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A Scientific Plan for Caribbean Marine Research in Support of Marine Resource Development

Prepared for the

Bureau of Oceans and International Environmental
and Scientific Affairs
by
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for the
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Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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EXECUTIVE SUMMARY

Based primarily on the results of a two-day workshop in Washington, D.C., in January 1986 and the written responses of over 115 scientists, a scientific plan is presented here as the framework within which the United States can develop and carry out a program of marine research in the Caribbean region. The plan consists of several parts, each of which provides opportunities for U.S. and Caribbean marine scientists to undertake high-quality scientific research. Each part involves scientific objectives that will be responsive to local marine resource needs and should be of eventual economic benefit to each Caribbean nation involved.

The plan calls for resource mapping surveys in the nations' Exclusive Economic Zones (EEZs), research on coral reefs and beach sand deposits, and biological studies in relation to fisheries. The last includes research on coastal ecosystems of importance in the life cycles of commercial species and specific studies of various other factors of critical importance in the development and management of Caribbean fisheries.

Training and education of local personnel are essential components of the plan and will contribute to the long-term goal of developing an indigenous marine science capability so that Caribbean nations can respond to their own needs for resource development and management. It is important that the training efforts be closely tied to the above research projects.

The plan is composed of two phases. The first phase has two objectives: (1) acquiring confirmation from experts and authorities in the region that the plan has captured the substance of Caribbean interests and needs, and (2) convening a small group of experts to critique the plan and consider specific target projects and countries. The second phase entails the specific research indicated above.

INTRODUCTION AND BACKGROUND

The Caribbean region has for many years interested U.S. researchers from the various disciplines of marine science. Geologists from the United States have studied the beaches of the Antilles and the Central American nations, and from their research ships they have investigated the trenches, basins, and rises of the Caribbean Sea and speculated on processes occurring along the boundary between the Caribbean and North American tectonic plates. U.S. marine biologists and fishery scientists have explored the abundant coral reefs, mangroves, and seagrass beds; studied and catalogued the marine fauna; carried out exploratory fishery surveys; and studied the productivity and food-chain dynamics within the region. U.S. physical oceanographers have monitored the tides, measured currents in the interisland passages, and used satellites to track free-drifting current buoys. In short, there is a lengthy history of U.S. involvement in Caribbean marine science. It is a pleasant region in which to work, and the scientific questions are numerous and challenging.

Although past research has increased our knowledge of the region and has advanced the professional careers of many U.S. scientists, the direct benefits of the research to the nations and the people of the region have been minimal. Often U.S. scientists working in the region have carried out their research projects, taken their samples and data, and returned home with little or no consideration of how the research might have been used to the advantage of the people in the Caribbean.

With the global interest in the Law of the Sea Treaty and the establishment of Exclusive Economic Zones (EEZs) by most coastal states, international cooperation in marine science has taken on a new importance for U.S. marine scientists who wish to work in foreign waters. U.S. marine scientists face an increasingly regulated regime in the coastal waters of other states. Foreign approval of U.S. marine research requests more frequently considers not only whether the research addresses interesting marine science

opportunities, but also whether it directly meets some of the more pressing needs of the foreign country. The challenge is to develop an effective scientific program of mutual benefit to both the United States and the Caribbean nations and their scientists.

Knowing the importance of the Caribbean region to the United States, and realizing the potential of using marine science as a means of assisting the nations of the region in solving some of their problems, the Department of State called on the National Research Council for assistance. In a letter dated 18 October 1985 (Appendix 1), the Department of State asked David A. Ross, chairman of the International Ocean Studies Policy Group of the Ocean Studies Board (OSB) to develop "a resource-oriented, marine science program in the Caribbean." The OSB, at its meeting on 4 November 1985, approved the plan for a January workshop to provide scientific input to the development of a scientific plan that would, with OSB approval, be submitted to the U.S. State Department. The stated objectives (Appendix 2) call for the program to focus on geological and fishery processes and resources and to be developed within five months of undertaking the task.

The U.S. oceanographic community was alerted to the project via two announcements in Eos Magazine (Appendix 3) and via the electronic mail facilities of UNOLS (University National Oceanographic Laboratory System) and the Sea Grant Program. Researchers were invited to a workshop and asked to provide one-page summaries of projects they would like to undertake in the Caribbean. Over 115 expressions of interest were received (Appendix 4), and 76 persons from 14 states, the District of Columbia, Puerto Rico, the Virgin Islands, and Canada attended a two-day workshop (Appendix 5) in Washington, D.C., 8-9 January 1986, to provide scientific input to the preparation of the plan. The workshop resulted in the determination of the priorities for marine resource oriented projects and provided the specific guidelines that form the basis on which this plan was prepared. The plan provides an overall framework within which specific research projects can be developed.

THE NEED

The need for a marine science program in the Caribbean is a mutual one, both on the part of the United States and on the part of the Caribbean nations. However, there might be some question about the extent to which the North American scientists participating in the workshop could realistically evaluate the marine scientific and resource needs of the Caribbean. In response, it is noted that by conservative estimate the participants represented well over 200 man-years of experience in the Caribbean. In addition, many previous reports on the Caribbean were available to the participants and drafters of this document, including the results of the UNESCO/IOC 1985 mission to the Caribbean, which chronicled the marine science needs of the English-speaking islands of the region, and numerous reports on the resource problems of the Caribbean prepared for AID and other organizations, both national and international. Discussions with leaders in appropriate countries also should be carried out to ascertain perceived needs before specific projects are chosen.

Within the Caribbean in recent years, the various nations have felt a growing need to map and to evaluate the resources in their EEZs. Although on a global scale the fisheries resources of the Caribbean are relatively small, on a local scale they are extremely important. This importance stems from the fisheries' relevance to local employment, economics, and nutrition, as well as to the balance of payments, as most Caribbean nations import more fish and fish products than they produce. Needed for eventual fisheries management--not only of the diminishing coastal and reef fishery, but also of the migratory pelagic fishery--is a better understanding of regional organic productivity, of the role of various habitats in the life cycle of commercial species, and of the mechanisms of stock recruitment.

