada imbricata*, off the coast of Venezuela.

Other Molluscs

Research on the culture potential of a wide variety of other molluscs is underway at marine research institutions in the region. One of the more promising candidates includes the West Indian Top Shell *(Cittarium pica)*, a highly prized Caribbean snail, overfished in most parts of its range. Adaptation of the algal turf and cage culture technology (Adey, 1986) for this grazing mollusc has yielded positive results at the Smithsonian Institute's new regional mariculture research facility on Grand Turk. Other groups include octopus and giant squid *(Loligo sp.)*, in pilot culture at the University of Texas, Galveston, and at the Universidad del Oriente in Santa Marguerita, Venezuela, and scallops (family *Pectinidae*). The latter are reared commercially on the Pacific coast of Latin America and are currently under study for culture in selected sites of the Caribbean.

Requirements for Mariculture Development

Formulating a mariculture program requires extensive research and planning. Given the many constraints to mariculture development, careful attention must be paid to local, regional, and international conditions when attempting to determine the feasibility of developing a particular culture project or technology. Once species and site feasibility are established, the most important factors are those related to the administrative and technical organization of the individual farm and marketing structures. The following is a checklist of important factors for evaluating proposed mariculture projects:

- availability of seed stock (or brood stock);
- site suitability;
- availability of proven culture technology;
- on-site availability of individuals competent to apply technologies;
- adequate capitalization to sustain delays during start-up;
- sound business management including realistic economic projections;
- ability to sustain prodution and income generation;
- availability of a stable market for the product at a price which allows for profit; and,
- adequate infrastructure and transportation to market product reliably.

Recommendations

THE PRIMARY RECOMMENDATION FOR MARICULTURE DEVELOPMENT IS TO PROCEED WITH CAUTION.

The opportunities listed above are identified more on the basis of their potential than on their present ability to contribute to the region's development. Considering the economic constraints of most Caribbean countries together with the high-risk character of mariculture, it is difficult to justify national investment in such ventures.

The potential of such ventures, however, is sufficient to warrant application of development assistance funds to pilot scale projects which meet basic criteria described by Sandifer (1985). Once established, such projects can provide the basis for overcoming many of the technical constraints described above, as well as opportunities for training in locally proven mariculture technology. Successful pilot projects will also provide a more stable basis for subsequent private and public investment, and will improve access to existing credit facilities for capitalization. Successful mariculture ventures are often more dependent upon the human, technical, and economic characteristics of particular projects than upon the species being cultured.

III

GEOLOGICAL and NON-LIVING RESOURCES

The resources considered in this chapter are divided into hard-mineral resources, non-conventional energy and petroleum resources. Hard mineral resources are considered to be of major importance because of their immediate potential and because they can be developed at lower costs by the countries themselves. Petroleum resources of economic importance to several countries are well documented, managed by private or national companies, and beyond the scope and objectives of this report. Therefore, only minor, general information is presented. Non-conventional energy such as geothermal is considered as a potential resource for some Caribbean countries and is pertinent to the overall resource picture.

Background

Hard Mineral Resources

Sand and Gravel

Sand and gravel are ubiquitous on beaches around the shores of the Caribbean, and are universally needed for construction and beach replenishment. Widespread availability does not mean, however, that this resource can be extracted without severe economic and environmental penalties. Sand mining has resulted in significant coastal erosion and loss of beaches that are major concerns for tourism and residential development in the Caribbean.

Sand and gravel are the most economically important non-hydrocarbon marine mineral products. The unusually high construction costs of the Caribbean region are reduced somewhat due to the availability of these resources. On the northern coast of South America there are large coastal deposits of sand and gravel being exploited for building materials (Picard and Goddard, 1974). On many islands of the eastern Caribbean, onshore supplies of sand have been depleted and nearshore supplies are the only remaining sources available for construction needs (Rodriquez, 1981). Much of the available sand is not construction grade quality, and appropriate tests to determine suitability are needed prior to mining.

Placer Deposits

High density minerals can be concentrated by stream and beach processes into deposits known as placers. Similar effects by waves produce the layers of dark grains commonly observed on beaches. The dense minerals that are concentrated frequently are valuable; they include gold, platinum, titanium, chromium, and rare earth-bearing minerals. Placer deposits may be found in present streams and beaches, but they were created during lower sea levels of the Neocene when the continental shelves were exposed above sea level. Both stream placers and beach placers may be found on the present continental shelves.

Phosphate Deposits

Phosphates are an important source of fertilizer in the northern portion of South America. These deposits occur as guano formed from the weathering of bird excrement and as marine phosphorites formed in areas of upwelling. Phosphates in nutrient-rich waters are accumulated by organisms of the marine environment with high phosphate concentrations. This results in chemical alteration of sediments, forming phosphorites, which are likely to be further concentrated by sedimentary processes. Phosphate contents can range from 20% to 40% by weight (Benton, 1980; Manheim, et al., 1980).

Limestone (Calcium Carbonate)

The major sources of limestones are the coral and algal reef environments, shell banks, and deposits by direct precipitation of calcium carbonates from seawater in the form of oolites and needles. In the Caribbean area, on some parts of the northern coast of South America, most Caribbean islands and the Bahamas, limestone is undoubtedly the most abundant marine mineral resource available.

Limestone is used in the manufacture of cement, as blocks and coarse aggregates for building purposes, roadbeds, agriculture fertilizer and for the chemical industry. High quality calcium carbonate needed by the chemical industry is supplied mainly from the Bahamas.

Ferromanganese Deposits

These deposits are known to exist on the seafloor as nodules and crusts in the major oceans of the world. Their economic importance lies not so much in their iron and manganese contents but in the cobalt, copper and nickel abundances.

Recent dredging on the Aves Ridge, near St. Croix, have produced ferromanganese crusts. No information as to their elemental composition is known at present. Deposits are not known to exist in other parts of the Caribbean. In any case, current world metal markets probably would not make extraction economically feasible.

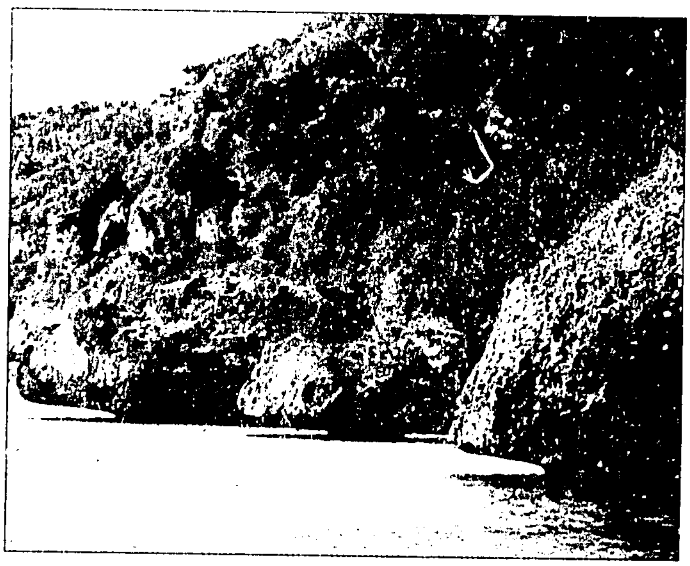
Salt

The only known production of salt in the Caribbean is by evaporation of seawater. The arid climate in some areas of the Caribbean guarantees a continuous supply of marine salt in those areas where salt flats are formed. Modern production techniques in some areas such as Bonaire, Galerazamba in Colombia, and the Araya Peninsula of Venezuela are used for extracting salt from marine evaporites for industrial and domestic use. Refined salt is important for domestic consumption as well as for preservation of foods (meat and fish). The region is a net exporter of salt and on some Caribbean islands marine salt may prove to be a major export product in the future (UNEP/CEPAL, 1979).

Non-Conventional Energy

Non-conventional energy sources include geothermal, wind, solar energy, and ocean thermal energy conversion (OTEC). These resources may not be strictly of marine origins, but they affect the coastal zone and are necessary for the development of countries and island states that are predominantly coastal.

OTEC is an experimental technology for generating electricity from the temperature difference between warm surface waters and cold subsurface waters. The temperature differential most often used as a minimum standard for OTEC resource is 20^{o} C. This differential is found throughout the Caribbean basin, reaching even 22^{o} C. Proposals to build OTEC plants in undeveloped tropical island countries exist, including Jamaica and in St. Croix, U.S. Virgin Islands, but none have been successfully demonstrated in the Caribbean region largely due to high start-up and operating costs (OTA, 1984).



Limestone, formed by reef building corals (Scleractinia) and coralline aglae, is a primary mineral resource in many areas of the Caribbean. (Photos: Meriwether Wilson)

Aerial view of oil rigs and refinery, from which leakage is polluting the water and the air. (Photo: FAO)

Non-conventional energy resources are not developed nor widely used in the Caribbean region (UNEP/CEPAL, 1979). There are some applications of solar energy and wind energy generation, but only on a very small scale and in isolated places. The region is suitable for the development of solar energy, yet large-scale solar applications are not competitive with other types of energy generation at this time. There have been demonstrations of small-scale use of solar energy for water heating, crop drying, and solar pumps. In Mexico, solar water pumps have been installed in arid areas and technicians suggest that up to 25,000 more wells could be equipped (Hinrichsen, 1981). Wind and solar energy demonstrations in St. Kitts and geothermal efforts in St. Lucia have been started, as part of the UNEP Regional Energy Action Program (UNEP, 1983). Limited technology development and unknown economic feasibility currently hinder development. Small scale generation of projects to exploit these resources has not been cost effective.

Oil and Gas Resources

Mexico and Belize

In the offshore region of southern Mexico, major oil-producing areas are located in the Campeche Province. Although geologic data are incomplete, it appears that these oil-rich carbonate reservoirs do not extend to the eastern coast of the Yucatan Peninsula or Belize. Seismic and drilling operations in the vicinity of ancient reefs are currently underway in Belize, but results to date have been disappointing.

Central America

Ninety percent of the commercial energy supplies are imported here, with fifty-five percent as crude oil and thirty-five percent as oil derivatives (Hinrichsen, 1981). The offshore areas of eastern Central America have been explored (more than 35,000 km of seismic data have been collected offshore Honduras). Though 30 wells have been drilled, none has proven productive. Four wells drilled to the north of Honduras in the Tela Basin are dry. To the east, oil has been detected in marine carbonates from one Union Oil Company well drilled nearshore in the Mosquita Basin. A Shell Oil Company well off Nicaragua has yielded 250 barrels per day, but offset wells have been dry. A Union well in the portion of the Limon Basin close to the Costa Rican shore has produced 200 to 1000 barrels per day, but no offshore drilling has been attempted.

Greater Antilles

With the exception of Cuba, the only oil production in the Greater Antilles came from the Azua field in southwestern Dominican Republic. Discovered in 1904, the field produced a total of about 30,000 barrels before production ceased in the 1940s. The source of the oil is unknown, but may have come from the Cordillera Central which is separated from the Azua field by a major thrust fault. Other drilling indicates that offshore locations at both ends of the Cibao Valley have oil and gas potential.

Haiti has seven onshore wells, all of which are dry. Small targets that are of little interest to major oil companies have been identified offshore and warrant additional investigation for alternative investors. There are several important deepwater targets with great potential, the primary one lying off the northern coast.

The western end of the Greater Antilles ridge is submerged and is called the Nicaragua Rise. Two wells, both dry, have been drilled on the Rise in the vicinity of Pedro Bank. Jamaica lies on the eastern end of the Rise where ten additional dry wells have been drilled. There appears to be little potential for finding oil-bearing rocks in Jamaica.

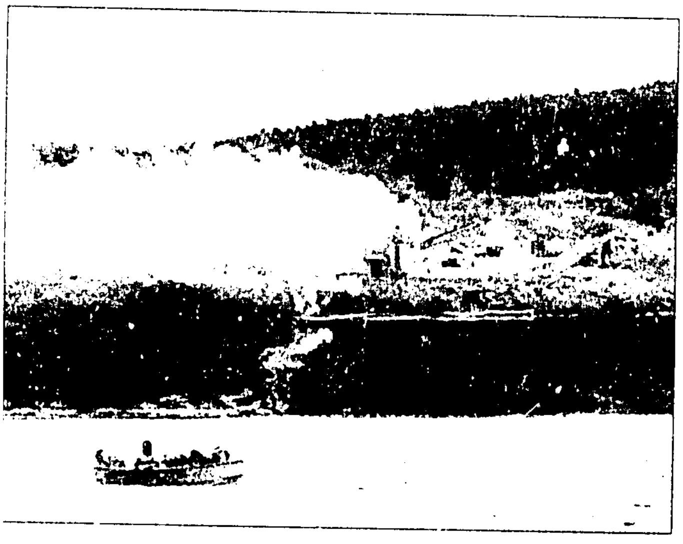
The geology of the Greater Antilles is extremely complex, and is understood primarily through geologic studies of the islands and limited offshore geophysical data. Aside from Cuba, no oil is being produced within the region, and available data suggest that prospects for a major oil discovery are slim. Small basins may contain limited accumulations that could be of great local benefit, but such basins would be difficult and expensive to find.

