

VIRGIN ISLANDS RESOURCE MANAGEMENT COOPERATIVE

BIOSPHERE RESERVE
RESEARCH REPORT NO. 7

MARINE ECOSYSTEMS OF THE LESSER ANTILLES
IDENTIFICATION OF REPRESENTATIVE SITES

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U.S. MAN AND THE BIOSPHERE PROGRAM



Virgin Islands National Park

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The Virgin Islands Resource Management Cooperative (VIRMC) was formed in 1982. Signatories to the Memorandum of Understanding are: Virgin Islands National Park, the Department of Planning and Natural Resources of the U.S. Virgin Islands Government (Division of Fish and Wildlife and Division of Natural Resources Management), University of the Virgin Islands, West Indies Laboratory, Island Resources Foundation, Eastern Caribbean Natural Area Management Program, U.S. Geological Survey, U.S. Fish and Wildlife Service, Southern Forest Experiment Station, University of Puerto Rico (Sea Grant Program and the Center for Energy and Environment Research), Caribbean Fishery Management Council, the Ministry of Natural Resources and Labor of the British Virgin Islands Government, and the British Virgin Islands National Parks Trust.

The objectives of the cooperative are:

1. To establish a Virgin Islands Resource Management Cooperative for the purpose of providing coordinated research, extension, and educational support of programs to achieve full benefits of island forests, wildlife, water resources, the marine environment, and historic areas and their associated resources for their cultural, social, commercial, economic, and recreational utilization and enjoyment.
2. To provide for the direction and management of the Cooperative by forming an Executive Committee, comprised of one representative from each of the organizations who are parties to this agreement, which will a) elect annually a Chairman from the membership of the Executive Committee to serve for a term of one year, b) appoint an Executive Officer to a staff position to coordinate the work of the cooperative, c) appoint technical committees and project leaders, d) provide for the orderly process of development and implementation of policy, and e) foster cooperative activities and relationships among participating parties and with other agencies and institutions.
3. To coordinate and facilitate financial and other support for research on environmentally acceptable uses of forests, wildlife, the marine environment and historic areas, and their associated resources in order to provide for their better management.
4. To provide for the collective utilization of the unique attributes and resources (personnel, facilities, equipment, and other support services) of the parties as they may relate to objectives pursued under this agreement.
5. To plan for appropriate dissemination, publication, and application of research and information.