The abundant coral reefs in the Caribbean constitute a valuable resource. They are, of course, an attraction for tourists. Of greater economic value, however, is the role

of reefs as habitats for locally important fish and shellfish. The reefs also act as barriers protecting the coast from damage by waves and are the source of much of the calcareous sand on the region's attractive white beaches. Studies indicate, however, that many Caribbean coral reefs show signs of stress, and dead corals are abundant. An understanding of the condition of the reefs and of the factors causing their apparent destruction in some areas is needed.

Beaches are another important local resource in that they provide protection from coastal inundation and serve as a major tourist attraction as well. Yet coastal erosion and the indiscriminate mining of beach sand for construction aggregate have had serious deleterious effects on this resource. Alternative sources of construction aggregrate, an improved understanding of coastal erosion, and the development of enforceable laws regarding the mining of beach sand are needed throughout the region. It would also be valuable to investigate the occurrence of offshore mineral deposits, including areas having oil and gas potential.

The continuing need for training and education of local scientists and administrators is recognized throughout the Caribbean. A long-term goal is the development of an indigenous marine science capability, so that the nations of the region will be better equipped to identify and resolve their marine resource problems.

The more than 115 proposals received (see Appendix 4) suggested research related to many more regional and local Caribbean needs. Obviously, all could not be included, and the workshop participants selected the aspects described above as being those that would provide the best opportunities for combining good science with a means for assisting in the solution of marine resource problems.

THE RESPONSE

Based on the significant input of the one-page proposals and the concepts and research priorities established by the workshop participants, a three-part scientific plan has been devised: (1) geological research, (2) biological research in relation to fisheries, and (3) training, education, and international cooperation.

Within the area of geological research, three research agendas were proposed. In order of priority, these include (1) offshore resource mapping surveys, (2) evaluation of reef and sand resources, and (3) research on the geologic and tectonic history of the Caribbean plate boundaries. The plan presented here focuses on the first two as having the higher priority when evaluated against the stated research criteria. The tectonic project, although very attractive scientifically, could not be accomplished with the imposed budgetary limits, and the relevance to the immediate resource needs of the region was unclear. The section on biological research considers two related aspects: coastal ecosystem research and fisheries development research. Proposed work in aquaculture, albeit of significant value in marine resource development for the Caribbean region, would be too expensive for a plan of this scale. Training and education will be relatively specific and closely tied to the research program.

GEOLOGICAL RESEARCH

Offshore Resource Mapping Surveys

New technological developments in scientific instrumentation have historically led to exciting research opportunities for scientists. A recent example in the marine geological field is swath-sounding, or sidescan acoustic-sounding, techniques. To marine geologists, their usefulness rivals that of modern scientific satellites. The various versions of the acoustic techniques have

different physical arrangements, but all have transponders that insonify the water beneath a ship and then receive echoes from beneath and to either side of the ship. The British-developed GLORIA system can map a swath about 60 km wide, the U.S. SEAMARC system has a swath width of about 10 km, and the swath width of the SEABEAM system is a few kilometers. Contiguous swaths can be arranged to produce a mosaic "shadow graph" that displays all the features of the sea floor with the resolution of a few percent of the swath width.

The U.S. Geological Survey (USGS) used GLORIA in 1985 to map half of the eastern Caribbean (Venezuelan Basin) and the Cayman Trough, and the Institute of Ocean Sciences (United Kingdom) has used GLORIA to map much of the area north and south of Barbados. SEABEAM has been used to map more limited areas. It is now feasible to complete this acoustic imagery for the entire margin of the Caribbean. The USGS "pictures" of the seafloor provided by the GLORIA system have given marine researchers new insight into the processes that shape the topography of the ocean floor and have facilitated discoveries of hitherto unknown features. Such pictures also are useful for marine biologists and benthic ecologists. In the past, bathymetric surveys with the standard narrow-beam echo sounders provided topographic resolution limited to that which could be interpolated between adjacent sounding lines, often many kilometers apart. At the other end of the scale, submersibles or cameras provided information within the range of visibility, on the scale of several meters. There was, prior to the availability of swath-sounders, no means for looking at the whole picture, incorporating those features that fall between these two extremes. This new technique not only offers a unique opportunity for marine scientists to advance man's knowledge of the seafloor, but also provides the Caribbean nations with highly detailed maps, which may serve as the foundation for the discovery, exploitation, and management by these countries of their marine resources.

Much specific information relative to many offshore resources will be provided by these surveys. For example, hard and soft bottom environments--with their own unique communities of organisms, including those of commercial interest--may be located and delineated. Heavy minerals such as gold, platinum, titanium, and magnetite are resistant to weathering and are commonly concentrated and preserved in submerged beaches and insular shelves seaward of their sources on land. The mapping surveys will identify drowned river and stream channels, beaches, terraces, and other offshore locations where such minerals may accumulate. Likely target areas are the insular shelves of the Dominican Republic (gold and titanium), Panama and Costa Rica (gold and magnetite), and El Salvador

and Guatemala (gold). The recent discovery of phosphorites off the northern coast of Venezuela suggests that it might be worthwhile to include this mineral among the potential resources of the EEZs of the Caribbean. Any work relating to phosphorite should be coordinated with Project 156 - Phosphorites, a Caribbean project of the International Geological Correlation Program sponsored by the USGS and UNESCO. The presence of mud volcanoes detected south of Barbados and near Panama may be due to outgassing of sediments and may indicate an economic source of methane gas. The extent of such features could be determined during the survey.

The acoustic mapping of the seafloor will also provide data about the underlying geology, providing important information for the siting of drilling platforms, routes for seafloor pipelines, and potential sites for offshore dumping. Surface structural trends that could be of later use in oil and gas exploration might also be identified. Sediment type and distribution will provide clues as to bottom transport mechanisms. Nearshore sand and gravel deposits for construction aggregate can be located and mapped.