Lesser Antilles

The geologic history of most of the Lesser Antilles has been dominated by volcanic activity which is conducive to oil and gas deposits. The best potential is on the southern part of the island chain where thick sediments of the deep Tobago Trough and the Grenada Trough pinch out against the ridges on which the islands are located. Barbados, which is not a volcanic island, is producing oil (Woodbourne Oil Field) and some gas (Springvale 1). Barbados is located on the crest of a major sedimentary ridge that has been subjected to strong deformation, resulting in highly contorted strata and much faulting. Intense deformation generally reduces the possibility of finding major oil fields on- or offshore; but the Woodbourne field demonstrates that oil is generated and trapped in commercial quantities. Though there is an element of high risk, the potential for offshore discoveries is good.

Colombia, Venezuela, Trinidad and Tobago

These are oil-producing nations that have onshore and offshore potential. Additional oil and gas deposits have been discovered on the continental shelves of these countries in the past five years. Future exploration in these areas may be necessary to properly appraise the finds. At present, gas deposits appear to have greater potential, while oil deposits in some areas are marginal.



Beach sand mining; uncontrolled mining can destroy coastal habitats. (Photo: RARE)

Constraints to Economic Development and Resource Management

Location, Extent and Quality of Resources

The primary constraint to developing geologic resources is the absence of sufficiently detailed information to guide economic use. Recent meetings between Caribbean countries underscore the need for baseline information at several map scales (Galavis, 1985). Detailed small area surveys are needed to develop particular placer deposits or sand and gravel resources, including information on location, thickness, and quality of deposits. Small regional maps provide useful indications to geologists of where such resources may be found. Broad regional coverages showing rock type, structures (faults, folds, etc.), and seafloor morphology are needed for a general understanding of the geological and mineral resource development of a country or region.

Uncontrolled Sand Mining

Beach sand mining, though it does not introduce chemical pollutants into the marine ecosystem, may be the single most destructive coastal industrial activity, producing severe beach erosion in many places and adding particulate matter to the water column. For example, Dickinson Bay, Antigua, has experienced very serious beach erosion believed to have been caused by extraction for hotel construction in the 1960s. The public has lost the use of a section of the beach, and sea defense work for protecting two hotels cost about US $190,000 in the past decade. In St. Thomas, U.S. Virgin Islands, hard corals were damaged by sedimentation associated with the release of clays brought about during sand dredging. No exploratory cores were taken to detect the possible presence of such clays (Wood and Johannes, 1975).

The effects of sand extraction from an ocean beach can be widespread. Attempts to regulate such extraction are often ignored, and illegal sand mining is common. Through these processes, the zone of erosion and beach damage is widened. Secondary effects can be even more serious. Commonly a continuous stream of sand moving along the beach face, known as littoral drift, is constantly adding and removing sand from the beach. When sand is extracted the tendency exists to restore the equilibrium shape of the beach. This reduces sand supply to downstream beaches. Beaches provide protection for coastal areas, so beach destruction can result in large economic losses during major storms. If a beach is constantly nourished with sand, controlled mining might be appropriate. Commonly, however, the rate of supply is slow and beach mining causes widespread damage (DuBois and Towle, 1985).

Uncapped oil from a blown well, Ixtox I, caused the world's largest oil spill in the Bahia de Campeche, Mexico. (See page 25 for details; Photo: NOAA)

Marine Pollution

The Caribbean Action Plan of UNEP and the Economic Commission for Latin America establishes petroleum as the pollutant of primary concern in the region. The Caribbean Marine Pollution Research and Monitoring Program (CARIPOL) has accumulated more than 8000 observations of petroleum pollution from 1979 to 1986. Major conclusions from the study are:

- a serious level of petroleum pollution exists throughout the region with the possible exception of the southwestern Caribbean, but even this area is beginning to show evidence of contamination, some of which is coincident with the opening of the trans-Panama oil pipeline;

- exposed windward shores on islands and other land masses in the region have seriously polluted beaches from oil spills. Some are so contaminated with tar that they are virtually unusable for recreational purposes. Others are so heavily contaminated that they cannot be used for any purpose; this is particularly true on Grand Cayman;

- best estimates from CARIPOL data and participating scientists indicate that about 50% of the contamination is carried into the Caribbean by the North Atlantic Gyre System via the Caribbean Current, Gulf Loop, and Gulf Stream. The remaining 50% of contamination appears to be caused by ship traffic in the Caribbean and ballast washing conducted in violation of treaty agreements under the International Maritime Organization; and,

- marine turtles have been found to feed on floating tar from tanker ballast washings, causing illness and death.

Visible and radar remote sensing imaging from satellite and aircraft can provide quantitative data useful for identifying and tracing such pollutants as sediment runoff, sewage effluents, and petroleum (particularly tanker ballast washings). Advanced remote sensing techniques using satellite altimetry (supplemented by sea level measurements from tide gauges as verification data) can be helpful for the determining surface currents. This could be useful for assessing the fate of pollutants in detail and is particularly true in those regions where satellite tracked drifters have shown complicated eddy-scale motion. The Tropical Ocean and Global Atmosphere (TOGA) program will provide improved circulation information. The World Ocean and Circulation Experiment (WOCE) of the Intergovernmental Oceanographic Commission's (IOC) World Climate Research Program (WCRP) should provide information and opportunities for Caribbean basin-wide circulation studies.

Opportunities for Economic Development and Resource Management

Sand and Gravel

Marine deposits of these products offer significant potential for meeting the needs of the construction industry as well as for eliminating the problem of beach mining. The recommended tactic is to take sand from offshore areas not in the longshore drift system that nourishes beaches downstream. In the Caribbean such situations commonly occur on the western ends of islands due to the general westerly longshore drifts set up by tradewind conditions. This is not universal but several examples have been noted such as on the northwestern and southwestern corners of Puerto Rico and the western end of an adjacent island.

Placer Deposits

Stream gold placers (referred to as "alluvial gold") have been worked from one end of the Caribbean to the other (Puerto Rico and Hispaniola to Panama, Colombia and Venezuela). Indeed, about 60% of Colombia's present gold production comes from alluvial sources and represents a significant export earner for the country. In general, because gold is extremely dense and very difficult to transport by water in streams, gold placers are generally found in fairly close proximity to their source (within 50 kilometers). Therefore regions with mountainous coastlines, and a history of gold production nearby might be primary candidates for coastal surveys for gold placers. The coasts of Colombia, Panama, the Dominican Republic and Puerto Rico might be worthwhile candidates, but all the Central American countries also have had gold production and should be resurveyed. The presence of significant alluvial gold mining in Colombia indicates that considerable expertise in extracting gold from stream placers already exists in the region. This technology could be applied toward development of offshore placer deposits.

Other placer-forming minerals likely to be found in the Caribbean are chromium, titanium and rare-earth-bearing minerals. Garnet placers are worked for abrasives. In contrast to gold, which is most likely to be found in stream placers, all of these minerals are less dense than gold and are likely to be produced from beach placers.

Platinum placers may be found off Panama and titanium and rare-earth-bearing deposits off Panama and Colombia. Titanium minerals are likely off Puerto Rico and chromium-bearing minerals off the volcanic islands and Colombia (Guild, 1974; Cunningham, et al., 1984, Knecht, et al., 1984). This is clearly only a partial list of the possibilities and a survey of any continental shelf is likely to reveal other placer deposits with economic potential.

The initiation of low cost surveys of the continental shelves are needed to encourage the development of marine placer deposits. Exploration should include low-cost high resolution seismic profiling surveys of the continental shelves to identify ancient-drowned beaches and stream valleys. Coring to sample potential locations should follow and core sites should be chosen on the basis of seismic data. The surveys needed to locate placer deposits are similar in many ways to those needed for the exploration of sand deposits. The co-production of heavy minerals and sand may be profitable. In order to obtain heavy minerals the sand must be processed and the desired minerals separated. If the deposit is near a market, the sand could become a valuable by-product. Precaution is needed when mining sand because of the possible damage to coral reefs when a plume of fine sediment is released in the ocean. See the requirements section for more detailed information and cost estimates of conducting continental shelf surveys.

Phosphate Deposits

Small amounts of guano phosphorites have been reported from Aruba, Curacao and Los Roques (situated north of Venezuela). Similar deposits exist on several other Caribbean islands where carbonate terraces and sands have been covered by bird excrement to form phosphatic crusts. Coastal phosphate deposits of marine origin are found in Venezuela and in the area of the Serrania Bahia de Portete, Colombia. However, inland deposits near major sources of demand have significantly reduced interest in these coastal deposits.

At present, it would be difficult to consider the known deposits in the Caribbean as a marine resource of significant economic value. Nevertheless, the importance of phosphates as fertilizers and their high costs warrant detailed studies of the known deposits in order to determine their abundance and purity for small-scale industries.

Limestone

Calcium carbonate deposits abound in the Caribbean. Detailed chemical and mineralogical mapping would be extremely helpful to delineate the quality as well as the particular use for each limestone deposit.

Salt

With very little cost and manpower, salt production is possible from existing salt flats in the shoreline areas of the Caribbean. For some island countries, salt is a significant foreign exchange earner. For example in the Turks and Caicos Islands, it is considered to be the only known mineral wealth (UNEP/CEPAL, 1979).

Excrement from boobies and comorants forms guano phosphorites on carbonate rocks. (Photo: Meriwether Wilson)

Non-conventional Energy

The high level of solar radiation received in the Caribbean has potential for countries lacking other natural energy sources. Wind energy has similar potential in areas exposed to constant and strong winds such as the tradewinds. These areas are mainly located on the leeward islands and on the north coast of South America. Geothermal energy has potential in countries where volcanic activity is present, particularly in the Antillean islands and continental countries of Central America. Nations with high and nearshore mountain ranges may have hydroelectric potential.

At present, the Caribbean region is dependent upon fossil fuels to meet its need for energy. Non-conventional energy resources are "cleaner" and there is little concern as to the environmental problems they may cause. Because tourism is one of the major economic activities in the Caribbean region, the generally non-polluting aspect of these energy sources may favor their development.

The tropical Caribbean waters are ideal for OTEC development in terms of having the required temperature differential (described on page 50), but this does not itself create an economic potential. The Caribbean countries may well have more immediate and feasible sources of energy for the near future, such as solar or wind energy. Tide-generated energy may be disregarded because of the low tidal range in the region.

Requirements for Economic Development and Resource Management

1 Information on Location, Extent, and Quality of Mineral Resources

Detailed geologic mapping of coastal areas to present information on the location, extent and quality of mineral resources is imperative for developing sand, gravel and placer mineral deposits. These are the commodities (excluding petroleum) with the most apparent immediate value. Mapping of this type is also important to understand environmental problems such as beach erosion and damage to coral reefs, and can be useful for fisheries development. Creation of detailed geologic maps requires:

- high resolution seismic profiling;
- short-range sidescan sonar imaging;
- portable radio navigation; and,
- coring and sampling.

The first three are complex electronic systems that are not extremely expensive, but require competent well-trained, experienced electronic technicians to maintain and operate them. Adequate budget for supplies and spare parts is necessary. A high resolution profiler, sidescan sonar and radio navigation system would cost approximately US $200,000. In addition to small bottom grab samplers (available in some countries), provision must be made for coring. The logical choice is a vibracorer. This costs US $75,000, as vibracorers of adequate size (perhaps 10 meter coring capacity) are very large and difficult pieces of equipment to handle. High resolution seismic and sidescan sonar operations can be carried out on boats of approximately 10 to 20 meters in length. Local fishing boats, possibly equipped with a portable electric generator for adequate power, would be suitable. Vibracoring would require somewhat larger vessels (18 meters or larger) and a winch and crane, A-frame or boom. Again, larger local fishing boats might be usable.

2. Sand and Gravel

In order to develop and manage an offshore sand mining operation several requirements must be fulfilled:

a. A large sand source must be identified and mapped to prove that a resource is available. Geologists familiar with coastal sedimentation should carry out high resolution seismic profiling and sidescan sonar surveys to locate deposits, and from their internal structure, interpret the history and present activity of sediment migration. Other information such as current measurements and remote sensing data can aid in analyzing the coastal sedimentation processes. Coring is imperative to determine the volume of any deposits and to identify the nature of acoustic returns observed in seismic profiles.

b. The source must be located near a market, because transportation costs rise quickly with distance hauled. There is considerable advantage to mining marine deposits, because barge transportation is much more economical than truck transportation, especially to markets in large coastal cities with port facilities.

c. Sediment dynamics of the deposit must be known so that major environmental disruptions can be avoided.

d. There must be indications that adequate quality of the resource can be maintained (quality means a low mixture of fine-grained material, no difficulty with washing salt from the grains, adequate grain shape characteristics and composition for the intended market, etc.). Standards for concrete aggregate must be fairly high, while standards for beach replenishment are lower because fine material will wash away. Angularity and salt content are not concerns. Terrigenous sand is commonly considered to be preferable to carbonate sand for concrete aggregate. Clean quartzose sand may be used for glassmaking.