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RESEARCH

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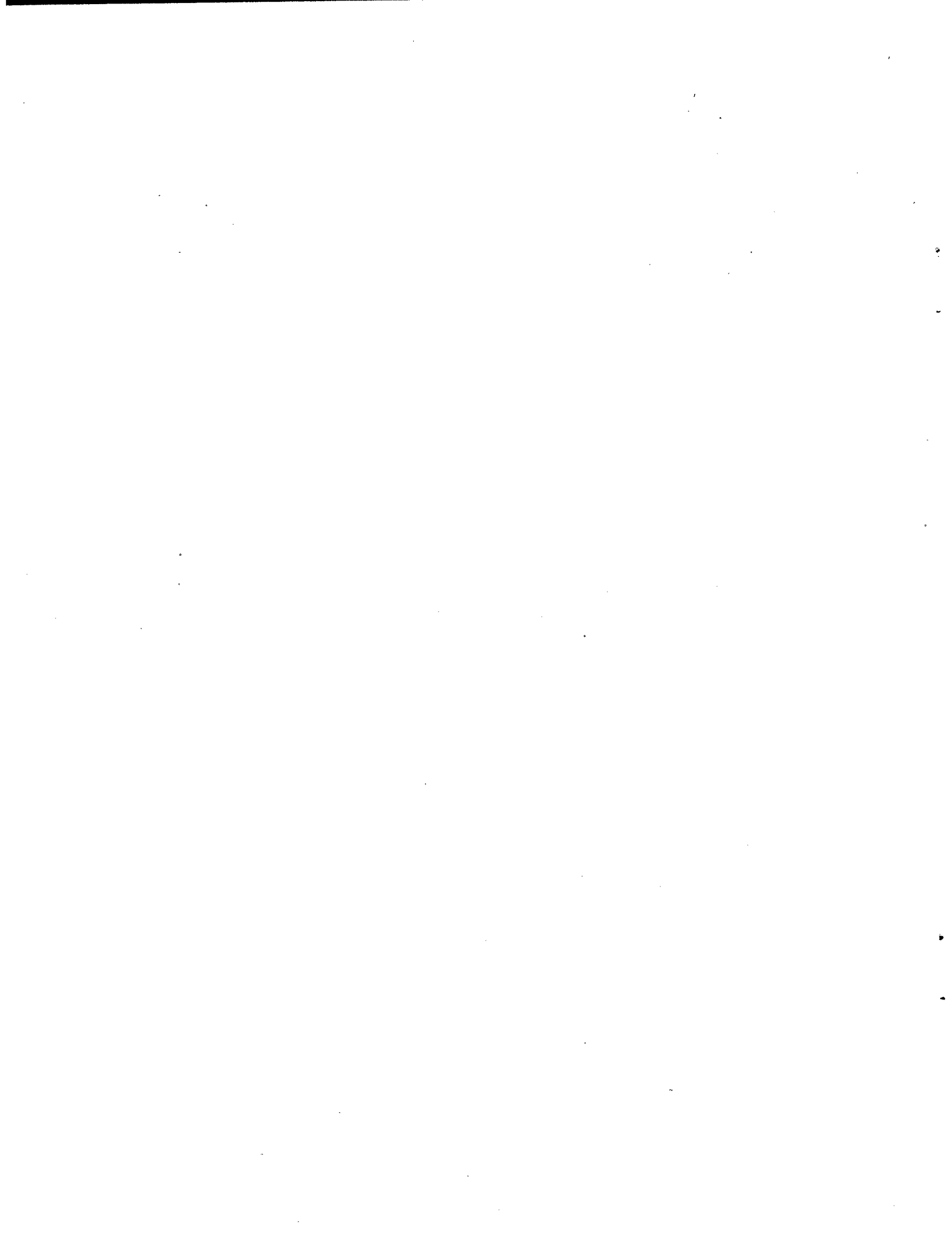
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Abstract

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MARINE ECOSYSTEMS OF THE LESSER ANTILLES - IDENTIFICATION OF REPRESENTATIVE SITES

This report includes discussion of: (1) scientific criteria to consider in designating a site as a Biosphere Reserve, (2) man's use of the marine ecosystem of the Lesser Antilles, (3) available scientific information (publications, research facilities, projects) focusing on marine ecosystems of the Lesser Antilles and greater Caribbean, (4) methods to evaluate marine ecosystems (5) several coastal marine ecosystems on islands in the Lesser Antilles (Curacao, St. Lucia)

Scientific criteria to be noted in selecting ecosystems appropriate for inclusion in the UNESCO Biosphere Reserve Program include 1) species richness and diversity, 2) organic productivity and trophic composition, 3) habitat complexity, 4) rare species and species interactions and 5) relationship with other ecosystems. Factors modifying these criteria include 1) size, 2) relationship to modifying marine and terrestrial ecosystems, 3) proximity to areas of human population and to areas with existing scientific research facilities and 4) the natural and social history of the area including traditional use patterns.

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FOREWORD

Virgin Islands National Park was designated as an International Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in June, 1976. However, the formal dedication did not take place until May, 1983. The standardized, single-page description of the area which was issued by UNESCO under the Man and the Biosphere Program, MAB Project 8, in 1976 is entirely inadequate for the purpose of meeting Biosphere Reserve Objectives.

The purpose of the present (VIRMC I) project was to provide more detailed descriptions of the Reserve's physical and biological features as well as certain aspects of human use, such as fishing and boating. Inherent in the concept of the Reserve is the belief that it is intimately related to the nearby British Virgin Islands and that it should also fit within a future multi-site Lesser Antillean Biosphere Reserve.

The following reports are included in the VIRMC I Research Series Reports.

The West Indies Laboratory (Fairleigh Dickinson University) prepared the reports for "Ecological Community Type Maps and Biological Community Descriptions for Buck Island Reef National Monument and Proposed Marine Park Sites in the British Virgin Islands," "Trends in Recreational Boating in the British Virgin Islands, A Preliminary Assessment of Impact from Human Activities on Anchorages and Development of a Monitoring Program for Safe Anchorages," "Geographic Range and Research Plan for Monitoring White Band Disease," and "Marine Ecosystems of the Lesser Antilles - Identification of Representative Sites."