The basic requirement for such a survey is a vessel equipped with the SEAMARC system and adequate positioning equipment. If magnetic, gravity, single-channel seismic, and 3.5-kHz data are also deemed necessary, they can be acquired at additional cost. The ship would operate in the region on a nation-by-nation basis for about 45 days per year.

Utilization of a vessel from the area for this work should be considered. In addition, coordination should be established with the IOC plan for the International Bathymetric Chart of the Caribbean Sea and Pacific Ocean off Central America (IBCCA) and with the Caribbean regional charting group of the International Hydrographic Office (IHO) proposed to be established in 1986.

The education and training component of the overall Caribbean program will be covered in a separate section. Local personnel--scientific, technical, and administrative --will be involved in every phase of this mapping effort, from planning through shipboard operations and data processing to analysis and publication of results. Computer processing, analysis, and interpretation of the SEAMARC data can probably be done in the region.

Reef and Sand Resources

Coral reefs and sand beaches often are tourist attractions and as such are a major marine resource throughout the Caribbean. In addition, reefs are an important habitat for commercial species of fish, and the

sand beaches, particularly on the islands, constitute the only land source of construction aggregate. Thus the preservation and intelligent utilization and management of these coastal resources have considerable economic benefits for the nations of the area. Reefs and beaches also present interesting challenges to the marine scientist, and opportunities for productive research on coral reef ecology and beach processes abound in the Caribbean. These two features nicely meet the plan's criteria of opportunities for good science and economic relevance.

In addition to their importance as tourist attractions and as habitats for commercial fish, Caribbean coral reefs provide sites for local recreation and sport fishing, source material for sand beaches, breeding and nursery grounds for edible fish and shellfish, coastal protection from storm waves, educational opportunities through teaching and research, and the potential for drugs for medical use. Yet the occurrence, abundance, composition, and "health" of the reefs off Central America and the islands of the Caribbean are poorly known.

It is thought that many of the coral reefs off Central America and around the Antilles are under stress. This is caused by man's activities (anchoring, chumming with rocks, dynamiting fish, ocean disposal of banana bags, coral collecting and pollution) and natural causes (blanketing sedimentation and severe storms). Bucco Reef, Tobago, is a classic example of a reef stressed by pollution and by tourists walking over the shallow corals. Some reefs, such as the extensive reefs around Bonaire and Curacao and the patch reefs near Portsmouth on St. Lucia, are now protected as national marine parks. These, however, are the exceptions to the more general practice of benign neglect of the region's productive coral reefs.

The proposed plan calls for coral reef ecologists to map the distribution of coral reef areas off the coast of selected nations, determine whether these reefs are flourishing or under stress, identify the source of such stress, and make recommendations for improvement of the local reef condition. Satellite imagery, aerial photography, and underwater photography would be used in compiling these maps. Of particular concern should be the evaluation of present and future impacts from pollution generated by coastal construction projects, sewer outfalls, soil erosion, pesticides and herbicides, and thermal effluent. Water quality in reef areas should be examined for pollutants. Local personnel and laboratory facilities should be used whenever possible.

In contrast to other mineral deposits, coastal sand represents a renewable resource if properly managed, and its economic importance is greater for the island nations than for Central and South American countries, where tourism constitutes a smaller portion of the national

economy and where other sources of construction aggregate are available. Thus, this portion of the plan is directed primarily at the island nations of the Caribbean.

Although extensive literature has been developed on the complex problems of the mechanisms involved in the sources, routes, and sinks of sand movement along the coast, little research has been done specifically in the Caribbean, and there is almost no literature on coastal sand transport specifically along island coasts. Because this presents an interesting scientific challenge, and because coastal sand resources are locally of economic importance, an improved understanding of coastal sand transport dynamics can lead to better utilization and eventual management of this marine resource. The task is to provide a scientific basis for exploiting renewable sand resources in a way that will provide maximum benefits from the resource with minimum deleterious effects on the environment.

Caribbean island sands are primarily calcareous and derive from the breakdown of the hard "stony" corals by boring organisms, by the feeding activities of parrotfishes and sea urchins, by storm activity, and from the production of sand-size sediment by clacareous algae such as Halimeda and Goniolithium. Given the general energy pattern around an island, and assuming an available supply of this carbonate sand, two working hypotheses follow and form the basis for this segment of the research plan. First, coastal sand deposits form in the lee of intensified current zones where sand is removed from transport as the carrying capacity of currents is reduced. Part of the sand is driven ashore by wave action and accumulates in shore reentrants such as pocket beaches or in the convergence zones of longshore currents. Second, the natural processes forming sand deposits seek to establish a balance between the rate of sediment supply and the available energy to transport the sediment. If the supply and energy input are not in balance, transport processes act to establish equilibrium by eroding or depositing sediment.

These hypotheses will be tested on a few selected islands utilizing four types of information: (1) published reports and other available data; (2) direct field observations of nearshore currents, beach, and coastal dune dynamics, and the volume of sand in accreting and eroding environments; (3) numerical calculations of sand transport; and (4) discussions with local residents to determine the erosional and depositional history of local sites. The study should develop an assessment of sand resources at specific sites; a methodology for assessing deposits, including a sand-transport model for locating renewable resources; and a group of trained personnel to continue the study in the region.

BIOLOGICAL RESEARCH IN RELATION TO FISHERIES

In the past, fisheries assistance programs in the Caribbean have concentrated primarily on exploratory fishing surveys and on methods to improve the harvesting of commercially valuable species. Too little attention has been paid to the complex biological, physical, and chemical systems that result in the availability or absence of species useful to man. The understanding of such aspects of the system as spawning, larval recruitment, habitat availability, primary and secondary productivity, trophic-level interactions, energy fluxes, predator-prey relationships, and life histories is essential if effective fisheries management is ever to become a reality.