3. Placer Deposits

The key to encouraging development of marine placer deposits is to initiate low cost surveys of the continental shelves. As noted above, gold is not easily transported because of its density and is dropped quickly when stream gradients decrease. Eroded coastal shelves, now below water, were exposed during the low sea levels associated with recent ice ages. The gradients of streams during that period would have decreased abruptly where coastal mountains are adjacent to these shelves, and gold deposits would have formed. Other heavy minerals would have been concentrated in beaches that could have formed anywhere on the shelves and could have been preserved as sea level rose after the ice ages (between 15,000 years ago and the present).

Exploration should include low-cost, high-resolution seismic profiling surveys of the continental shelves to identify ancient drowned beaches and stream valleys. Coring to sample likely locations must follow in sites chosen on the basis of seismic data. Surveys to locate placer deposits are similar in many ways to those needed for sand deposit exploration, and the relevant geological expertise is closely related. Heavy minerals may be separated from mined sand, and co-production of heavy minerals and sand is likely to be a profitable undertaking if the deposit is near a suitable market.

4. Pollution Control

Plumes of turbid water from sand or placer mining can do significant damage if these impinge upon coral reefs. This possibility must be evaluated and controlled with consideration to the amount of fine sediments that would be released in the water, current directions and strengths, and the location of reefs relative to the mining operation.

5. Non-conventional Energy

There is an apparent lack of research and knowledge concerning non-conventional energy sources in the Caribbean region. For this reason, development of such sources is highly dependent upon technological developments in the industrialized countries. Developing opportunities for non-conventional energy depends upon technology transfer programs and practical application of this technology to economic development.

Sediments released into the water from sand or placer minings can damage reefs. (Photo: Meriwether Wilson)

Recommendations

1. SUPPORT SHOULD BE PROVIDED FOR BOTH LARGE SCALE AND SMALL SCALE GEOLOGIC MAPPING in the Caribbean region. This would encourage development of mineral resources, as well as support other aspects of marine resource management in problems of marine pollution, coastal habitats, fisheries and human resources.

2. A MAJOR CONCERN IN IMPLEMENTING A PROGRAM TO UNDERTAKE THIS TYPE OF MAPPING IS THE MAINTENANCE OF EQUIPMENT. The survey devices described above will be most productive and will only be dependable if run frequently and maintained constantly. If allowed to remain unused, this equipment will deteriorate. From an operational point of view, a single Caribbean center for technicians and equipment would be best. Whether a single technical center is politically feasible is a question that we do not consider here.

3. A DIFFERENT APPROACH TO OPERATING EQUIPMENT IN THE CARIBBEAN AREA WOULD BE TO DEVELOP COOPERATIVE PROGRAMS BETWEEN REGIONAL SCIENTISTS AND ACADEMIC OR GOVERNMENT SCIENTISTS IN THE UNITED STATES AND OTHER COUNTRIES. In such an effort it is necessary to have a commitment on the part of the responsible scientists to complete practical surveys, analyze the data in light of resource limitations, and make the results generally available. Such commitments are not always easy to secure.

4. BROAD REGIONAL MAPPING CAN BENEFIT FROM SUPPORT TO THE INTERNATIONAL BATHYMETRIC CHART OF THE CARIBBEAN PROGRAM, sponsored by IOCARIBE. This activity also can benefit from satellite imagery such as LANDSAT, and new technology developments such as the Geological Long Range Inclined Asdic (GLORIA), a long range sidescan sonar that can provide images of the seafloor along a swath 60 kilometers wide. Such new methods provide large amounts of data very efficiently, make the field work easier and are relatively inexpensive. Large parts of the Caribbean already have been imaged by GLORIA. Application of this technology to development of geological resources in the Caribbean has recently been recommended by the National Academy of Sciences, Ocean Studies Board (Ross and Stewart, 1986).

5. SATELLITE, AIRCRAFT, AND ACOUSTIC REMOTE SENSING TECHNIQUES CAN BE USED FOR SUCH GEOLOGICAL REQUIREMENTS AS THE STUDY OF THE REMOVAL AND TRANSPORT OF SAND AND GRAVEL. Of particular interest to many island nations is the need for fresh water. Nearshore discharges of fresh water may be detectable from low-flying aircraft using passive microwave sensors. Bathymetry from airborne Lidar and shipborne side scan sonar can provide the primary source for acoustic information.

IV

HUMAN RESOURCES: Education, Training and Technical Support

Background

The colonial history of most Caribbean countries has caused social, cultural, and economic systems to be based almost entirely upon land resources (agriculture, mining and bulk materials). Until very recently, the disinterest of European colonists in marine resources continued to be reflected in the priorities of contemporary Caribbean governments. Marine resource managers and developers are in a complex situation: governments are reluctant to expend limited human and financial resources on a sector which has not produced impressive benefits; but these benefits cannot be obtained unless such resources are available.

Current economic conditions, and in some cases new political independence, are causing more attention to increased use of all natural resources including the marine sector. Much of this interest, however, is focussed upon rapid economic benefits rather than sustainable development and resource management. Often, "development" and "progress" are equated with emulation of more economically advantaged countries, despite fundamental differences in type and magnitude of available resources.

These circumstances have obvious impact on marine science and related educational resources. The low priority accorded to the marine sector results in limited employment for professionals in the field. Salaries, advancement opportunities and prestige for marine scientists are well below comparative national standards for other professional categories. The emphasis upon rapid economic benefit reduces interest and support for creative research. The general perception is that it is simply necessary to learn to apply existing technology, not to develop new technologies tailored to conditions of the Caribbean.

Considering these limitations, there are a surprisingly large number of marine scientists and marine science institutions in the Caribbean (Annex B). Still, the influence of the circumstances described above is evident:

- about 85% of marine scientists in the region are biologists, as most of the few jobs available in marine resources are in government fisheries units;

- there are few educators, researchers, or technicians in physical oceanography, coastal dynamics, marine pollution chemistry, or marine geology and geophysics; ocean or coastal engineers are virtually non-existent due to poor employment opportunities;

- the marine science cadre has few advanced degree holders (MS and PhD) and is consequently limited in experience and preparation necessary to conduct meaningful independent research; and,

- research capabilities are often constrained by inadequate laboratories, instrumentation and equipment; poor capabilites for maintenance, repair and calibration; limited vessel facilities; poor reference collections and standards; and unsatisfactory library and literature holdings.

These conditions represent major shortcomings. But it is unrealistic to expect small developing nations to invest heavily in advanced research when limited financial and human resources are already severely strained. At the same time, marine resources offer significant potentials which can only be realized with improved technical capabilities. Development assistance agencies must encourage and support activities that:

- demonstrate tangible economic benefits from integrated management and development of marine resources;

- strengthen human resources with he technical capabilities needed for such activity;

- build national and regional institutional capabilities to support economic development and management of marine resources; and,

- increase the availability and dissemination of scientific literature to individual institutions throughout the region.

Constraints to Improving Human and Institutional Resources

Lack of National Commitment

With few exceptions, the primary constraint to economic development and resource management in the marine sector is the lack of substantial national commitment to these activities. Low priority, inadequate financial support, shortage of trained personnel, and deficiencies in marine science institutions are all related to this fundamental problem of limited national commitment to the marine sector.

Uncoordinated Development Activity

In the past five years, international activity related to the Caribbean marine sector has dramatically increased. At present there are at least 48 separate projects dealing with environmental affairs, most of which include marine components. Ideally, these efforts should be directed toward meeting goals and supporting programs articulated by the Caribbean nations. In reality, most of these projects have had minimal local participation in their development, but all place significant demands upon local counterpart personnel. Conceptually, all of these efforts are valid and necessary (and in any case, developing nations are unlikely to reject any offer of assistance). But the present situation has two important implications:

- marine sector personnel may be almost totally occupied with a variety of uncoordinated projects, particularly in the smaller countries; and,

- there is little incentive for preparation of the comprehensive resource development and management programs needed for long-term progress in the Caribbean marine sector.

In short, there is danger that chronic personnel shortages are being exacerbated, while the fundamental need for long-range development and management strategies remains unmet.

Current Needs and Opportunities for Improving Human and Institutional Resources

The level of current activity described above does not imply that additional development assistance is unnecessary; more than ever, assistance is needed to strengthen human and institutional resources for development and management of marine resources. The potentials described in previous chapters indicates a need for a variety of technical skills,

- resource management: MS-level training in management policy, population biology, statistics;

- extension service and education: training in instructional techniques, information access, and public education methods;

- applied research: MS-level training in survey and analytical methods, pollution research and monitoring, geological techniques, aquaculture, development of techniques for resource enhancement;

- harvest technology: training in techniques for underutilized species, and means for increased efficiency in small-scale fisheries;

- processing technology: training for preservation and processing of selected fishery stocks for local and export markets;

- marketing: training in market identification, consumer information, and basic marketing practices;

- remote sensing: training in these environmental monitoring technologies would allow local scientists the ability to develop future products for specific needs; the feasibility of remote sensing data processing would be more realistic with computer linking between research institutions; and,

- scientific literature: increased availability of pertinent scientific journals, texts and technical reports to researchers and university students.

The diversity of institutions described in Annex B, as well as the varied short-term projects referred to above, offer opportunities for meeting these needs. For example, the Caribbean Fisheries Training and Development Institute (Trinidad) is providing training in some aspects of fisheries extension; the Caribbean Environmental Health Institute offers training in pollution monitoring; the University of Puerto Rico and College of the Virgin Islands offer marine advisory services; IOCARIBE proposes to develop a network of educational and research institutions within the Caribbean, the University of the West Indies is developing the use of satellite television and video cassettes for multi-island off-campus instruction.

But improvement of human and institutional resources does not depend solely upon training and material support; many training efforts have been undertaken in the past without due regard for how trainees will be able to apply their new skills when training is completed. Improvements are also needed in the overall context within which human and institutional resources must operate. It is clear that the central issue of national commitment cannot be resolved through external effort alone. It is also clear that the need for increased support to human and institutional resources is growing more rapidly than the commitment to provide such support.

The historical background described above suggests that national commitment to develop and manage marine resources may grow gradually in response to perceived benefits from these resources. In the meantime, training programs are likely to face continued frustration with the lack of opportunity and support for individuals who complete such programs.

Requirements for Improving Human and Institutional Resources

To deal with this problem, institutional and human resource development efforts must be based upon:

1. The economic realities of the nations which these efforts are intended to serve.

It is generally not desirable for Caribbean governments to increase their recurrent budgets by expanding the civil service. This means that requirements for developing and managing marine resources must be met by improving the capabilities and efficiency of existing staff positions.

2. Provision for follow-up support on an interim basis.

National commitment should result in continuing support for individuals who receive technical training and for marine-related institutions, but this does not happen for reasons described above. Recognizing that such commitment requires both time and visible results, projects to improve human and institutional resources should include provision for continuing follow-up support.

Formulation of activities along these lines should begin with articulation of comprehensive programs for marine resource management and development at the national level. These programs should not be limited to statements of broad goals and objectives, but should specify:

- necessary activities to achieve goals and objectives;
- what these activities will cost;
- what facilities are needed to undertake these activities;
- needed personnel skills to undertake these activities;
- what training is necessary to acquire these skills;
- how support will be maintained for requisite personnel;
- what opportunities exist to meet these requirements; and,
- what additional assistance is needed.

This procedure will:

- focus government attention upon the marine sector;
- help to ensure that specific activities and projects are compatible with local realities and perspectives;
- help to ensure that training activities are targeted toward actual needs and that follow-up support and employment opportunities will be available; and,
- provide a framework for the coordination and direction of externally-driven projects.

Caribbean students observing marine organisms in aquaria of research laboratory. (Photo: RARE)

Recommendations

1. DEVELOPMENT ASSISTANCE AGENCIES SHOULD ENCOURAGE NATIONAL COMMITMENT TO MARINE RESOURCES MANAGEMENT by supporting the formulation of comprehensive management programs and activities that demonstrate the economic importance of these marine resources through tangible, sustainable benefits. Encouragement may be provided in a variety of ways, such as requiring approval of such programs prior to funding specific activities, or by providing technical assistance to Caribbean countries for the formulation of national programs.

2. DEVELOPMENT ASSISTANCE AGENCIES SHOULD SUPPORT COLLABORATIVE EFFORTS AMONG REGIONAL INSTITUTIONS. Training and follow-up efforts should be directed toward meeting the needs of national programs. University-to-university partnerships should be encouraged, but exclusivity should be avoided. At present, many U.S. institutions with diverse capabilities are seeking greater involvement in the Caribbean. This diversity is generally healthy, though substantial guidance often appears needed to avoid previous mistakes and to achieve maximum effectiveness.

3. SUPPORT SHOULD BE PROVIDED TO REGIONAL ACTIVITIES THAT CANNOT BE MET AT A NATIONAL LEVEL. An example of this type of need is geologic mapping of offshore resources. Support may include funds for upgrading facilities involving scientific equipment, vessels, and laboratories where these are clearly relevant to regional needs. Considering the importance of continuing commitment, it is highly desirable that such support be provided jointly by development assistance agencies and the cooperating nations and institutions.

4. TRAINING SHOULD TAKE PLACE IN THE CONTEXT OF PROJECTS RELATED TO NATIONAL PROGRAMS whenever possible. This will help ensure maximum relevance of the training as well as the opportunity to apply the skills acquired. In particular, opportunities exists for educational institutions to develop certifiable in-service training projects and workshops, so that academic credit can be accumulated for such activities.