The Division of Fish and Wildlife (Department of Conservation and Cultural Affairs, Government of the U.S. Virgin Islands) prepared, "Map of Fishery Habitats Within the Virgin Islands Biosphere Reserve," "Fisheries Habitat of the Virgin Islands Region of Ecological Importance to the Fishery Resources of the Virgin Islands Biosphere Reserve," "Utilization of the Virgin Islands Biosphere Reserve by Artisanal Fishermen," and "Long-Term Monitoring of Fisheries in the Virgin Islands Biosphere Reserve."

The Caribbean Research Institute (College of the Virgin Islands) prepared, "Marine Community Descriptions and Maps of Bays Within the Virgin Islands National Park/Biosphere Reserve," and "Collection of Common Organisms Within the Virgin Islands National Park/Biosphere Reserve."

The Island Resources Foundation prepared, "Assessment of Fish and Shellfish Stocks Produced in the Virgin Islands Biosphere Reserve," "Socioeconomic and Cultural Role of Fishing and Shellfishing in the Virgin Islands Biosphere Reserve Area," "Characterization of Lesser Antillean Regional Fisheries," as well as the Synopsis and Executive Summary.

Field work for the project was carried out during the period December, 1983, through October, 1984. Copies of the individual reports can be obtained from: The Virgin Islands National Park, Red Hook Headquarters, P.O. Box 7789, St. Thomas, Charlotte Amalie, VI 00801.

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A number of persons throughout the greater Caribbean region responded to our requests for information. They are acknowledged by name in the appropriate sections of our reports. Mike Robblee of the US National Park Service, Everglades provided literature about damage to tropical marine ecosystems due to boat anchoring activities.

Marine Ecosystems of the Lesser Antilles - Identification of Representative Sites

INTRODUCTION

The Lesser Antilles comprise an arc of islands rimming the eastern Caribbean Sea, extending from Sombrero, Anguilla and St. Martin in the north to Grenada and the Grenadines in the south, the ABC islands (Aruba, Bonaire and Curacao) to the south and west, and the US and British Virgin islands to the northwest. An adjacent area includes Trinidad and Tobago. Marine ecosystems surrounding these islands, e.g. coral reefs, mangroves and seagrass beds, are critical to the islands not only for providing food (in particular a source of protein) but also for important components of the islands economies (such as fishing and tourism). Other economic activities pose serious threats to the productivity and normal functioning of these tropical marine ecosystems. Among these threats are development projects resulting in increased sediment load in the water (e.g. construction or dredging), elimination of whole regions suitable for land fill (e.g., mangroves; associated salt ponds) and pollution (e.g., from the oil tanker traffic in the area).

Knowledge about the coastal marine ecosystems in the Lesser Antilles and adjacent regions is fragmentary (Table 1). It ranges from areas with almost no information, even about the distribution of these ecosystems around an island, to areas with rather complete and detailed studies on the structure and function of these ecosystems (found primarily where a large

scientific research institution is based). This report will consider the scientific basis for identifying representative coastal marine ecosystems in the Lesser Antilles.

The Biosphere program should seek to maintain for future generations examples of the magnificent diversity of the ecosystems of the world, as well as to further our understanding of man's interaction with these ecosystems. A "representative" island ecosystem implies that it is common in the region and suggests that the communities in a designated Biosphere Reserve would be similar in structure and function to those found in localities other than the designated site. A "representative" ecosystem should be a (relatively) unaltered site (suitable for preservation or experimental manipulation) coupled with an altered site (suitable for proper renewable resource use or restoration). The degree of alteration could be determined by appropriate comparison (both static and dynamic) with an unaltered site. This report will discuss the ecological criteria that can be used to assess the ecosystems of a region, recognizing fully the additional need of social, economic and political information before the actual establishment of a Biosphere Reserve Unit. It is divided into the following five chapters:

1. The first section will consider what ecological factors are important scientifically in designating an area as a representative ecosystem as well as modifying factors to be taken into account in establishing boundaries to such areas.
2. The second section will briefly discuss man's use of the

coastal marine ecosystems in the region.

3. The third section will discuss published sources of scientific information about the ecosystems. It will also list institutions and projects currently engaged in scientific research in the region.