This portion of the plan consists of two biological projects, both designed to contribute to the eventual understanding and protection of the intricate system that underlies Caribbean fisheries. The first project focuses on understanding and protecting coastal habitats--important in the development and management of living marine resources. The second project is designed to investigate specific elements of the ecosystems, knowledge of which will lead to management practices that should in time result in increased landings of commercial species.

Coastal Ecosystem Research

In order to manage economically important species, it is essential to identify the critical food resources and habitats which control the occurrence of these organisms. Caribbean nations are being forced to make decisions on coastal developments that may have an impact on various coastal resources. At present, these decisions are being made in the absence of the biological knowledge necessary to assess the magnitude of these impacts. Thus it is important that studies be undertaken to identify critical habitats for various life stages of economically important species, quantify sources of organic matter production in these habitats, and determine the food-web processes through which the organic matter is transferred to these organisms.

This project will include the identification of important coastal habitats, resources, and primary productivity. These studies should be carried out in several of the Caribbean islands and along at least one mainland coast. This research must be coordinated with the ongoing program in coastal ecosystems productivity under the aegis of the United Nations Educational Scientific Cultural Organization/United Nations Development Program (UNESCO/UNDP). Under this pilot project, a network of U.S. and Caribbean scientists has been established with a

steering committee of scientists from five nations in the region. This group should be asked to assist in the coordination of research sites for coastal ecosystem investigation and the facilitation of involving and training of Caribbean scientists.

Suggested research projects include the following:

- identification of specific habitats important in the development and management of marine resources, especially those that are important nursery areas for marine animals (e.g., mangroves, sea grass beds, and coral reefs);
- identification of factors important in controlling primary productivity in coastal areas, including terrestrial inputs, proximity to areas of coastal development, upwelling, and degree of coupling between the water column and the benthos;
- identification of those factors that control the transfer of primary productivity to economically important species;
- determination of the transformations and nutritional value of organic matter; and,
- identification of predator-prey linkages.

Fisheries Development Research

Increasing fishery landings is a common development goal throughout the Caribbean. However, attaining this goal is often constrained by (1) depleted inshore stocks, which are the target of traditional fishing activities; (2) inadequate fishing technology with which to harvest underutilized stocks; or (3) lack of recognition of the commercial potential of native species (e.g., blue crabs and mantis shrimp). Solutions to these problems include enhancement of available habitats (e.g., artificial reefs), development of new fishing technology, and study of the resource potential of underutilized species.

Utilization of certain Caribbean stocks is also limited by a lack of information on population dynamics. Information on stock sizes, demographics, spawning strategies, and rates of recruitment is necessary for the effective management of Caribbean fisheries. Successful development and management of these fisheries will also require more detailed information on life histories of economic species and the relationship between life history stages and water movement. This will allow an understanding of factors that control dispersal and recruitment of important species in the region. Detailed knowledge of current patterns would also have useful applications in problems involving sediment transport, impacts of sewage outfalls, site selections for tourism

development and nature preserves, and air-sea rescue operations. These studies would provide the quantitative basis for protecting certain areas that can be shown to be important spawning or nursery grounds for marine animals.

The scientific objectives of this portion of the plan are four in number: (1) to determine the relationship between shelter and carrying capacity or productivity of nearshore habitats; (2) to develop statistical sampling designs appropriate for stock assessment in tropical regions and determine stock size of deep-water species not currently fished; (3) to elucidate life history tactics of underutilized species, such as the mantis shrimp (Stomatopoda), the blue crab (Calinectes arcuatus), and possibly the land crab (Cardisoma gunahumi); and (4) to investigate Caribbean current patterns important in the dispersal and recruitment of economically important fish and shellfish.

Initially, the research will be conducted at one site near an island and one near the mainland. Additional sites will be selected if the funding and time are available. Habitat enhancement will be undertaken utilizing artifical reefs and possibly fish aggregation devices (FADs) at each site, and their effects on species diversity and abundance will be determined. Target species, including deep-water species, will be identified for stock assessment, and appropriate sampling and statistical procedures will be developed. Reproductive biology and demography of target underutilized species will be studied to determine feasibility of developing new fisheries. Concurrent studies of larval fish and invertebrates will be carried out along with measurements of current flow in coastal and adjacent deep-water regions. This will be done seasonally and with intensive sampling during periods of peak reproduction. The patterns of larval distribution in ocean currents will be mapped, and the coastal regions that experience the greatest recruitment will be determined.

Actual work at sea to accomplish these goals will include the following:

- measurements of biomass and population-age structure of target species will be made using standard collection techniques;
- studies of reproductive biology will include field studies of seasonality of reproduction and laboratory studies of larval development; and
- fisheries oceanography studies will consist of collection of larval fish and invertebrates using metered closing nets rigged with electronic instrumentation for simultaneous measurement of temperature and depth. Measurements of current flow will utilize moored current meters, surveys from boats using expendable bathythermographs, as well as various remote sensing techniques (e.g., satellite-tracked drifters).

TRAINING, EDUCATION, AND INTERNATIONAL COOPERATION

Many of the countries of the Caribbean are island nations and are strongly influenced by ocean processes. All are coastal states and can have, under the terms of the Law of the Sea Treaty, jurisdiction over Exclusive Economic Zones extending up to 200 nautical miles offshore. At this time, many are interested in gleaning benefits from their marine resources, but few have people trained in marine research or management of marine resources. Thus their hopes for improvement of their economic status by developing their marine resources may have to wait until people are trained for the tasks ahead.

The training and education of people in the region via the gaining of experience in marine science must be an integral part of the program. It is through people thus trained that the program will have local benefits long after the U.S. ships and scientists have returned home. Experience has proven that the cooperative involvement of local individuals knowledgeable of the area and of the potential socioeconomic implications of the planned research can be of considerable assistance in any international marine science project. Thus training and education provide benefits to all parties involved in such international marine science projects.