5. SPECIFIC PROVISION SHOULD BE MADE IN ALL PROJECTS FOR PUBLIC AWARENESS AND INFORMATION. Use should be made of various available media for this purpose, including television, radio, and local or regional newspapers.

6. DEVELOPMENT ASSISTANCE AGENCIES SHOULD SUPPORT EFFORTS TO INCREASE LIBRARY HOLDINGS IN MARINE SCIENCE INSTITUTIONS. Increased communication, and literature sharing between scientists and institutions could be achieved by the establishment of a regional electronic mail network.

Coral reef research is being conducted at a number of regional institutions in collaboration with U. S. and Caribbean scientists. (Photo: RARE)

LITERATURE CITED

Adey, W., 1986. The Biology, Ecology and Mariculture of *Mithrax spinosissimus*, Based on Cultured Turfs. Final report to AID, Grant LAC-0605-G-SS-3070, Marine Systems Laboratory, Natural Museum of Natural History, Smithsonian Institution, Washington, DC.

Atwood, D., 1982. Unusual Mass Fish Mortalities in the Caribbean and Gulf of Mexico. Symposium at Gulf and Caribbean Fisheries Institute, Mayaguez, PR, 20 Nov. 1981., 46 p.

Bak, R., 1983. Aspects of community organization in Caribbean stony corals (Scleractinia). (in) Ogden, J. and E. Gladfelter, eds., *Coral Reefs, Seagrass Beds, and Mangroves: Their Interaction in the Coastal Zones of the Caribbean.* UNESCO Reports in Marine Science No. 23, Montevideo, Uruguay, p. 51-68.

Benton, Y., 1980. Phosphorites - The unsolved problems, (in) Benton, Y. K., ed., *Marine Phosphorites - Geochemistry, Occurances, Genesis.* Society of Economic Paleontologists and Mineralogists No. 29, p. 3-18.

Birkeland, C., 1985. Ecological interactions between mangroves, seagrass beds, and coral reefs. (in) *Ecological Interactions Between Tropical Coastal Ecosystems.* UNEP Regional Seas Reports and Studies No. 73, p. 1-25.

Bobin, J., 1986. Premiers essais d'Elevage du Crabe Araiqne *(Mithrax spinosissimus)* en Martinique (F.W.I.). Abstract of Proceedings of the 39th Annual Gulf and Caribbean Fisheries Institute Meetings, Bermuda, 1986.

Carpenter, R., 1983. *Natural Systems for Development: What Planners Need to Know.* MacMillan Publishing Company, New York, 483 p.

Chacko, E., and Odunton, N., 1979. *Marine and Coastal Area Development in the Wider Caribbean Area: An Overview.* United Nations Department of International Economic and Social Affairs, GE 79-4551, New York, NY, 65 p.

Chow, B. A., 1985. Overview of coastal zone management in Jamaica. Paper presented to Commonwealth Science Council Project Planning Meeting and Workshop in Coastal Zone Management, St. Lucia, July 1985, 27 p.

Cintron, G., and Schaeffer-Novelli, Y., 1983. Mangrove forests: ecology and response to natural and man-induced stressors. (in) Ogden, J. and Gladfelter, E., eds., *Coral Reefs, Seagrass Beds, and Mangroves: Their Interaction in the Coastal Zones of the Caribbean.* UNESCO Reports in Marine Science No. 23, Montevideo, Uruguay, p. 87-113.

Clark, R., 1986. *Marine Pollution.* Clarendon Press, Oxford, United Kingdom, 215 P.

Creswell, K. L., 1986. Mariculture of the Caribbean King Crab, *Mithrax spinosissimus*, in the Caribbean region: progress and constraints. Abstract of proceedings of the 39th Annual Gulf and Caribbean Fisheries Institute Meetings, Bermuda, 1986.

CTRDC, 1985. *Caribbean Tourism Statistical Report,* Christ Church, Barbados, 97 p.

Cunningham, C., Fary, R., Guffanti, M., Laura, D., Lee, M., Masters, C., Miller, R., Quinones, F., Peebles, R., Reinemund, J., and Russ, D., 1984. Earth and Water Resources and Hazards in Central America. U. S. Geological Survey Circular 925, Alexandria, VA, 40 p.

DOSP, 1985. *Management and Utilization of Marine Resources of the British Virgin Islands.* Dalhousie Ocean Studies Programme, Halifax, Nova Scotia, 125 p.

DuBois, R., 1985. Coastal fisheries management: lessons learned from the Caribbean. (in) Clark, J., ed., *Coastal Resources Management: Development Case Studies.* Renewable Resources Information Series, Coastal Management Publication No. 3. Research Planning Institute, Columbia, SC, p. 291-362.

__________, and Towle, E., 1985. Coral harvesting and sand mining management practices. (in) Clark, J., ed., *Coastal Resources Management: Development Case Studies.* Renewable Resources Information Series, Coastal Management Publication No. 3. Research Planning Institute, Columbia, SC, p. 203- 283.

FAO, 1981. A Review of the Marine Resources of the Western Central Atlantic Fisheries Commission Region. FAO Fisheries Technical Paper No. 211, Rome, Italy.

_____, 1984. *Yearbook of Fisheries Statistics*, Rome, Italy.

Galavis, J., 1985. Importancia de las investigaciones de geologia marina en Venezuela dentro del marco de la Convencion de las Naciones Unidas sobre el Derecho del Mar, VI Congreso. Geologico Venezolano, p. 5469-5781.

Goodwin, M., Moore, E., Nunn, T., Simpson, K., and Towle, E., 1984. An Assessment of the Mariculture Potential of Indigenous Eastern Caribbean Brine Shrimp. Report to U.S. Agency for International Development, Grant No. DPE-5542-G SS-3054-00. Island Resources Foundation, St. Thomas, U.S. Virgin Islands, 115 p.

__________, Orbach, M., Sandifer, P., and Towle, E., 1985. Fishery Sector Assessment for the Eastern Caribbean. USAID Regional Development Office/Caribbean, contract no. 38-0000-C-00-5011. Island Resources Foundation, St. Thomas, U.S. Virgin Islands, 284 p.

__________, Bannerot, S. and Rogers, C., 1986. Information for Coral Reef Management: A Handbook for the Eastern Caribbean. Unpublished manuscript, 120 p.

Guild, R., 1974. Mineral Resources of the Caribbean Region. U.S. Geological Survey open file report No. 74, Washington, DC, 9 p.

Hinrichsen, D., 1981. Energy resources in the wider Caribbean. *Ambio* 10 (6): 332-334.

IUCN, 1980. *World Conservation Strategy: Living Resource Conservation Strategy for Sustainable Development.* IUCN, Gland, Switzerland.

_____, 1982. *Directory of Neotropical Protected Areas.* Tycooly International Pub. Ltd., Dublin, Ireland, 436 p.
_____, 1985. *1985 United Nations List of National Parks and Protected Areas.* IUCN, Gland, Switzerland and Cambridge, England.

IUCN/CMC, 1987. List of threatened coastal and marine taxa in the Caribbean region. IUC/CMC Computer Services Unit, Cambridge, England, 22p.

Jernelov, A., and Linden, O., 1981. Ixtox I: a case study of the world's largest oil spill. *Ambio* 10 (6): 299-306.

Jory, D., and Iverson, E., 1985. Molluscan Mariculture in the greater, Caribbean: an overview. *Marine Fisheries Review* 47 (4): 1-10.
Kenchington, R. A., and Hudson, B. E. T., 1984. *Coral Reef Management Handbook.* UNESCO Regional Office for Science and Technology for South-East Asia. Jakarta, Indonesia, 281 p.

Knecht, R., Cicin-Sain, B., Broadus, J., Silva, M., Bowen, R., Marcus, H., and Peterson, S., 1984. The Management of Ocean and Coastal Resources in Colombia: An Assessment. WHOI-84-21, Woods Hole Oceanographic Institution, MA, p. 109-138.

Manheim, F. T., Pratt, R. M., and McFarlin, P. F., 1980. Composition and origin of phosphorite deposits of the Blake Plateau. (in) Benton, Y., ed., *Marine Phosphorites - Geochemistry, Occurances, Genesis.* Society of Economic Paleontologists and Mineralogists No. 29, p. 117-137.

McMillan, J. P., Granade, H. R., and Hoffman, P., 1980. Ciguatera fish poisoning in the United States Virgin Islands: preliminary studies. *Journal of the College of the Virgin Islands* 6: 84-107.

Munro, J., 1983. A cost-effective data acquisition system for assessment and management of tropical multispecies, multigear fisheries. *Fishbyte* 1 (1): 7-12.

NOAA, 1977. Long Island Beach Pollution: June 1976. Marine EcoSystems Analysis (MESA) Special Report, U. S. Department of Commerce, Washington, DC, p. 35.

OTA, 1984. Staff Paper on the Review of Ocean Thermal Energy Systems. Washington, DC, 33 p.

Ogden, J., and Gladfelter, E., eds., 1983. *Coral Reefs, Seagrass Beds, and Mangroves: Their Interaction in the Coastal Zones of the Caribbean.* UNESCO Reports in Marine Science No. 23, Montevideo, Uruguay, 86 p.

Olson, D. A., and Wood, R. S., 1983. Marine recreational fisheries in the eastern Caribbean. *Proc. Gulf and Caribbean Fish. Institute* 35, Miami, FL, 9 p.

Picard, X., and Goddard, D., 1974. Geomorfologia y sedimentacion de la costa entre Cabo Codera y Puerto Cabello. *Boletin Informativo Asociacion Venezolana de Geologia, Mineria y Petroleo* 18 (1): 39-106.

Ray, C., Dobbin, J., Miller, K., and Putney, A., 1978. *Data Atlas (Preliminary), Planning a Marine Conservation Strategy for the Caribbean Region.* James Dobbin Associates Incorporated, Alexandria, VA, 50 p.

Rodriguez, A., 1981. Marine and coastal environmental stress in the wider Caribbean region. *Ambio* 10 (6): 283-294.

Rogers, C., 1981. Caribbean coral reefs under threat. *New Scientist* (5): 382-387.

Ross, D., and Stewart, H., 1986. A Scientific Plan for Caribbean Marine Research in Support of Marine Resource Development. Report to the Bureau of Oceans and International Environmental and Scientific Affairs. National Academy Press, Washington DC, 39 p.

Ross, F., 1982. The Distribution and Abundance of Larval and Juvenile Reef Fishes in Jamaica. University of the West Indies Zoology Dept. Research Report No. 6., Jamaica.

Ryther, J., Winfree, R., Creswell, R. L., Chaiton, J., Wingrove, R., Prahl, F., Holt, J., Tunberg, B., Bolton, C., 1986. Antigua Crab Mariculture (Semi-Annual Progress Report), AID Grant No. 538-0140.03 (A).

Salm R., and Clark, J., 1984. *Marine and Coastal Protected Areas: A guide for Planners and Managers.* IUCN, Gland, Switzerland, 302 p.

Sandifer, P., 1985. Mariculture. (in) Goodwin, et al. Fishery Sector Assessment for the Eastern Caribbean. USAID Regional Development Office/Caribbean contract no. 38-0000-C-00-5011. Island Resources Foundation, St. Thomas, United States Virgin Islands, p. 48-64.

Scheuer, P. J., Takahasi, W., Tsutsumi, J., and Yoshida, T., 1967. Ciguatoxin: isolation and chemical nature. *Science* (155): 1527-68.

Schmeid, R., 1985. Marine recreational fisheries in the Caribbean, how and why. *Proc. Gulf and Caribbean Fish. Institute* 38, Miami, FL, 8 p.

Silva, M. E., Gately, E. M., and Desilvestre, I., 1986. *A Bibliographical Listing of Coastal and Marine Protected Areas: A Global Survey.* Woods Hole Oceanographic Institution Technical Report No. 86-11, Woods Hole, MA, 156 p.

Sorensen, J. C., McCreary, S. T., and Hershman, M. J., 1984. *Institutional Arrangements for Management of Coastal Resources.* Renewable Resources Information Series, Coastal Management Publication No. 1. Research Planning Institute, Columbia, SC, 165 p.

Stevenson, D. K., 1981. A Review of the Marine Resources of the Western Central Atlantic Fisheries Commission (WECAFC) Region. FAO Fish. Tech. Paper No. 211, Rome, Italy, 8 p.

Tacket, C., 1981. Studies of epidemiological and clinical apects of ciguatera. Paper read at 1st Conference on Ciguatera, Caribbean Fisheries Mangement Council, San Juan, PR.

UNEP, 1983. Action Plan for the Caribbean Environment Programme, UNEP Regional Seas Reports and Studies No. 26, Nairobi, Kenya, 23 p.

UNEP/CEPAL 1979. Marine and Coastal Area Development in the Wider Caribbean Area: Overview Study. Prepared in co-operation with the United Nations Department of International Economic and Social Affairs for the UNEP/ECLA Caribbean Environment Project (FP-1000-77-01), New York, NY, 65 p.

UNDP/FAO, 1981. Regional Cooperation for Aquaculture Development in the Caribbean. Report of a Working Group Meeting in Freeport, Bahamas, FAO, Rome, Italy, 21 p.