4. The fourth section will discuss methods to teach and develop skills to assess and monitor marine coastal ecosystems of the Lesser Antilles region.

5. The final section will discuss several specific sites designated as notable examples of these marine coastal ecosystems suggested by several scientific research personnel and land managers in the Lesser Antillean region.

1. ECOLOGICAL BASIS FOR SELECTING REPRESENTATIVE ECOSYSTEMS

There are several ecological factors to consider when evaluating an ecosystem. These include 1) species richness and diversity, 2) organic productivity and trophic composition, 3) habitat complexity, 4) rare species or species interactions and 5) relationships with other ecosystems. Any one of these factors may be important in itself in designating an area as "scientifically interesting". The fourth factor may appear to be the opposite of representative, but may be important for marine ecosystems and will be discussed below.

There is also a certain amount of dependency of each of the above factors on another. In addition there are a number of modifying factors which should be considered in selecting a given area as a representative ecosystem. These include 1) size,

2) relationship to influencing marine and terrestrial ecosystems, 3) proximity to population centers and to areas with scientific research institutions and 4) natural and social history of the area including the traditional use patterns. The remainder of this section will A) suggest a logical progression of how to obtain information at an increasing level of conceptual complexity in the coastal zones of the Lesser Antilles and B) consider the factors listed above in more detail.

A. Scientific Information of increasing conceptual complexity-

1) IDENTIFICATION: where are the ecosystems located?

We need to know first where these coastal marine ecosystem occur, and second the size of these ecosystems in any given geographical area (for instance around an island).

The initial determination of the position of these ecosystems is available in the series of data atlases prepared by ECNAMP for the Lesser Antilles (Putney, 1982). The sources of information for these atlases were varied and thus the accuracy of the information in some areas is less than in others (Putney, pers. comm.), yet it is a valuable first step in our knowledge about this region. Another important reference is the IUCN Coral Reef Directory, currently being compiled (Wells, pers. comm.) This provides a catalogue of known information about current or recommended to be managed coral reef ecosystems in the region. The region is divided by political units (for instance the U.S. Virgin Islands is presented in one chapter) and the format includes the following topics: Geographic location, area, depth and altitude, land tenure, physical features, reef structure and corals,

noteworthy fauna and flora, scientific importance and research, economic and social benefits, disturbances and deficiencies, legal protection, management, recommendation and references

It is hoped that recent satellite imagery (Armstrong, 1983; Putney pers. comm.) may be soon be applied to mapping the location of marine ecosystems. After the initial step of locating the sites of the marine ecosystems is the construction of a series of maps outlining the coastal marine ecosystems. The ultimate goal is a set of maps which show the marine communities composing each ecosystem.

In addition to geographically locating the ecosystems, it is necessary to identify both natural and man-induced influences. This includes ocean currents, seasonal changes such as temperature or fresh water input, sources of sediment, sources of pollution (both oceanic and from the island) and man's historical and present use of these marine ecosystems. Again, Putney's data atlases (1982) provide preliminary information of this sort.

2) STRUCTURE: What are the elements of the ecosystem?

Once the presence of an ecosystem is established, the next stage is a description of the elements of the ecosystem. This description can range from coarse resolution, e.g., a very broad qualitative description, to very detailed quantitative description which includes species abundances and distributions.

Naturally, the level of resolution about the elements of the system will depend on 1) the reasons the information is needed 2) the amount of effort (both time and financial) to be expended on the project and 3) the level of technical expertise

available. In some regions and for some studies a list of major taxa with some notations of dominant species might be sufficient. In others, for instance one in which long term effects of some sort of man induced stress (like anchoring or sediment stirred up by swimmers on an underwater trail through a coral reef) is to be determined, one would require a detailed monitoring method.

This might include detailed censuses on relocatable transects or repeated phototransects of a given site or sites. Preferably a study of this sort (e.g. effects of stress) would include an unstressed control area as well.

3) FUNCTION: What are the important metabolic and ecological mechanisms?