Once the areas have been selected where the initial offshore surveys and the research projects will take place, appropriate local scientists and relevant government personnel must be identified and encouraged to participate in the operational planning, the fieldwork, and the data analysis and the publication of results. During initial meetings, local scientists or administrators should be identified to serve as members of the program steering committee (see section on "Program Management" below). These early gatherings should address also the mechanisms for training and educating local personnel. The possibility of financial or in-kind assistance should be investigated. The latter might include providing government vessels and vehicles, housing U.S. participants and other nationals, making available laboratories for analyses, and offering facilities for public lectures and training classes.

A research program of the type encompassed in this plan can provide significant opportunities for training and education for people in the Caribbean at modest cost. Activities could include having local personnel working and learning at sea and on shore with their U.S. counterparts. U.S. participants could provide public lectures and run workshops on specific aspects of the program, such as the processing of SEAMARC records, planning and executing beach surveys, sorting biological samples, and conducting

sediment analyses. The training component should closely parallel the research efforts of this program so that in time trained local personnel can carry out the research effort begun under this program.

If significant additional funding for training and education can be made available, a more ambitious program can be undertaken. Outstanding high school students with an expressed interest in marine science could be given scholarships for university training. Those with undergraduate degrees could be selected for graduate training. Visiting professors from U.S. universities could provide intensive short courses or could be supported for a year or more as faculty members at universities such as the three campuses of the University of the West Indies (Jamaica, Trinidad, and Barbados), the University of Costa Rica, the University of Puerto Rico, Universidad Nacionale Autonoma de Mexico (UNAM), the University of Panama, or any of the 46 universities and institutes that are members of the Association of Caribbean Universities (UNICA).

In formulating the training and education component of the program, the following points should be borne in mind:

- long-term, small-scale, discrete projects are often better than intensive, short-term efforts;
- projects that involve both local government and private sector institutions are more likely to have long-term impact;
- in situ training is generally better than training outside the region and works better if a local cooperating institution is involved and in a position to provide follow-up;
- local resource users or resource data users and local management institutions should be involved in project design and implementation;
- findings and data should be translated into user-friendly formats for dissemination to local institutional users and archiving repositories;
- research efforts involving local institutions should address not only local participation, but also institutional strengthening (i.e., capacity building) often requiring specific budget line item allocations for the host or local cooperating institutions;
- long-term university education for local scientists should take place at universities within the region if possible; and
- means should be found to provide pertinent technical literature to local participants and national libraries.

It is important to keep in mind the fact that one of the program goals is the development and enhancement of an indigenous marine science capability in each country

involved. The promotion and maintenance of self-sufficiency in marine science activities will result in the development of the capability of the various nations to conduct their own marine research programs in response to their own needs.

COORDINATION WITH OTHER CARIBBEAN MARINE PROGRAMS

The proposed Caribbean effort should ensure that other programs with similar goals are informed and their cooperation solicited. Coordination of the EEZ mapping with the IOC plan for bathymetric mapping of the Caribbean and with the proposed IHO regional charting group has already been mentioned. The goals of the UNESCO/UNDP program mentioned previously are similar to those of the proposed coastal ecosystem research portion of the present plan, and this coordination tie must be made for the mutual benefit of both projects. But these are only the beginning of the list of organizations with which coordination should be established.

The IOC's Regional Subcommission for the Caribbean and Adjacent Regions (IOCARIBE), with its office currently in Cartagena, Colombia has a 10-year history of promoting cooperative marine research in the region. The United States has supported this organization, and it would be valuable to consult with IOCARIBE on our effort. In addition, the IOCARIBE communication network and the established oceanographic data center for the Caribbean could be of use to this program. The IOC also has in progress a proposal for the support of marine science in the Caribbean based on the report of a month-long mission to the region in 1985. This mission determined the present status of marine science in some eight nations together with their marine resource problems and needs. IOC headquarters in Paris should be contacted early in the planning stages of this program.

The U.S. Geological Survey has an ongoing program of geological and marine geophysical surveys in the Caribbean, and their experience with the GLORIA surveys around Puerto Rico could well be utilized in planning and executing the EEZ resource mapping portion of this plan. Similarly, NOAA has recently conducted nautical charting surveys off Central America and is producing a publication on Caribbean marine science.

The Gulf and Caribbean Fisheries Institute, Inc. (GCFI), with headquarters at the University of Miami, has

over 30 years of experience in international cooperation in all aspects of Caribbean fisheries. The GCFI has a highly developed network of fishery scientists and administrators throughout the Caribbean and could be of considerable assistance. Similarly, the Western Central Atlantic Fisheries Commission of FAO, with headquarters in Panama, and the recently established Fisheries Desk of the Organization of Eastern Caribbean States (OECS) funded by the Canadian International Centre for Ocean Development (ICOD) should be contacted and cooperation encouraged. Their Fisheries Desk will be located on St. Vincent, and the OECS headquarters is at Castries on St. Lucia. The Caribbean Community Secretariat (CARICOM) is located in Georgetown, Guyana, the Organization of American States (OAS), headquartered in Washington, D.C., and the Regional Seas Program of UNEP all have Caribbean marine resource programs and must be contacted.

The Agency for International Development (AID) in 1985 received the report "Fishery Sector Assessment: Antigua/Barbuda, Dominica, Granada, Montserrat, St. Christopher/Nevis, St. Lucia, St. Vincent and Grenadines" in anticipation of supporting a Caribbean fisheries project. AID interests and plans must be considered as this program develops. The NOAA Undersea Research Program (NURP) has plans for using a manned seafloor habitat in the Caribbean that could be useful in the biology projects.