UNEP/FAO, 1985. *Directory of marine environmental centres in the Caribbean.* UNEP Regional Seas Directories and Bibliographies, 2nd edition, Rome, 214 p.

Weidner, D. M., 1985. A view of the Latin American shrimp culture industry. *Aquaculture* (2): 16-24.

Wood, E. J. F., and Johannes, R. E., 1975. *Tropical Marine Pollution.* Elsevier Oceanography Series, 12. Elsevier Scientific Publishing Company, Amsterdam, 192 p.

Yasumoto, T., Inoue, A., Bagnis, R., and Garcon, M., 1979. Ecological survey on a dinoflagellate possibly responsible for the induction of Ciguatera. *Bull. Jap. Soc. Fish.* (45): 395-399.

Zieman, J., 1983. Food webs in tropical seagrass systems. (in) Ogden, J. and Gladfelter, E., eds., *Coral Reefs, Seagrass Beds, and Mangroves: Their Interaction in the Coastal Zones of the Caribbean.* UNESCO Reports in Marine Science No. 23, Montevideo, Uruguay, 86 p.

ADDITIONAL READING

Atwood, D., 1986. Marine Pollution Research and Monitoring in the Wider Caribbean. Unpublished manuscript to be submitted to *Mar. Poll. Bull.* in behalf of the CARIPOL steering committe, 5 p.

Beller, W., ed., 1979. *Proceedings of the Conference on Environmental Management and Economic Growth in the Smaller Caribbean Islands.* Wildey, St. Michael, Barbados, September 17-21, 1979. U. S. Department of State Publication 8996, Washington, DC, 187 p.

BOSTID, 1985. *Opportunities in Marine Science and Technology for Developing Countries.* National Research Council, National Academy Press, Washington, DC, 131 p.

C/CAA, 1984. *Caribbean and Central American Databook,* 3rd edition. Caribbean/Central American Action, U. S. House of Representatives, Washington, DC, 378 p.

CCA/UNEP, 1985. *Directory of Environmental Education Institutions, Programmes and Resource People in the Caribbbean Region.* UNEP Regional Seas Directories and Bibliographies, FAO, Rome, 89 p.

Cambers, G. and Schwartz, M., 1985. Report on Beach Stability - Coastal Management Awareness Seminar in Six East Caribbean Islands: Grenada, St. Vincent, St. Lucia, Dominica, St. Kitts, Antigua. Prepared for the UNESCO Regional Office for Science and Technology for Latin America and the Caribbean. Unpublished draft, 17 p.

DOSP, 1984a. *Development and Ocean Management in the Eastern Caribbean: The Case of the Leeward Islands.* Dalhousie Ocean Studies Programme, Halifax, Nova Scotia.

_____, 1984b. Ocean Use and Resource Development and Management in the Eastern Caribbean. Proceedings of a seminar held in Basseterre, St. Kitts, West Indies, 7-9 June, 1983, Dalhousie Ocean Studies Programme, Halifax, Nova Scotia, 219 p.

Goodwin, M., 1984. *Characterization of Lesser Antillean Regional Fisheries.* Island Resources Foundation, St. Thomas, U. S. Virgin Islands, 48 p.

Hartshorn, G., Gustavo, A., DuBois, R., Harcharik, D., Hedkadon, S., Newton, H., Quesada, C., Shores, J., Staples, G., 1981. *The Dominican Republic: Country Environmental Profile.* JRB Associates, McLean, VA, 118 p.

IOC, 1976. Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions. Workshop Report No. 11, Port-of-Spain, Trinidad, 30 p.

Jackson, I., 1986. Carrying capacity for tourism in small tropical Caribbean islands. *Industry and Environment* 9 (1): 7-10.

Lopez, J. M., ed., 1979. Proceedings of the Symposium on Energy, Industry and the Marine Environment in Guayaquil Bay. Center for Energy and Environment Research. U. S. Department of Energy, Mayaguez, PR.

McNeeley, J., and Miller, K., eds., 1982. *National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society.* Proceedings of the World Congress on National Parks, Bali, Indonesia, Smithsonian Institution Press, Washington, DC, 825 p.

Morelock, J., 1980. Sediments and recent geological history of the Guayaquil submarine canyon system, Puerto Rico. (in) *Memorias, 9th Conference Geologica del Caribe,* Santo Domingo, Republica Dominicana, 1:129-139.

__________, 1983. Oceanography and patterns of shelf sediments, Mayaguez, Puerto Rico. *Journal of Sedimentary Petrology* 53 (2): 0371-0381.

Munro, J., 1983. *Caribbean Coral Reef Fishery Resources.* International Center for Living Aquatic Resources Management (ICLARM), Manila, Phillipines, Studies and Reviews 7, 276 p.

NOAA, 1981. *Annotated Acronyms and Abbreviations of Marine Science and Related Activities,* 3rd. edition, Washington, DC, 349 p.

Norman, P. E., 1984. Sewage pollution of the coastal waters of Trinidad and Tobago. Paper presented to the 18th meeting of the Association of Island Marine Laboratories of the Caribbean, St. Augustine, Trinidad, 13-15 August 1984, 21 p.

Rickards, C., ed., 1978. *The Caribbean Year Book,* 49th edition. Caribook, Limited, Toronto, Canada, 948 p.

Ried, R., 1984. Environment and public health in the Caribbean. *Ambio* 10 (6): 312-318.

Rodriguez, R. W., 1984. Submerged sand resources of Puerto Rico. (in) Clarke, S. H., ed., *U. S. Geological Survey Highlights in Marine Research.* USGS Circular 983, Alexandria, VA, p. 57-65.

Sanger, P., Hegerl, E. J., and Davie, J. D. S., eds., 1983. *Global Status of Mangrove Ecosystems.* Commission on Ecology Paper Number 3, International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, 88 p.

Snedaker, S. C., and Getter, C. D., 1985. *Coastal Resources Management Guidelines.* Renewable Resources Information Series, Coastal Management Publication No. 2. Research Planning Institute, Columbia, SC, 205 p.

Spitzer, J. D., 1984. Developing marine pollution response capability in the wider Caribbean region. Paper prepared for the International Maritime Organization, Santurce, PR.

Stevenson, D., Pollnac, R., and Logan, P., 1982. *A Guide for the Small-Scale Fishery Administrator: Information from the Harvest Sector.* International Center for Marine Resource Development, University of Rhode Island, Kingston, RI, 124 p.

Thatcher, P. S., and Meith, N., 1982. The caribbean example. *Ocean Yearbook 3.* University of Chicago Press, Chicgago, IL, p. 223-257.

Thorhaug, A., Marcus, J., and Booker, F., 1986. Oil and dispersed oil on subtropical and tropical seagrasses in laboratory studies. *Mar. Poll. Bull.* 17 (8): 357-361.

United Nations, 1983. Protocol Concerning Cooperation in Combating Oil Spills in the Wider Caribbean Region. New York, NY, 25 p.

United Nations Department of International Economic and Social Affairs, 1982. Coastal Area Management and Development. United Nations Department of International Economic and Social Affairs, Ocean Economics and Technology Branch. Pergammon Press, Great Britain, 188 p.

UNEP, 1983. Marine Pollution. UNEP Regional Seas Reports and Studies No. 25, Nairobi, Kenya, 10p.

_____, 1984a. Regional Seas Programme in Latin America and Wider Caribbean. UNEP Regional Seas Reports and Studies No. 22, Rev. 1., Nairobi, Kenya, 22p.

_____, 1984b. The State of Marine Pollution in the Wider Caribbean Region. UNEP Regional Seas Reports and Studies No. 36, Nairobi, Kenya, 45 p.

UNEP, 1985. Report of the Third Intergovernmental Meeting on the Action Plan for the Caribbean Environment Programme. UNEP/IG.55/4, Nairobi, Kenya.

Waldichuk, M. Retrospect of the Ixtoc I blowout. *Marine Pollution Bulletin* 11 (7): 184-186.

ANNEX A

Institutions

There are numerous institutions throughout the Caribbean which focus their efforts on regional fisheries and resource management issues. These institutions are sponsored by local governments, inter-governmental cooperative bodies, memberships at-large, and the United Nations. As diverse as these institutions are in their origin, they are equally diverse in their influence on the fisheries affairs of the Caribbean community.

Issues of regional concern throughout the Caribbean community are often addressed by international institutions. These multilateral bodies encourage communication and cooperation among member countries, and provide assistance to the region for expanded development and technology. They are capable of directing funds for development, assigning personnel with expertise to training and advisory functions, and developing a regional strategy for addressing fisheries issues. The headquarters for many of these institutions are located in international centers such as Paris or Washington, D.C. with local representatives operating in specific Caribbean countries. While not exclusively dedicated to fisheries, these institutions commonly include fisheries issues on their agendas for discussion and programming.

The scientific community is well established in the Caribbean. Scientists and academic institutions in the region often concentrate their efforts on biological research, and are not often involved with development assistance or the study of Caribbean fisheries per se. This section lists country specific institutions that have a marine research focus. Many academic institutions in the region have the equipment and human resources to conduct investigations and experiments dealing with marine biology, marine ecology, and marine resource management.

Governments in the region have established ministries or departments to deal with fisheries regulations. research, and industry development. These departments vary markedly in their abilities and expertise. Specific fisheries and marine-related governmental departments are not included unless associated with a research insitiution. For a detailed directory of research and governmental marine departments (including addresses, laboratory equipment and staff capabilities) consult the following reference: UNEP/FAO, 1985, Directory of Marine Environmental Centers in the Caribbean.

Together, these institutions form a potentially large pool of human resources and expertise, as well as scientific data and equipment, that can and should be used by foreign donors and development agencies during programming and planning for marine resource development and management.

REGIONAL INSTITUTIONS and PROGRAMS

Caribbean Community (CARICOM)

An intergovernmental body of Caribbean nations for economic cooperation, coordination of foreign policy, and cooperation in health, education, culture, communications, and industrial relations. CARICOM is to receive funds within the next two years from the Canadian International Development Agency for activities related to marine resource development. Member states are: Antigua and Barbuda, the Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St.Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago.

Caribbean Fishery Management Council (CFMC)

Established in 1976 by the Magnuson Fishery Conservation and Management Act, it is to recommend fishery management and conservation measures to the U.S. Government for Puerto Rico and the U.S. Virgin Islands.

Caribbean Marine Pollution Research and Monitoring Program (CARIPOL)

A long-range scientific effort established under the Intergovernmental Oceanographic Commission's Regional Sub-Commission for the Caribbean and Adjacent Regions (IOC/IOCARIBE) to carry out research and monitoring programs related to pollution in the Caribbean. Acts as a regional component of IOC's Global Investigation of Pollution in the Marine Environment (GIPME) conducted cooperatively with the United Nations Environment Program. Vice-chairmen are responsible for implementation of mussel watches, petroleum monitoring, and data archiving.

Gulf and Caribbean Fisheries Institute (GCFI)

A non-profit organization founded to increase communication and exchange of information on development and management of fisheries and aquaculture resources; now operating through the South Carolina Sea Grant Consortium. Annual meetings are held in varying Caribbean locations that feature technical sessions, workshops, and demonstrations which are attended by fishermen, fisheries administrators, and scientists from countries throughout the Caribbean. A journal of proceedings is published annually.

Intergovernmental Oceanographic Commission (IOC)

An autonomous body established by UNESCO, in Paris, to promote scientific investigations by its member states of the nature and resources of the ocean. Functions include development and coordination of scientific investigations, interaction with other inter-governmental organizations, exchange of oceanographic data, recommendations for education and training, and assistance programs in marine science and technology (see CARIPOL).

IOC Subcommission for Caribbean and Adjacent Regions (IOCARIBE)

Serves as the regional body to coordinate and implement IOC program activities of particular interest to the region (see CARIPOL).

Organization of Eastern Caribbean States (OECS)

An intergovernmental body established to promote regional cooperation among its member states, now based in Castries, St. Lucia. It has served as the focal point for FAO-sponsored workshops for regional harmonization of fisheries legislation. A fisheries desk is being established with funds from the International Centre for Ocean Development (Canada), consisting of one officer responsible for fisheries policy and another for data collection and exchange. Member states are Antigua and Barbuda, the British Virgin Islands, Dominica, Grenada, Montserrat, St.Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines.

United Nations Development Programme (UNDP)

Assists lesser developed countries with establishing and expanding technological capabilities. The headquarters are in New York, N.Y. It operates research vessels suitable for fisheries research and technology development. It undertook Caribbean fisheries development projects jointly with FAO from 1965 to 1971.

United Nations Environment Programme (UNEP)

Operates Regional Seas Program in Latin America and the Wider Caribbean. The headquarters are in Nairobi, Kenya, and there are member representatives in the Caribbean region. UNEP collaborated with the Economic Commission for Latin America and the Caribbean in the development of an action plan for the Caribbean region. Objectives of the plan inlcude: identification and development of programs to minimize marine environmental problems; development of a framework for activities that require regional cooperation for implementing sound environmental management of marine resources (UNEP, 1983). Between 1976 and 1984, with other United Nations specialized agencies, workshops were convened in Trinidad to identify the highest priority marine pollution problems and to consider specific proposals to counter them. This has stimulated preparation of oil spill contingency plans in Trinidad and Tobago, St. Lucia, Haiti, the British Virgin Islands, Antigua, Turks and Caicos, and Grenada; similar work is under way in Mexico and Central American nations.