At the ecosystem level, one can monitor the metabolic responses of respiration and primary production. These can also be determined by the component method: knowing the component composition of the ecosystem and the metabolic responses of individual components a total component response can be derived (Rogers and Salesky, 1981). Another element in understanding how an ecosystem functions is to determine what physical (e.g. water movement, light, sediment) and biological (predation, competition) factors are most critical in determining the structure of this ecosystem. To answer both metabolic questions and questions about community structure requires a certain degree of scientific expertise and in fact may not yield much more information about the condition of a given ecosystem than knowledge about elements of the system. It would probably be more efficient to investigate ecosystems near major scientific

institutions to answer such questions as "how does an ecosystem function". Where possible, these findings could then be applied to other appropriate areas where predictions about changes might be needed for management discussions. Unless the structure of these ecosystems is well documented, however, accurate predictions of changes (natural or man induced) cannot really be made.

B. Factors in evaluating an ecosystem-

Five factors have been listed as important when evaluating ecosystems. The first two: 1) species richness and diversity and 2) organic productivity and trophic composition have been partially discussed above. An area that has a greater variety of species, interacting in more different kinds of ways is inherently more interesting than a less diverse system. A scientist can be interested not only in the elements of this complexity in itself, but might be interested in investigating how such a condition developed (from an evolutionary or from an ecological view point) as well as how such a condition is maintained. The answers to the questions may ultimately be useful in predicting the results of a phenomenon currently under study throughout the Caribbean: what will be the effects on the benthic fauna and flora due to the sudden mass mortality of the black long-spined urchin Diadema (Lessios et al., in press, Hughes et al., in press, Bak et al., in press). This animal occurred in high abundances throughout the region. It grazed on benthic plants, and probably affected (to some degree at least) the composition of the benthic

community (plants, corals and other sessile animals). Ultimately, information about the fundamental mechanisms controlling community structure and function will be important for management decisions as well.

The "intermediate disturbance hypothesis" suggests that relatively frequent, relatively minor disturbances to an ecosystem may result in high diversity while no disturbance or a major disturbance may result in a low diversity system. This appears to be important in complex tropical ecosystems, especially coral reefs (cf. Connell, 1978; Grigg, 1983). Reefs affected by major disturbances (hurricanes or chronic high pollution) will probably be less diverse than less drastically altered areas. A more diverse reef may not be more productive in the short term, but will continue to maintain habitat complexity which is important in the long term.

The third factor, habitat complexity, relates partially to the first two. For instance, in a coral reef, the diversity and abundance of reef fishes is most highly correlated with habitat complexity (Gladfelter and Gladfelter, 1978). In an ecosystem with high structural complexity such as coral reefs or mangroves, the more complex the structure, the more microhabitats are created. When a variety of types of spaces are available, a greater variety of organisms can live together.

Rare species or species interactions may appear to be a paradoxical criterion of a "representative" ecosystem, but they may play an important role in a multi-unit regional Biosphere Reserve. For example, in the Caribbean, barrier reefs

are not so common as other reef morphologies, but (1) where they occur they may be very important to the entire marine sphere (2) they should be compared to the more commonly occurring Pacific barrier reefs. Another example of uniqueness is the algal ridge community. It is not found extensively in the Caribbean but is common in the Pacific. Algal ridges may play an important role in the entire reef ecosystem where they occur. These examples (barrier reefs and algal ridges) might not be common in the Caribbean, but might provide important comparative information on reef structure and function. Information about communities may be derived initially from species lists which take a minimum of field time (as long as the person collecting the data is thoroughly versed in the taxonomy of a group).

Finally, the attendees of a recent UNESCO conference discussed the types of interactions between the Caribbean coastal marine ecosystems. They classified these ecosystem interactions into five major categories: physical interactions, nutrients and dissolved organic matter, particulate organic matter, animal migrations and human impact. A more detailed explanation of these interactions can be found in the Proceedings of the Workshop (Ogden and Gladfelter, 1983). It was recognized that the degree of these interactions would vary from area to area, but that the presence of an adjacent ecosystem could be of critical importance to the "normal" structure and processes of the ecosystem under consideration.

The first modifying factor to consider is the size of the "representative area of an ecosystem". It is a general

conservation principle that the larger an area that can be saved the better. This is particularly important in ecosystems (and biospheres) where knowledge of the size of an area necessary to sustain viable populations of key species is not even known. For instance, if migratory patterns are still not well understood or if the importance of nutrient exchange with adjacent ecosystems has not been quantified, then we may find that a designated area simply does not have the capacity to sustain the ecosystem of interest in a natural way. Thus, the larger an area that can be maintained the better.