Other organizations that should be made aware of this program for reasons of coordination and cooperation include but certainly are not limited to the following:

- Bellairs Research Institute, Barbados;
- Canadian International Development Agency (CIDA) and their two fisheries projects in the region, Marine Resource Survey and Training in Marine Space Management, both being done through CARICOM;
- Caribbean Conservation Association in Barbados and its collaborative program with the University of Michigan called the Eastern Caribbean Natural Area Management Program;
- Caribbean Development Bank, which also serves as a conduit for funding from the Inter-American Development Bank;
- Canadian International Development Research Centre (IDRC), with a sea moss culture project on St. Lucia and conch management on St. Kitts;
- Island Resources Foundation (IRF) on St. Thomas, U.S. Virgin Islands, with 13 years of broad involvement in the development and management of Caribbean marine resources; and
- Association of Island Marine Laboratories of the Caribbean, which represents 22 laboratories and 300 individual members from the Caribbean region, Canada, and the United States.

To reiterate, many organizations and institutions are actively involved in programs that deal with Caribbean marine resources, more than can be listed here. It is important for the success of this program that coordination be established where necessary or useful in order to avoid unproductive duplication of effort, to capitalize on the results of previous and ongoing research, and whenever possible to assist those other programs with the similar goal of quality marine research in support of local needs.

PROGRAM MANAGEMENT

It is premature to describe the actual mechanism for managing the program, as this will depend on its eventual size and scope, the countries involved, and the requirements of the funding agency. We do, however, propose a two-step process in the implementation of this plan. An initial Phase One is necessary to proceed to the actual research program--Phase Two.

Phase One has two important objectives. The first is the establishment of a small group to initiate the critical contacts mentioned previously in the section on "Coordination with Other Caribbean Marine Programs." This contact is important for various reasons, including the need to make these groups aware of our effort. Of primary importance, however, is the need for confirmation from experts and authorities in the region that we have captured the substance of Caribbean interests and needs in our plan. If necessary, appropriate adjustments can be made. We should note that the five-month period allowed for the preparation of this plan did not permit adequate time to invite significant Caribbean input. The second objective of Phase One will be to convene a steering committee to critique the plan and consider specific target projects and countries. Phase Two will entail specific research.

The steering committee, composed to a large degree of potential principal investigators, will develop the final proposal. The committee should have representatives of the disciplines of marine geology and mapping, coastal processes, coastal marine ecology, and fisheries. There also should be one social scientist and one representative of the funding agency. Once the initial target nation or nations have been identified, they should be represented on the steering committee. A competent program director may be required; he or she should be well acquainted with the Caribbean, have a background in both marine science and research program administration, and preferably be bilingual (Spanish and English). General oversight could be provided by a committee of the OSB.

BUDGETARY CONSIDERATIONS

It is difficult, if not impossible, to develop accurate cost projections for a four-year program of this magnitude and diversity. For example, vessel costs range through wide limits depending on the ship and gear used and the time involved. If both the EEZ mapping and the blue-water biological and physical oceanographic work can be accomplished from the same vessel (but not at the same time), the cost could be less than if separate ships were used because of logistic advantages.

The budget figures, which follow, must be considered as extremely rough estimates only. They do, however, represent the general order of magnitude of the costs that will be incurred in carrying out the several projects that make up this research program. As stated in the previous section, the costs and specific objectives of the various components of the program will be refined during Phase One, and a more realistic budget can then be developed. The estimates below are on a yearly basis.

PHASE ONE

The objectives here, as stated in the previous section, will be to visit the various Caribbean groups and ascertain their interest in the program and thoughts about the proposed research. The specifics of the proposed research will be refined by a small group of experts convened to critique the plan. Phase One funding is critical and should be the initial step in the program.

Estimated expenses will cover travel by two U.S. scientists to visit the various Caribbean interest groups and some secretarial costs. Expenses and travel costs for convening the steering committee of approximately 10 participants will also be covered. Total costs for Phase One should be about $90K.

PHASE TWO

Offshore Resource Mapping

Main costs here are for a research vessel (45 days a year) with a SEAMARC system (we estimate $14K per day, or $630K per year for three years). Shipboard staff, data reduction, map production, travel, and supplies are estimated at $210K per year. We should note that the actual cruise tracks have not yet been established.

Reef and Sand Resources

We have estimated two scientists at three months a year each for the two aspects. Travel, small boat time, field expenses, and assistants bring the total to about $145K per year for each aspect, or $290K per year total.

Coastal Ecosystems

The estimate here is similar to the above, but we anticipate additional personnel involvement, thus coming to about $165K per year.

Fisheries Development Research

Unknown at this time is the extent of ship time required. We have assumed similar scientific involvement as above. Thus estimated costs are $165K plus ship (assume $200K) for a total of $365K per year.

Training and Education

Assume here $150K per year.

Management

Costs are estimated for a full-time director ($40K per year), part-time assistant, travel, and overhead. Also included are costs associated with two annual meetings of the steering committee. Total estimate is $160K per year.

CLOSING COMMENTS

It is obvious that the total of the above estimates ($1.97 million per year) exceeds the $1.5 million per year suggested by the State Department as the approximate level of funding that should be considered. The participants in the January workshop and the drafters of this plan believe that the annual increments of the several top-priority projects proposed constitute an effective marine research program for the Caribbean and that the effort should be at least at this level if the science is to be of high quality and the results are to be of benefit to the nations of the region. A more accurate budget for Phase Two can be formulated as the result of the Phase One operation; in any case, Phase One should be undertaken at the recommended level of support ($90K). Substantially more funding would be needed to make a comprehensive study of the region.