Western Central Atlantic Fisheries Commission (WECAFC)

An advisory body of the United Nations Food and Agriculture Organization (FAO) currently with 28 member countries from Latin America and the Caribbean. FAO is based in Rome. Meetings are held every two years to discuss fishery matters. Working parties on resources assessment and statistics have been established. They meet annually.

Association of Island Marine Laboratories of the Caribbean

It coordinates programs of common interest to marine laboratories in the Caribbean region. Annual meetings are held throughout the Caribbean, yet most of the activites are handled through correspondence. A proposal for a regional research project, Caribbean Coastal Marine Productivity (CARICOMP), is under consideration.

NATIONAL INSTITUTIONS

BAHAMAS

Caribbean Marine Research Center (CMRC)
Lee Stocking Island, Exuma, Bahamas

Private institution operated by the Bahamas Undersea Research Foundation and the Perry Foundation. Conducts studies on tropical and subtropical ecosystems, aquaculture, and supports activities to foster marine education.

Morton Salt Company (MSC)
Matthew Town, Inagua

Private institution set up to incorporate mariculture with solar salt operations. Projects include the development of a grow-out facility and hatchery for penaeid shrimp. Also conducts algal culture research.

BARBADOS

Bellairs Research Institute of McGill University
Holetown, St. James

Private institution with undergraduate and graduate programs in applied tropical ecology, marine biology and geology, fisheries biology and pollution effects on coral reef ecosystems.

University of the West Indies
Cave Hill Campus

It conducts undergraduate programs in marine biology. A Center for Environmental and Resource Management Studies has recently been started. Plans are to develop long and short-term training programs, begin research, promote public awareness of environmental concerns, and establish a regional information center for resource development projects.

COLOMBIA

Centro de Investigaciones Oceanograficas
e Hidrograficas (CIOH)
Cartagena

Governmental institution for research, principally in oceanography and hydrography. It has participated in cooperative research programs with Harvard University, the University of Miami, Woods Hole Oceanographic Institution and other academic institutions. Physical oceanography courses are offered to cadets at the Colombian Naval Academy.

Facultad de Biologia Marina,
Fundacion Universidad de Bogota,
Jorge Tadeo Lozano (UJTL)
Cartagena

Private institution with undergraduate training in marine biology; research principally in marine biology, fisheries science, aquaculture and marine pollution.

Facultad de Ingenieria Pesquera
Universidad Tecnologica de Magdalena (UTM)
Santa Marta, Magdalena

Public university for professional training in the capture, processing and marketing of fishes and fish products. Research emphasis is on fish diseases, new methods of fish processing, and aquaculture; courses in fisheries and in marine geology.

Instituto de Investigaciones Marinas
de Punta de Betin (INVEMAR)
Santa Marta, Magdalena

Governmental facility for basic and applied research on marine and estuarine resources. Emphases are on demersal fishes, mangrove ecosystems, preservation of marine areas, and aquaculture. There are short extension courses in marine biology and there is a two-year graduate program in cooperation with the National University of Colombia.

Laboratorio del Instituto Nacional de los
Recursos Naturales Renovables y del Ambiente
(INDERENA)
Cartagena

Government research institution with responsibilities for resources management and enforcement, including fisheries, parks and water pollution monitoring.

COSTA RICA

Centro de Investigacion en Ciencias del Mar y
Limnologia, Universidad de Costa Rica (CIMAR)
San Pedro de Montes de Oca

One of 21 research institutes attached to various faculties and schools of the University of Costa Rica with undergraduate and graduate degrees in marine sciences. The research program includes studies in ecology and fisheries, oceanographic applications of remote sensing, pollution of coastal waters, marine biology, marine geology, and evaluation of Costa Rican fishery resources.

Cooperative programs are carried out with a number of foreign universities, including the Universidad Nacional Autonoma de Mexico, the University of Delaware and the University of Southern California.

Escuela de Ciencias Biologicas, Facultad de Ciencias Exactas y Naturales, Universidad Nacional
Heredia

Bachelors and five-year degrees in marine biology with concentration on aquaculture. Emphases on aquaculture, marine biology, physical oceanography and fish genetics.

Laboratorio de Investigaciones Marinas de Punta Morales (LIM)
San Jose

Governmental research facility with specializations in aquaculture and marine fisheries.

CUBA

Centro de Investigaciones Marinas (CIM)
Havana

Research and educational institution offering undergraduate and graduate training in marine biology and some marine biological specialties. There are research emphases on fishes and crustaceans of commercial importance to Cuba, aquaculture of lobsters and tilapia, and marine ecosystems of Cuban coastal waters. Cooperative programs exist with institutions in the USSR, Rumania, Mexico and Panama.

Centro de Investigaciones Pesqueras (CIP)
Havana

Research center involved in education, fisheries research and assistance to the fishing industry. Research emphases on shrimp, lobsters, tuna, and estuarine and coral reef fishes; graduate courses in fisheries and marine biology.

Instituto de Oceanologia (IO)
Havana

Research and graduate education institution for oceanography, fisheries and marine ecology. There is a two-year program for the training of oceanographic technicians and graduate courses in biological, chemical and geological oceanography. The research emphasis is on the ecology of Golfo de Batabano and decontamination of Havana Bay.

DOMINICAN REPUBLIC

Centro de Investigaciones de Biologia Marina
Santo Domingo (CIBIMA)

Center within the Universidad Autonoma de Santo Domingo; offers courses, seminars, conferences, and supervision of student research projects in marine biology and related fields. The research emphases are on the biology of aquatic animals, fisheries development, aquaculture, hydrology and oceanography, marine pharmacology, and an inventory of marine flora and fauna.

GUADELOUPE

Institut national de la recherche agronomique (INRA)
Petit-Bourg

Governmental research institute and one of the regional centers of the Paris-based agronomy institute. Research emphases in tropical bioagronomy, including aquaculture, tropical ecology, mangrove ecosystems, and analysis of agricultural impacts. Offers instructional programs to train technicians, agronomy engineers, and doctoral level scientists.

GUATEMALA

Centro de Estudios del Mar y Acuacultura, Universidad de San Carlos de Guatemala (CEMA)
Ciudad de Guatemala

Small private research institution and educational facility including extension services. Focus on shrimp and lobster culture studies and pelagic fisheries research.

Direccion Tecnica de Pesca y Acuicultura, (DITEPESCA)
Ciudad de Guatemala

A small research facility which also oversees the untilization of marine resources including, research on penaeid and freshwater shrimp, and specialization in marine demersal and pelagic fishes.

GUYANA

Department of Biology, University of Guyana
Georgetown (UG)

Undergraduate and graduate training for teaching, research, industry, agriculture, health and administration; some research in limnology and cytogenetics.

JAMAICA

Discovery Bay Marine Laboratory (DBML)
Discovery Bay, St. Ann

A field station for the University of the West Indies. A variety of research projects are carried out by visiting investigators from North America and Europe. Has developed a recent research emphasis on coral reef ecosystems, sedimentology, water chemistry, physiology, behavior and ecology of reef organisms. Offers an international graduate level course each summer on some aspect of marine science.

Port Royal Marine Laboratory
Kingston

Part of the zoology department of the University of the West Indies with undergraduate and graduate zoology degrees. Research and training programs emphasize marine ecology, coastal management, fisheries biology and aquaculture.

MARTINIQUE

Institut francais de recherche pour l'exploitation de la mer, Station du Robert (IFREMER)
Pointe Fort, Le Robert

Government research institution exclusive to aquaculture and fisheries work, focusing on primary productivity studies.

MEXICO

Centro de Investigacion y de Estudios Avanzados del Instituto Politecnico Nacional, Unidad Merida (CINVESTAV)
Merida, Yucatan

Research center integrating work of departments of biochemistry, physics, mathematics, genetics, molecular biology, biotechnology, neuro-sciences and others of the Instituto Politecnico Nacional. There are research opportunities and graduate instruction in marine biology with research emphases on exploitable resources of the Yucatan, fisheries and aquaculture.

Centro de Investigacion y Entrenamiento para Control de la Calidad del Agua (CIECCA)
Mexico City

Government research institution focusing on limnology, pelagic fisheries and technology transfer.

Instituto de Biologia, Universidad Nacional Autonoma de Mexico (UNAM)
Mexico City

Institute of UNAM with undergraduate and graduate training. Recent research in biology and geochemistry, coastal lagoons, studies of fishes and crustaceans, aquaculture, fisheries ecology, fish parasites, and plankton.

Centro de Ciencias del Mar y Limnologia (CCML)

Established at UNAM with installations at the main UNAM campus in Mexico City, El Carmen Station, Puerto Morelos Station, and Mazatlan Station. The principal areas of research include physical oceanography, chemical oceanography and pollution, geological and geophysical oceanography, biological oceanography and fisheries biology, and limnology. About twelve graduate students are admitted each year from UNAM, other Mexican universities, and from many Latin American countries. The CCML has participated in international cooperative projects with universities and research institutions in the United States, the United Kingdom, France, Costa Rica and other countries.

Instituto Nacional de la Pesca (INP)
Mexico City

Government research institution responsible for monitoring Mexican fisheries resources. Research emphases on fisheries biology of commercially important species, fish harvesting methods, fisheries product technology, and oceanography. Offers graduate courses in fisheries sciences.

Universidad Autonoma Metropolitana, (Unidad Ixtapalapa) Departmento de Zootecnica, Division Ciencias Biologicas y de la Salud (UAM), Mexico City

Private education and research facility, focusing on marine fisheries limnology, and aquaculture.

Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM)
Gyuamas Campus

Private institution offering undergraduate and graduate level training in marine biology and food technology. Research in aquaculture, marine mammals and shrimp by-catch utilization in collaboration with U. S., Japanese and other institutions.

NETHERLANDS ANTILLES

Foundaction Carmabi
Willemstad, Curacao

Private research foundation; formerly the Caribbean Marine Biological Institute. Research emphasis on fisheries, coral reef ecology, and marine resource management. Has facilities for visiting scientists and students.

NICARAGUA

Centro de Investigaciones Pesqueras, (CIP)
Instituto Nicaraguense de la Pesca, Managua

Fisheries research institute for aquaculture studies, principally in stock assessment and the determination of resource abundance and distribution.

PANAMA

Centro de Ciencias del Mar y Limnologia
(CCML)
Panama City

Center of the University of Panama with research, technical training and technology transfer programs in marine science. Research emphases on chemistry, sediments, primary productivity and fisheries resources of the Gulf of Panama. Has participated in cooperative projects with Smithsonian Tropical Research Institute, the University of Havana, and the University of Delaware. Offers undergraduate courses in marine biology, oceanography, ichthyology and marine ecology.

Smithsonian Tropical Research Institute (STRI)
Balboa

Center for advanced tropical studies on basic biological processes and conservation with the support of advanced training and tropical research by scientists from other institutions. Has an environmental sciences program at the Galeta Marine Laboratory on the Caribbean which monitors air and sea conditions, and distribution, abundance and diversity of reef plants and animals. About 200 visiting scientists and students use the facilities each year. There are fellowships for students to conduct independent research projects under the direction of resident staff. Assistantships provide students and recent graduates with the opportunity for field experience. Qualified students from Latin America and elsewhere are eligible to participate. Research projects have been carried out in collaboration with many institutions in Europe and the Americas.

PUERTO RICO

Departmento de Ciencias Marinas,
Universidad de Puerto Rico (DCM)
Mayaquez

Government research institution with academic programs at the graduate level. Participates in NOAA's Sea Grant extension program. Offers courses and research opportunities in aquaculture, biological oceanography, demersal and pelagic fisheries.

SAINT LUCIA

Caribbean Environmental Health Institute (CEHI)
Castries

Inter-governmental organization established by CARICOM in 1981 to coordinate all aspects of environmental health activities with member states. Conducting waste management studies and marine pollution monitoring network. Currently studying bacterial and chemical pollution and their effects on St. Lucia.

TRINIDAD AND TOBAGO

Institute of Marine Affairs (IMA)
Carenage

Founded as a joint project of the Government of Trinidad and Tobago and the United Nations. Offers graduate courses in marine biology and fisheries. Conducts research and monitoring studies on water quality, stock assessment of commercially important fish species, and coastal erosion. Personnel perform instructional, research and extension functions similar to a university; several staff members are associate faculty at the University of the West Indies.

U.S. VIRGIN ISLANDS

West Indies Laboratory,
Fairleigh Dickinson University (WIL)
Teague Bay, Christiansted, St. Croix

Private research and teaching facility with graduate and undergraduate courses in tropical marine ecology. Site of NOAA Hydrolab facility for advanced underwater and marine research.

VENEZUELA

Centro de Investigaciones Biologicas,
Facultad de Humanidades y Educacion,
Universidad de Zulia (CIB)
Maracaibo, Zulia

Private education and research facility, focusing on marine fisheries limnology, and aquaculture.