It is true that "larger" in some ecosystems implies more well developed, e.g. mangroves. In this case a Lesser Antillean Biosphere Reserve should include not only examples of small areas (and less well developed) mangroves but also at least one large and well developed mangrove (such as in Barbuda or Guadeloupe) as well. The large ones, unfortunately have been the first to be destroyed in development, e.g. Krause Lagoon, St Croix.

Related to size is the question of boundaries. In any designated "protected" area, "good fences make good neighbors". The marine realm is faced with severe problems in this respect however. First, water moves from place to place generally without respect to man's wishes. Of course, air moves from area to area as well but is much less likely to carry detrimental agents such as sediments, pollutant chemicals and so forth. Thus a boundary designated on a map and enforced at the water's surface may have no effect in preventing agents capable of

disturbing a marine coastal ecosystem from reaching and affecting the protected area.

Likewise, our lack of knowledge about the effects of one ecosystem upon another may result in "preserving" one but destroying an adjacent region which plays an important modifying role. An example of this would be the protection of a bay with seagrass beds and fringing mangroves which may serve as a local fishery, but no protection of a nearby reef which provides a barrier to wave energy.

The proximity of a designated area to a population center must also be considered. There are examples of ecosystems which may not be as "outstanding" or "scientifically interesting" or biologically "representative" as others which could be designated, but they may serve as the only example of the ecosystem which the majority of the region's residents ever gets to visit. A population which comes to take pride in its natural heritage (e.g. natural ecosystems) will be much more likely to try and enforce the protection of these areas. But before that pride is developed, some personal knowledge of their benefits of an ecosystem is necessary. Therefore representative areas located nearby population centers, which can be visited by the general public are an important consideration in designating representative ecosystems.

As discussed above, the proximity to scientific research institutions is also a consideration. This is particularly true when questions of ecosystem function are to be addressed. Most ecosystems can be described to a certain degree by local

technicians trained by knowledgeable persons. These trained personnel could then carry out monitoring projects and provide continuity of information about a local region. The questions addressing how an ecosystem functions, however, can best be answered where scientific expertise and equipment are in close proximity to the study site; they would most logically be located near the scientific institutions and projects listed in Table 4.

The last modifying criterion is the historical and traditional use patterns of a given ecosystem. The Caribbean has a long and intense period of human use with the sea providing food, transport and communication. It may well be that none of the marine coastal ecosystems are "pristine", or natural. Nevertheless, we live in the world as it is today and some areas are "more natural" than others. Many areas of the Caribbean are considered to be overfished. Once productive fishing areas now require much more effort for fewer and smaller prey (Soares, pers. comm.). The effect of these commercially important fishery populations on the structure and function of the ecosystem is unknown. Yet, there have been areas on some of the Caribbean islands which have traditionally served the local population as sources of food. Perhaps if we could determine (through interviews with long time residents) the pattern of use of an area, effective regulations on fishing and gathering in a designated area could be established.

To summarize: the designation of areas within coastal marine ecosystems in the Lesser Antilles and adjacent regions should take into consideration not only a number of scientific factors,

but also modifying factors as well.

2. MAN'S USE OF COASTAL MARINE ECOSYSTEMS IN THE LESSER ANTILLES AND ADJACENT REGIONS.

The intrinsic value of coastal marine ecosystems as part of the earth's natural heritage cannot really be quantified. Their value scientifically can more easily be evaluated (see Section 1). Their value as a traditional use area, e.g. one which might have historical and economical importance to the local inhabitants could be determined with appropriate studies. Finally, the economic value of the coastal marine ecosystems of the Lesser Antilles concentrates on two major activities, tourism and fishing, along with several smaller (although locally significant) activities such as sand or salt mining, or in recent years mariculture activities. Table 2, adapted from ECNAMP's final report, the Data Atlas Summary (Putney, 1982), indicates the main economic activities in the coastal marine ecosystems in the islands of the Lesser Antilles and some adjacent islands. It can be seen that the features which attract tourists (who theoretically can enhance the islands economic base) are beaches, reefs, caves, sailing features (including picturesque coves and protected anchorages), and historic wrecks.