APPENDICES

United States Department of State

Washington, D.C. 20520

BUREAU OF OCEANS AND INTERNATIONAL
ENVIRONMENTAL AND SCIENTIFIC AFFAIRS

October 18, 1985

Dr. David Ross
Chairman, International Ocean
Science Policy Group
c/o Woods Hole Oceanographic Institution
Marine Policy and Ocean Management
Program
Woods Hole, Massachusetts 02543

Dear Dave:

As you are aware, the Caribbean region is politically and scientifically of high interest to the United States. Including Mexico, the United States conducts most of its marine scientific research in this region. Ambassador Negroponte has expressed strong interest in developing a resource-oriented, marine research program in the Caribbean. After serving as Ambassador in Honduras, coupled with his previous experience in OES, he sees marine science as a medium for improving relationships and understanding in the region, and he also views the region as important to marine scientists. For the program to be attractive to the region, it will have to be resource oriented, which does not preclude accomplishing scientific objectives in parallel.

I would like to request that the Ocean Studies Board, through the International Ocean Science Policy Group, undertake the task of developing a plan for such a program. The Department of State would seek funding for the program from the appropriate funding sources, realizing it will be competitive with other programs and subject to priorities. We envision a 3-4 year program with an annual budget of $1.5 million.

In discussions with scientists and administrators, it is apparent to me that minerals, hydrocarbon and fisheries research would be welcome components of a program. It will be necessary to have active participation by individuals from the region and training opportunities, perhaps through scientific organizations, and political support from regional or sub-regional scientific bodies. Participation by U.S. academic scientists and use of institution research vessels should be a component of the program, as well as U.S. government agencies.

If you agree, we would hope to have a plan within five months from beginning the task. The Department of State is prepared to provide funding to accomplish the task, including the costs of a consultant for drafting. We can discuss these details later if you agree to accept our request.

Thank you for your consideration, and I look forward to your response.

Sincerely,

William Erb
Director
Office of Marine Science and
Technology Affairs

cc: Walter Munk
John Perry
Mary Hope Katsouros

CARIBBEAN STUDY

Objectives:

1. Develop a marine scientific plan for the Caribbean region, recognizing that the plan must have a sound scientific basis as well as be of benefit to the countries and scientists involved.

2. Focus of plan will be on geological and fishery processes and resources.

3. IOSPG will convene a small group of experts to develop the plan and consider existing proposals. Drafting of the plan will be by Harris Stewart as a consultant.

4. A subsequent meeting may be held if appropriate.

5. Plan will be presented to OSB for review.

6. After approval, the plan will be presented to the Department of State who will attempt to obtain funding.

Other Information: A 3-4 year program of about $1.5 million per year is anticipated.

Appendix 3

Marine Plan for Caribbean

The National Academy of Sciences Ocean Studies Board is organizing a meeting on January 8-9, 1988, in Washington, DC, to develop a marine scientific plan for the Caribbean region. The plan, which will focus on geological and fishery processes and resources, is expected to be of high scientific quality and be beneficial to the countries involved.

Interested individuals should prepare a one-page description of their potential project describing their objectives, geographical area of research, potential for involvement of foreign countries, timing, ship use if necessary, and estimated costs. Copies of the description should be submitted prior to the meeting to: David Ross, Woods Hole Oceanographic Institution, Woods Hole, MA 02534, and to Mary Hope Katsouros, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418.

CARIBBEAN INVESTIGATORS-PROPOSALS

INVESTIGATOR	AFFILIATION	DISCIPLINE	PROPOSAL TOPIC	OTHER	WORKSHOP
Abel	NJMSC	Interdis	Culinary		
Anderson et al	RiceU/UWindies	Geology	CoopSedsProg-UWI		
Anderson/Lobel	WHOI	Biology	FishToxins		
Aronson	RiversideTech,Inc	Computer	AnnotatedBibliography		
Aubrey	WHOI	Geology	SeaLevel		
Austin/Bally	U Tx-Austin	Geophysics	Multichannel Seismics		
Backman	Independent	Bio-Econ	ShrimpPop/MgtModel		
Behrens/Vargo	FLInstOcean(FIO)	Interdis	CoralReef/PrimProd		no/yes
Berg	MBL	Biology	DeepWater/Fisheries		yes
Berg	MBL	Biology	LarvaDrift Fisheries		yes
Bergeeren	WHOI	Geology	Biostratigraphy	see Miller	
Bowin	WHOI	Geology	Geo/Geophy/Earthquake		
Burke	LunarPlanetinst			info only	
Buskirk	U Tx-Austin	Geophysics	Biogeography		
Coblentz	OregonState	Biology	FishResources		yes
de Sylva	RSMAS	Biology	Ciguatera		
Droxler et al	U South Carolina	Geology	Carbonates		
Durako	FIDept Nat Res	Biology	Seagrass		
Edgar at al	USGS	Geology	GeophysSrvy/Oil&Gas		yes
Edgar/Rodriguez	USGS	Geology	HardMinerals		
Ehrhardt	RSMAS	Biology	PelagicBiomas		
Epifanio	U Delaware	Biology	BlueCrabFisheryDevel		yes
Etter/Lamb	OSDI/IIWaterSurv	Phys Ocean	Heat Budgets		yes
Farrington/Cappuzz	WHOI	Biogeochem	Training/CoastEcosys		
o	U Wa	Biology	CoastalResource Asses		yes
Galluci	U Miami	Geology	CarNatResCenter	arrivewkshp	
Ginsberg	Or State	Biology	Reef-Fish	arrivewkshp	
Hixon	RSMAS	Biology	CoralReef/EconDev		
Glynn					