Estacion de Investigaciones Marinas de Margarita,
Fundacion La Salle de Ciencias Naturales,
Campus de Margarita (EDIMAR)
Nueva Esparta

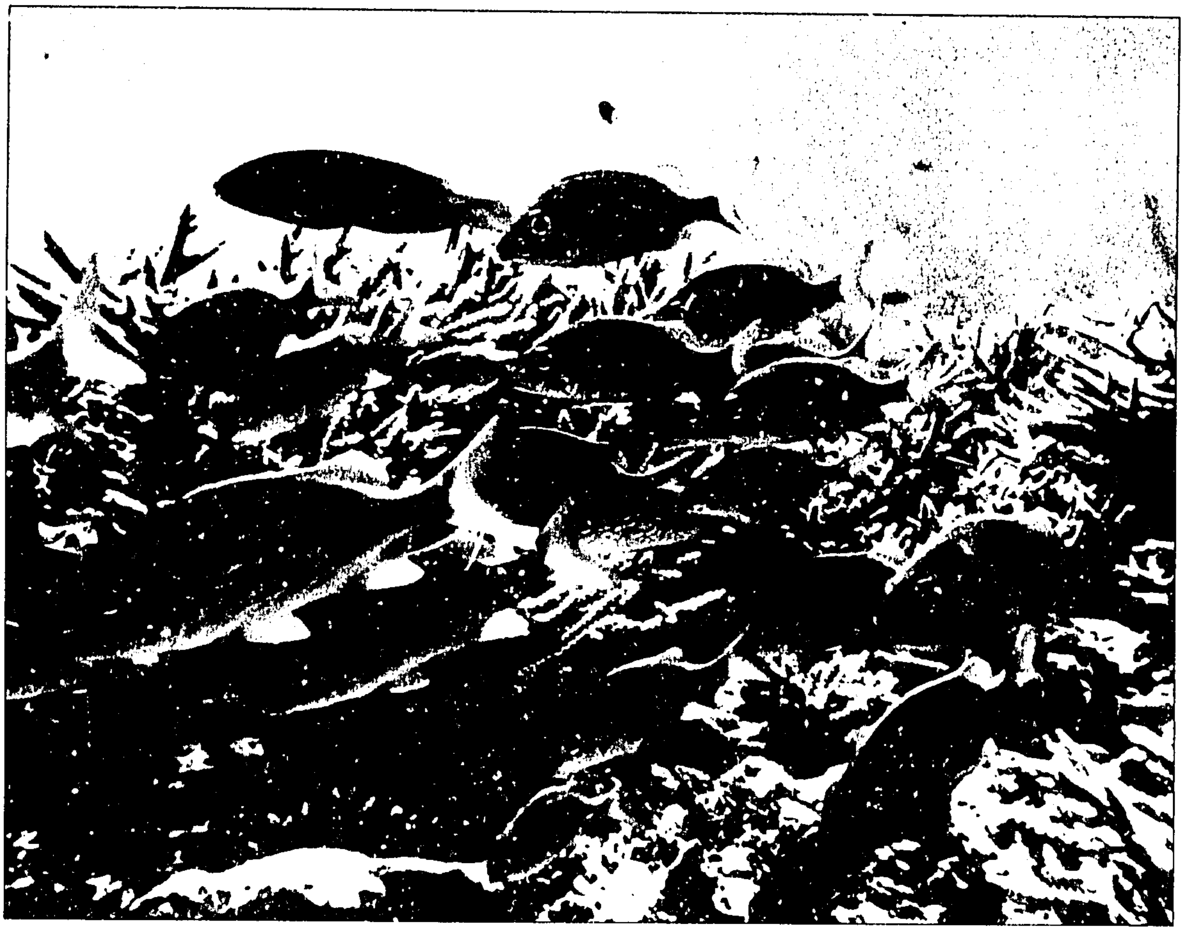
Private institution with extensive curricula and research in marine biology, fisheries biology, and aquaculture.

Instituto Oceanografico (IO)
Cumana, Sucre

Government research institution; diverse fisheries studies.

Instituto para el Control y la Conservacion de la Cuenca del Lago de Maracaibo (ICLAM)
Maracaibo, Zulia

Government research institution; fisheries, limnology, aquaculture.



Together the variety of institutions throughout the Caribbean form a wealth of expertise, which may be able to develop a balanced approach for integrating fisheries development with other marine resources. (Photo: M. W. Williams)

ANNEX B

Country Notes

No attempt has been made to produce a systematic marine resource "profile" for each Caribbean country. In the course of preparing this report, some country-specific information has been obtained that is relevant to the discussions in the preceeding chapters. This information is summarized below. The general absence of specific information on underexploited fishery and geological resources underscores the need for better data in support of development of the Caribbean marine sector. This dirth of information impedes the preparation of the comprehensive marine resource development and management plans that are needed throughout the region.

Antigua and Barbuda

Both islands rest on coral platforms, and are surrounded by relatively large submarine shelves. The fishing industry is small, and the country imports roughly half of the fishes consumed. Tourism is the mainstay of the economy with attendant problems for nearshore habitats. Large quantities of sand are mined in Barbuda for shipment to the U.S. Virgin Islands. Offshore oil leases have been granted within Antigua and Barbuda territory.

Aruba

As of January 1986, Aruba has acquired autonomous status within the Kingdom of the Netherlands and now has equal and separate status from the Netherlands Antilles. The island is located 24 kilometers from the Venezuelan coast. The island is arid and agriculture is relatively unimportant. Fisheries are primarily demersal due to proximity to the South American coast. Tourism is a significant source of revenue, and reefs, mangroves, and seagrass beds apparently are flourishing. Fisheries are underdeveloped, and there is potential for high-density mariculture. Solid waste and sewage disposal pose potential problems in urban areas.

Barbados

Based on a coral platform, Barbados is ringed by sand beaches and coral reefs. Tourism is the primary industry, followed by light manufacturing and sugar. The coastal shelf is narrow, and the major fisheries are oceanic pelagic and offshore demersal species. Nearshore fisheries have been overexploited, and stock depletion is aggravated by deteriorating water quality in coastal areas. Problems of coastal erosion are worsened by stress on coral reefs resulting from pollution from sewage, solid waste, fertilizers, industrial effluents, and suspended sediments.

Belize

This 257 kilometer long chain of islands and coral heads form the largest continuous barrier reef in the northern hemisphere. Miles of white sand beaches and protected waters offer substantial but undeveloped potential for tourism. There is a well-established and economically important fishing industry for lobster, conch, finfishes, shrimp, and turtles. Oil pollution and garbage disposal are major problems of immediate concern. A management plan has been drafted for creation of the first multi-use marine park in the barrier reef, near Ambergis Caye.

British Virgin Islands

These 36 islands are characterized by coral reefs, mangroves, white sand beaches, and salt ponds. Tourism accounts for seventy percent of the territory's GNP, as well as for many of its major coastal problems. Examples of tourism related impacts include the clearing of mangrove forests for construction, and damage to marine habitats by boat anchors and divers. Coastal pollution problems are expected to increase as the tourist industry continues to expand.

Colombia

The coastal area of Colombia represents a small proportion of the total national territory, but early industrial growth was concentrated around natural harbors at Barranquilla, Cartagena, and Santa Marta. Coastal tourism has less economic importance than the industrial and port sector, though government plans call for increased tourist activity along the Atlantic coast and in Colombia's Caribbean islands. Fishery resources are believed to be underutilized, but development is hampered by inadequate assessment of these resources. Highly destructive extraction methods of fisheries exploitation, such as dynamiting the shallow reefs, coastal pollution and sedimentation, are threatening the productivity of fisheries and destroying coral reefs. Comprehensive development and management plans are needed for coastal areas.

Costa Rica

Historically, coastal activities have been oriented toward the Pacific coast. In the past decade, there has been intensification of agricultural, industrial, petroleum-related, and tourist activity along the Caribbean coast. The documented impacts of these activities include siltation, increasing pesticide levels, eutrophication, and pollution from petroleum hydrocarbons. Research and monitoring to investigate these impacts are underway. Information on the extent of coastal and fishery resources is lacking.

Dominica

The coastal shelf is extremely narrow, with few protected bays or beaches. Coral reefs are not extensive, and consist primarily of coral veneers on rock substrates. Tourism is not heavily developed, and there has been substantial emphasis upon agriculture. The fishing industry is small, and concentrates primarily upon pelagic resources. Nearshore stocks have been heavily exploited and may be overfished. Domestic refuse, sewage, pesticides, and waste from light industry cause stress to limited nearshore habitats. Coastal erosion has been exacerbated by removal of beach stones for road construction.

Dominican Republic

A narrow shelf, low productivity of nearshore waters, and the lack of fishery tradition combine to make the country dependent upon imports for seventy percent of fishes consumed. A variety of incentives and tax privileges have been provided to encourage fisheries and aquaculture development, resulting in a seventy percent increase in domestic production since 1983. Emphasis on aquaculture is resulting in significant production of freshwater prawns and penaeid shrimp. Lack of adequate information on size of fishery stocks and location of critical habitats are major constraints to development. Inadequate enforcement of fishery legislation has led to possible overfishing of the spiny lobster. Problems with ciguatera have impeded the development of reef fisheries. The first offshore marine sanctuary has been declared on the Silver Banks for breeding humpback whales. The largest mangrove forest in the country (at the head of Samana Bay) is threatened by development of rice agriculture. High priority has been assigned to development of tourism, raising concern for adequate waste disposal, beach protection, and collection of curios (coral and ornamental shells).

Grenada

A large submarine shelf to the southwest combined with a portion of the Grenadine shelf provide Grenada with substantial fishery resources. Artisanal fisheries are relatively well-developed, and a successful fisheries improvement program has been in operation for several years. Coastal erosion, aggravated by sand mining and possibly pollution (in the case of Grand Anse beach) is a serious problem. Shallow-water fisheries are approaching limits of sustainable exploitation. Lobster and conch may be overexploited, and information is needed on underutilized deep water resources.

Guatemala

The Caribbean coast consists of two zones: the Bay of Amatique is characterized by wide, low-energy beaches, seagrass beds and shrub-like vegetation; while the open water zone has smaller medium-energy beaches and swamp areas with mangrove stands. Fisheries are small and underdeveloped. A small amount of lobster is exported, but there is signficant potential for expanded shrimp, tuna and snapper fisheries as well as aquaculture in estuarine areas. Oil pollution is the most significant environmental threat, both to fisheries and the developing tourist industry.

Haiti

Haiti has an extensive coastline with mangrove forests, lagoons, seagrass beds, coral reefs, sand beaches, estuaries, and protected bays. It is assumed that these systems are generally healthy except in areas affected by pollution (near Port-au-Prince) and sedimentation from agricultural runoff. Nearshore reef fisheries are overexploited, however, and there is a substantial export trade in coral, turtle shell, aquarium fishes, and ornamental shells. Stock assessments, improvements in fishing technology and marketing studies are needed to expand fishery activity offshore and to manage nearshore resources. Substantial opportunity exists for marine-based tourist activities including SCUBA and deep-sea fishing.

Honduras

Agriculture is a principal industry. The continental shelf varies in width from 19 to 238 kilometers, and offers significant development potential. Fishing activities are concentrated on lobster and shrimp for export, with little harvest for domestic consumption. Coral reefs, seagrass beds, mangrove forests, and white sand beaches are characteristic of the coast. The Bay Islands (including Roatan, Utila, and Guanaja) are the center of commercial fishing activity and are favored vacation spots. An oil refinery at Puerto Cortes poses potential environmental problems, as does expanding tourism. There are no environmentally sensitive development guidelines or comprehensive plans. The shortage of trained personnel and rational development and management plans are major constraints to securing optimum economic benefits from marine resources.

Jamaica

The shelf of the northern coast of the island is only about 1 kilometer wide, yet supports a well-developed system of fringing reefs. Traditional fishing grounds are located on banks to the south and east in the vicinity of Morant and Pedro Cays. The most pressing coastal area problems are:

- stock depletion due to overfishing and degradation of nursery areas;

- severe pollution from domestic sewage, pesticides, and wastes from petroleum, breweries, tanneries, rum, soap, bauxite, sugar, and food processing industries;

- high sediment loading from poor land management and bauxite mining;

- coastal erosion from indiscriminate removal of beach sand and construction; and,

- tourism-related damage to reefs including removal of coral, mechanical damage by divers, and local selling of corals.

Mexico

The Caribbean coast lies entirely within the state of Quintana Roo on the Yucatan Peninsula. A continuous fringing and barrier reef system extends from the Belize border to Cancun. Mangroves and seagrass beds are found along the coast, and are presently in pristine condition. The extent of marine resources is not known, but concern exists for high-value species, for example, spiny lobster and conch, which are increasingly harvested as tourism rapidly develops. Shrimp fisheries, supported by extensive mangrove wetlands, are prevalent along the Gulf of Mexico and in the Yucatan

Netherlands Antilles

This autonomous federation consists of two groups of islands: Curacao and Bonaire near the coast of Venezuela; and Saint Maarten, Saint Eustatius, and Saba to the north of St. Christopher. The southerly islands have extensive fringing reefs and white sand beaches. Because of the relatively narrow coastal shelf, the fisheries are almost wholly pelagic. Seagrass beds and mangroves have suffered from some human activity, but portions of the Curacao coast and all of the Bonaire underwater environment are managed as parks. The northern islands are characterized by fringing reefs and white sand beaches which make tourism a primary industry. Marine habitats are generally in good condition, but there is strong likelihood that the Saba Banks (widely reported in the 1960s to be promising fishing grounds) are being overfished by fleets from a variety of nations. Regulation of fishing access is a pressing need for protection of these resources.