As an example of what one island group is doing to study the relationship of tourism to the features which attract tourists, we can briefly examine the British Virgin Islands. All the features which attract tourists are present in the British Virgin Islands. In Lund et al. (1985) the various stresses placed by the tourist (especially the sailing public) industry on these

features are discussed. As with any interaction between man's use and the natural state of an ecosystem, a very delicate balance exists. The British Virgin Island government is well aware of the fine line between use and abuse and has initiated a program to establish protected areas (Jackson, 1981). These designated areas have been the object of several studies, both to map and describe marine communities within the coastal marine ecosystems (cf. Anderson et al., 1985; Rogers et al., 1982) as well as to evaluate these sites from an educated tourist's point of (West Indies Laboratory, 1983, 1983).

It is hoped that sane and practical management decisions can be established and enforced to enable future generations of British Virgin Islanders and their tourist guests to enjoy these areas as so many do today.

Fishing in the shallow coastal marine waters of the Lesser Antilles includes both catch for local use as well as catch for export. Tables 2 and 3 outline the important fisheries in these areas. A recent ECNAMP publication, Guidelines for Integrated Marine Resource Management in the Eastern Caribbean addresses management problems from a multiuse approach, but provides guidelines especially for the various social, historical and economical problems posed by over-exploitation of fishery stocks. Lastly, Table 2 lists areas where there are other uses of marine resources.

To summarize, man's use of marine resources in the Lesser Antilles is intense, is varied, and is potentially threatening to many areas in coastal marine ecosystems on which these island's

populations are so dependent.

3. AVAILABLE INFORMATION ABOUT SCIENTIFIC CRITERIA TO EVALUATE COASTAL MARINE ECOSYSTEMS IN THE LESSER ANTILLES.

Available information about the marine ecosystems of the Lesser Antilles consists of scientific literature describing specific regions (cf. Wells, IUCN Coral Reef Directory), a series of data atlases indicating the position and use of the coastal marine ecosystems prepared by Allen Putney (1982), proceedings of several workshops gathered to investigate scientific, management, and/or economic questions about these ecosystems and, finally, information kindly provided for this report from a number of people. The bibliography at the end of this subtask contains the citations for these publications, atlases and proceedings. Publication lists from two research institutions (West Indies Laboratory, St Croix and Guadeloupe University) are available from the directors upon request and may be available from the other institutions listed in Table 4. In addition to research institutions with a marine focus there are some special projects (Table 4) as well. Many scientists and managers at these sites are very willing to communicate information about questions with Caribbean wide focus.

4. DESCRIPTION OF METHODS TO TEACH AND DEVELOP SKILLS TO ASSESS OR MONITOR MARINE AREAS.

As part of the West Indies Laboratory contribution to the VIRMC Biosphere Reserve Project has involved mapping and describing the marine communities in the British Virgin Islands. The methods used for this section were developed to provide a uniform data set for each designated area in the BVIs and St John (the initial Biosphere Reserve designation in the Lesser Antillean region) which could then be used subsequently in evaluating the site. The data as presented can be used by a number of different types of potential resource users. For example, Putney (pers. comm.) has already used the information from two BVI sites in formulating management plans. Persons interested in diving in these areas can get an overall view of community distribution from our maps, and a more detailed presentation of the development and composition of these communities from our transect data. Finally, the plates are available for further confirmation. Sites in St. John were assessed not only for benthic community composition but also for fisheries potential. This information can be extrapolated to similar sites on other islands, so that potential fisheries can be assessed from a map of the benthic communities.

Other investigators have used a variety of approaches in describing a few of the same sites we investigated (cf. Rogers, et al, 1982; West Indies Laboratory, 1982, 1983). The difference in approach lies in the ultimate objective of one's description. Our goal was to provide a qualitative and quantitative (as possible with time and personnel constraints)

description of the designated park site, so that management decisions can be made. The information provided can be used to determine if the site has recreational or fisheries potential and if the site is heavily impacted at present by tourists. The method can be used by intelligent, trained personnel. These methods are described in detail (Anderson et al., 1985; Lund et al., 1985). They were developed with the cooperation of the USVI Department of Fish and Wildlife (Poulon), College of the Virgin Islands (Beets) and Virgin Islands National Park (Small, Brander).