Investigator	Affiliation	Discipline	Proposal Topic	Other	Workshop
Goodwin	SCSeaGrant	Biology	FisheriesDevelopment		yes
Goreau/Ryther et al	U Miami/HbrBrFnd	Biology	Agar Cultivation		yes/yes
Gose/Finch/Ritchie	U Tx/TnTch/ChrlC	Geophysics	Geol/Geophysics		
Gose/Mann	U Tx-Austin	Geophysics	Paleomag		
Harrison	RSMAS	Geology	LandsatThematicMap		
Heirtzler	WHOI	Geol/Geophys	MagneticAnomalyMap		yes
Hernandez	U Puerto Rico	Education	TropicalFishEducation		yes
Kellog	U Hawaii-Manoa	Geology	GasResourceSurvey	with Ladd	
Kjerfve	U South Carolina	Biology	OrgProd/UNESCO,UNDP		
Klemas	U Delaware	Biology	BiolProd/RemSensing		
Ladd	LDGO	Geology	ColumbianGeolCoop		yes
Lobel	WHOI	Biology	French grunt recruit		yes
Lobel	WHOI	Biology	Geochemicals in Fishes		yes
Lutz	RSMAS	Biolgoy	LandCrabFarming		yes
Lyons	UNH	Geochem	Limnl/Evals		
Mann	U Tx-Austin	Geophysics	SeismicStratig		yes
Masters/Edgar	USGS	Geology	Oil&GasAssess		
Matsumoto	U Tx-Austin	Geolphysics	Seismotectonics		
Maul/Gallegos	NOAA/UNAM	Phys Ocean	RegionalPhysOcean		yes
Cammen et al	Bigelow/U Maine	Biology	Benthic Food Web		yes
Miller/Kent	LOGO	Geology	Stratigraphy	see Berggren	
Muller	U South Florida	Biology	CoralReef		
Muller-Karger/ McClain	U Md/NASA	Biology	Phytoplank/RemSens		yes/yes
Myrberg/Roffer	RSMAS	Biology	Fisheries/Acoustics		yes
Neal	Oregon State	Interdis	Edu/Trng/Research		yes
Nichols	Is/CoastResFound	Geology	ModelCoastPollution	arrivewkshp	yes
Nichols	Is/CoastResFound	Geology	SandResources	arrivewkshp	yes
Ogden	WestIndiesLab	Biology	OrgProd/UNESCO,UNDP		

Investigator	Affiliation	Discipline	Proposal Topic	Other	Workshop
Ragotzkie	WIi-SeaGrant	Education	IntlRadioProgram		
Rathjen	FLInstTech	Biology	TrappingTech		
Ray	UVirginia	EnvSci	BiosphereReserves		yes
Reid	RSMAS	Geology	Carbonates		
Renzetti	JetPropulsionLab	Geodesy	GPS Network		
Robins	RSMAS	Biology	FishDistribution		
Rosencrantz/Mann	UTx-Austin	Geophysics	SeismicStratig		yes
Ross	WHOI	Interdis	ProgramCoordination		yes
Rothschild	UMaryland	Biology	Spiny Lobsters		
Ruivo	IOCSecretariat	Interdis	Coordination		
Schlanger	NorthwesternU	Geology	HydrocarbonPotential		
Schwartz	WestWashUniv	Geology	Education/Training		
Sclater/Rosencrantz	UTx-Austin	Geophysics	Htflw/Age/Subsidence		yes
Scotese/Rosencrantz /Mann	UTx-Austin	Geophysics	Stratig/Tectonics		
Silver	UCalifornia	Geology	Tectonics		
Speed/Torrini	NorthwesternU	Geology	Tectonics		no/yes
Szmant-Froelich	RSMAS	Biology	FishEnchance/ArtifReef		
Taylor/Mann/Austin	UTx-Austin	Geophysics	Geolo/Geophys		
Teal et al	WHOI/MBL	Biology	PlantProd-FishDevel		
Vernberg	USouthCarolina	Biology	Fisheries		
Wangersky	Dalhousie	Biology	EnvImpact/Eurtroph		yes
Watkins	WHOI	Biology	Whales/Fisheries		
Williams	GCFI,Inc	Biology	Fisheries/Resources		yes
Multer	NJMSC	Geology	Sand&ReefResources	arrivewkshp	yes
Ladd	LDGO	Geology	ResourceDataSyn	arrivewkshp	yes
Smith	HBF	Biology	Hydrographic/Upwellg	arrivewkshp	
Winn	WHOI	ReschLibrary	InfoNetwork		
Zieman	UVirginia	Biology	PlantProd-FishDevel		yes

Investigator	Affiliation	Discipline	Proposal Topic	Other	Workshop
Reinemund	IUGS	Geology	Geoscience Cooperator		
Reaka	UMaryland	Biology	Mantis Shrimp	arrivewrkshp	yes
Hanisak	HBF	Biology	MarinePlantResources	arrivewrkshp	yes
Gilmore	HBF	Biology	DeepwaterReef-Fish	arrivewrkshp	yes
Perfit	UFlorida	Geology	Tectonics/Resources		
Towle	IsResFound	Inter	Fish/Mgt/Res/ElAsses	arrivewrkshp	
Wormuth/Wolff	Tx A&M	PhysOcean	CirculationFeatures		yes
Gerwick	Oregon State	Biology	Pharmaceutical/Algae		
Davis	WHOI	Biology	Zooplankton/Larvae		
Adams	LSU	Geology	RiverDeltaSeds		
Kimberley et al	NCState	Geo/Multi	Cariaco Trench	arrivewrkshp	
Rosencrantz/Ness	UT/OrState	Geology	GravityCrustalStruct	arrivewrkshp	
Burnett	IGCP	Geology	Phosphorites		yes
Davis	USouthFlorida	Geology	CarbSedBeaches	arrivewrkshp	
Defant	USouthFlorida	Geology	ContCrustContam	arrivewrkshp	
Vargo	USouthFlorida	Biology	Ciguatoxic organisms	arrivewrkshp	
Herrnkind	Fl State	Biology	Spiny Lobster	arrivewrkshp	
Dawes	USouth Florida	Biology	MacroalgaeFarming	arrivewrkshp	
Goldberg	Fl Intl Univ	Biology	Black Corals	arrivewrkshp	
Hall/Casey	UHouston	Geophysics	Central VenezBasin	postworkshop	
Fujita	OregonState	Biology	CoralReefProductivity	postworkshop	
Fujita	OregonState	Biology	Ciguatera	postworkshop	

CARIBBEAN INITIATIVE WORKSHOP

8-9 January 1986

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