Nicaragua

Highly productive ecosystems are located along the Caribbean coast on a relatively large (average width of 112 kilometers) continental shelf shared with Honduras. Extensive seagrass beds, mangrove swamps and lagoons are relatively undisturbed because of heavy rainfall and insect pests. No tourism or industrial activity occurs on the Caribbean coast. The extent and characteristics of Caribbean marine resources are virtually unknown and probably offer significant potential for economic development.

Panama

Because of the importance of shipping and international finance to the economy of the country, relatively little emphasis has been placed upon development of coastal resources. Fisheries are artisanal and small, consisting primarily of lobster and green turtles. There are extensive mangrove forests on both the Pacific and Atlantic coasts, and coral reefs along the northern coast, which have been given priority for tourism development by the Panamanian government. There has been some overfishing of lobsters in the Caribbean waters and shrimp in the Pacific, but sharks and snapper may have potential for development. Inadequate information on coastal and fishery resources is a major impediment to reasonable development planning.

St. Christopher and Nevis

Both islands are volcanic, with narrow coastal shelves and scattered seagrass beds and coral reefs. Nearshore resources are heavily exploited, but a fisheries development program is being instituted which features exploration of deepwater stocks, small-scale mariculture, and improved management of nearshore stocks and habitats. Coastal erosion is a widespread problem aggravated by sand removal for construction. Industrial pollution due to sugar factory waste, has been confined to Basseterre Bay, but problems with sewage disposal are expected to increase with the development of tourism.

St. Lucia

The island is volcanic with few beaches. There is an extensive seagrass and coral reef system on the southeastern coast, and isolated reefs on the western coast which are significant tourist attractions. Of the Eastern Caribbean governments, St. Lucia's has indicated the greatest interest and commitment to fisheries development. Pelagic fisheries account for the majority of landings and are the primary target of development plans. Erosion is the most significant coastal problem, and has destroyed several beaches, coral reefs, and turtle nesting habitats. Natural erosion processes have been augmented by clearing of forests, sand mining, and poorly-planned reclamation projects.

St. Vincent and the Grenadines

These islands are volcanic, but while St. Vincent has little coastal shelf, the Grenadines rest upon one of the largest shelves in the Lesser Antilles. Extensive coral reefs, seagrass habitats, and white sand beaches are found throughout the Grenadines and are the focus of significant tourist activity. Shallow-water fisheries have been overexploited, a development which has been encouraged by lucrative markets for fishes in the French Antilles. Beach tar from seaborne pollution is a growing problem for recreational beaches, aggravated by solid waste from pleasure yachts. Removal of sand and stone for construction aggregate has caused significant erosion on the west coast of St. Vincent. There is a possibility of developing alternative sources at the Brighton and Diamond sand dunes, but such development requires adequate advanced impact assessment. St. Vincent expects to receive major funding from the Canadian Government for fisheries development in the near future.

Trinidad and Tobago

These islands are geologically part of South America, and have one of the highest gross domestic products in the region derived largely from petroleum production and refining. Trinidad has extensive tropical forests and large swamps, as well as numerous coral reefs and white sand beaches. Fishing is primarily artisanal, and appears to have little effect upon the available resource. There is a brisk export trade in tropical fishes and ornamental shells. Tobago, where tourism is the second largest source of foreign exchange, has a modest charter fishing fleet, but no such service exists in Trinidad. While the Government has established the Caroni Swamp as a national park, there is no comprehensive plan for coastal management or fisheries development. Inadequate marketing structure for fishes and inadequate information on resources are major disincentives to such planning.

Venezuela

Venezuela is a major producer and exporter of oil, and large-scale steel and petrochemical industries are being developed in Zulia, which is also the site of roughly 40% of the nation's fishing industry. The largest urban and industrial concentrations lie along the coast, including commercial fisheries, heavy industry, petroleum recovery, ports, domestic housing and tourism. The latter industry is increasing rapidly, but is relatively unimportant to the gross national product. Pollution near Caracas has caused some beaches to be closed to recreational use. Oil spills, other hydrocarbons, mercury residues, and thermal discharges have led to the disappearance of marine species (including mollusks, mangroves, and corals) in some areas. Removal of mangroves and dredging associated with coastal construction have increased erosion problems and sediment loading. A variety of marine species including shrimp, prawns and crabs are threatened and the Caribbean Monk Seal may be extinct.

ANNEX C

Threatened Taxa

This Annex provides a country-specific list of threatened coastal and marine animal taxa in the Caribbean region. The information here was provided by the International Union for the Conservation of Nature and Natural Resources (IUCN)/Cambridge Monitoring Centre (CMC), located in Cambridge, England. Species identified as threatened by IUCN are assigned a catagory indicating the degree of threat. Definitions are as follows:

EXTINCT (Ex): Species not definitely located in the wild during the past 50 years (criterion as used by the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

ENDANGERED (E): Taxa in danger of extinction and whose survival is unlikely if the casual factors continue operating.

VULNERABLE (V): Taxa believed likely to move in to the "Endangered" catagory in the near future if the causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security has not yet been assured; and taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range.

("Endangered" and "Vulnerable" catagories may include, temporarily, taxa whose populations are begining to recover as a result of remedial action, but whose recovery is insufficient to justify their transfer to another catagory.)

RARE (R): Taxa with small world populations that are not at present "Endangered" or "Vulnerable", but are at risk. These taxa are usually localised within restricted geographical areas or habitats or are thinly scattered over a more extensive range.

INDETERMINATE (I): Taxa known to be "Endangered", "Vulnerable" or "Rare" but where there is not enough information to say which of the three catagories is appropriate.

INSUFFICIENTLY KNOWN (K): Taxa that are suspected but not definitely known to belong to any of the above catagories, because of lack of information.

THREATENED (T): Threatened is a general term to denote species which are "Endangered", "Vulnerable", "Rare", "Indeterminate", or "Insufficiently Known" and should not be confused with the use of the same term by the U.S. Office of Endangered Species. In this document it is used to identify taxa comprised of several sub-taxa which have differing status catagories.

COMMERCIALLY THREATENED (CT): Taxa not currently threatened with extinction, but most of all of whose populations are threatened as a sustainable commercial resource, or will become so, unless their exploitation is regulated. This catagory applies only to taxa whose populations are assumed to be relatively large. In practice, this catagory has only been used for marine species of commercial importance that are being overfished in several parts of their ranges.

TAXON NAME	COMMON NAME	

CARIBBEAN REGION

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E
Phylum *CNIDARIA*		
Order *ANTIPATHARIA*		
Family *Anthipathidae*	Black Corals	CT
Phylum *MOLLUSCA*		
Order *ARCHAEOGASTROPODA*		
Family *Strombidae*		
Strombus gigas	Queen Conch	CT
Sub-Phylum *CRUSTACEA*		
Order *DECAPODA*		
Family *Palinuridae*		
Panilurus argus	Spiny Lobster	CT
Panilurus guttatus	Spotted Spiny Lobster	CT

ANTIGUA and BARBUDA

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

BAHAMAS

Class *MAMMALIA*		
Order *PINNIPEDIA*		
Family *Phocidae*		
Monachus tropicalis	Caribbean Monk Seal, West Indian Seal	E
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

BELIZE

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermatemyidae*		
Dermatemys mawii	Central American River Turtle	V
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E
Order *CROCDYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

CAYMAN ISLANDS

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

COLOMBIA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus inunguis	Amazonian Manatee, South American Manatee	V
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga, Tora, Barriguda, Tartaruga	E

Order *CROCDYLIA*
Family *Alligatoridae*

Caiman crocodilus crocodilus	Spectacled Caiman	V
Caiman crocodilus fuscus	Brown Caiman	V

Family *Crocodylidae*

Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

BRITISH VIRGIN ISLANDS

Class *REPTILIA*
Order *TESTUDINES*
Family *Dermochelyidae*

Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E

CUBA

Class *MAMMALIA*
Order *SIRENIA*
Family *Trichechidae*

Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V

Class *REPTILIA*
Order *TESTUDINES*
Family *Cheloniidae*

Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E

Order *CROCODYLIA*
Family *Alligatoridae*

Caiman crocodilus fuscus	Brown Caiman	V

Family *Crocodylidae*

Crocodyllus acutus	American Crocodile, Crocodilo, Largato Negro	E

DOMINICA

Class *REPTILIA*
Order *TESTUDINES*
Family *Cheloniidae*

Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

DOMINICAN REPUBLIC

Class *MAMMALIA*
Order *SIRENIA*
Family *Trichechidae*

Trichechus manatus	Caribbean Manatee, North American Manatee, Am. Manatee	V

Class *REPTILIA*
Order *TESTUDINES*
Family *Cheloniidae*

Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

Family *Dermochelyidae*

Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E

Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodyllus acutus	American Crocodile, Crocodilo, Largato Negro	E

GRENADA

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

THE GRENADINES

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E

GUADELOUPE

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E

GUATEMALA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermatemyidae*		
Dermatemys mawii	Central American River Turtle	V
Order CROCDYLIA		
Family Crocodylidae		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

HAITI

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V

Class *AVES*		
Order *PROCELLARIIFORMES*		
Family *Procellariidae*		
Pterodroma hasitata	Black-capped Petrel, Diablotin	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodyllus acutus	American Crocodile, Crocodilo, Largato Negro	E

HONDURAS

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermatemydidae*		
Dermatemys mawii	Central American River Turtle	V
Order *CROCDYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

JAMAICA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodyllus acutus	American Crocodile, Crocodilo, Largato Negro	E

MARTINIQUE

Class *REPTILIA*
Order *TESTUDINES*

Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

MEXICO

Class *MAMMALIA*		
Order *PINNIPEDIA*		
Family *Phocidae*		
Monachus tropicalis	Caribbean Monk Seal, West Indian Seal	E
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico andPacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Lepidochelys kempii	Kemp's Ridley, Atlantic Ridley Sea Turtle, Tortuga Lora	E
Family *Dermatemyidae*		
Dermatemys mawii	Central American River Turtle	V
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E
Order *CROCDYLIA*		
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E
Family *Alligatoridae*		
Caiman crocodilus fucus	Brown Caiman	V

MONSERRAT

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de pente	E

NETHERLANDS ANTILLES

Class *REPTILIA*		
Order *CROCODYLIA*		
Family *Crocodylidae*		
Crocodyllus acutus	American Crocodile, Crocodilo, Largato Negro	E

NETHERLANDS LEEWARD ISLANDS

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de pente	E

NICARAGUA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga, Tora, Barriguda, Tartaruga	E
Order *CROCDYLIA*		
Family *Alligatoridae*		
Caiman crocodilus fuscus	Brown Caiman	V
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

PANAMA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga, Tora, Barriguda, Tartaruga	E
Order *CROCDYLIA*		
Family *Alligatoridae*		
Caiman crocodilus fuscus	Brown Caiman	V
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

PUERTO RICO

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E

Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E

ST. LUCIA

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

ST. VINCENT

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E

TRINIDAD and TOBAGO

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E
Order *CROCODYLIA*		
Family *Alligatoridae*		
Caiman crocodilus crocodilus	Spectacled Caiman	V

UNITED STATES VIRGIN ISLANDS

Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga Tora, Barriguda, Tartaruga	E
Order *SAURIA*		
Family *Teiidae*		
Ameiva polops	St. Croix Ground Lizard	E

VENEZUELA

Class *MAMMALIA*		
Order *SIRENIA*		
Family *Trichechidae*		
Trichechus inunguis	Amazonian Manatee, South American Manatee	V
Trichechus manatus	Caribbean Manatee, North American Manatee, American Manatee	V
Class *REPTILIA*		
Order *TESTUDINES*		
Family *Cheloniidae*		
Caretta caretta	Loggerhead Turtle, Tortuga de mar, Cares, Tartaruga domar, Uruana, Suruana	V
Chelonia mydas	Green Sea Turtle, Tortuga Verde del Atlantico and Pacifico, Torgtuga Blanca	E
Eretmochelys imbricata	Hawksbill Turtle, Carey, Tortuga Carey, Tartaruga verdadeira and de Pente	E
Lepidochelys olivacea	Olive Ridley Turtle, Pacific Ridley Turtle, Tortuga verde, Parlama	E
Family *Dermochelyidae*		
Dermochelys coriacea	Leatherback, Leathery Turtle, Luth, Tortuga, Tora, Barriguda,Tartaruga	E
Order *CROCDYLIA*		
Family *Alligatoridae*		
Caiman crocodilus crocodilus	Spectacled Caiman	V
Caiman crocodilus fuscus	Brown Caiman	V
Family *Crocodylidae*		
Crocodylus acutus	American Crocodile, Crocodilo, Lagarto Negro	E

"I have dis impetus to continue fishin' 'til I die.
You will never find me for de rest of my life without fishin' tackle."
(Quote from Jamaican fisherman; Photo: FAO)