Briefly, the mapping involved three steps: (1) Taking a set of initial color aerial slides (from a small plane) flying parallel to the water's surface all around the region to be studied; (2) making a set of black and white negatives of existing charts of the islands, and projecting these to the desired scale on a drafting sheet, on which is drawn the appropriate land outline (with scale); and (3) superimposing the color aerial slides on this map at appropriate scale and drawing the outlines of different marine communities detectable in the photographs.

These maps were then reproduced on waterproof material and taken to the field where identification and quantification of marine communities was carried out. This involved assessing chosen linear transects across several representative communities. Profiles (showing water depth and position of community boundaries) were drawn of these detailed transects. In addition, spot checks of other communities in the site were also

made. The marine communities were then described in both a qualitative and semiquantitative manner and black and white photographs illustrating "typical" communities of the region were taken. Additional studies, including fish censusing were conducted by other researchers in this project, and the results can be obtained from the Virgin Islands National Park.

These same techniques can be conducted anywhere in the Caribbean. Results should yield data necessary to evaluate a site by the scientific criteria described in Section I. The aerial photography minimally requires a plane, pilot and a photographer. Ground truthing can be conducted by one or more persons by snorkeling or using SCUBA from shore or from a boat. The description of marine communities requires the recognition of the major Caribbean benthic fauna. The bibliography includes several references that might be used for this identification. In addition there is a UNESCO guide to research methods on coral reefs (Stoddart and Johannes, 1978). Similar guides to research methods for seagrasses (McRoy) and mangroves (Snedeker) are in preparation.

5. NOTABLE EXAMPLES OF COASTAL MARINE ECOSYSTEMS IN THE LESSER ANTILLES AND SOME ADJACENT REGIONS.

In the previous sections of this report, the lack of detailed knowledge describing the structure, function and use the coast marine ecosystems in many parts of this region was mentioned. There is enough information to make some recommendations about sites with "representative" ecosystems, with the knowledge that some steps must be taken before some of

these areas are irrevocably lost through human abuse.

A brief summary of land (and to a lesser extent marine) resource use of the islands of the Lesser Antilles was presented in the Virgin Islands MAB Proceedings of the Workshop held in May 1983 (Wood, 1984). During the meeting, Putney identified four priority areas in the region as representative examples of the Lesser Antilles Ecosystems (Table 5). His criteria were based on the Man and the Biosphere theme thus included representativeness (natural and human institutional use) and multiple zones potential (core, traditional use, experimental, rehabilitational) but also considered local involvement and sharing of human resources in the establishment and maintenance of these areas. In addition, Putney (1982) has also compiled a list of "the largest remaining contiguous areas of relatively unaltered ecosystems," shown in Table 6. As discussed in Section 1, size is an important modifying characteristic in designating representative sites.

In response to letters of inquiry about potential areas of importance several people generously supplied information. This is contained in Appendix I where Mr. Tom van't Hof of the Netherlands Antilles National Parks Foundation (1a) and Mr. Allan Smith of the Seamos Mariculture Project on St. Lucia (1b) provided extensive information about their areas. In addition Dr. Claude Bouchon of Guadeloupe suggested (pers. comm.) that in addition to other areas in his region, the large northwest facing bay between Basse Terre and Grande Terre (Grand Cul-de-sac Marin) is especially critical because it represents one of the best

areas in the eastern Caribbean where all three major coastal ecosystems: coral reefs, mangroves and seagrass beds are located in close proximity to one another and each is a well developed ecosystem in its own right as well. Guadeloupe University is currently conducting extensive scientific studies describing this unique area. Although the criteria used by these scientists may not have been precisely similar, their identification of location of potential sites as well as a qualitative description of the site and its potential value is most useful in suggesting possible sites for more intense evaluation. Until the MAP program has more clearly identified the form a Lesser Antillean Biosphere Reserve will take, a more concrete list of sites cannot be made.

Summary

The three major coastal marine ecosystems in the Lesser Antilles and adjacent regions are coral reefs, mangroves, and seagrass beds. The people of the region depend quite heavily on the sea for the major economic activities of tourism and fishing, but man's intense use of these coastal areas threaten the integrity of these ecosystems in many ways.

This subtask has identified five scientific criteria to use in selecting representative ecosystems: 1) species richness and diversity, 2) organic productivity and trophic composition, 3) habitat complexity, 4) rare species or species interactions and 5) interactions with other ecosystems. It has also recommended that the following modifying factors: 1) size, 2) relationship to

influencing terrestrial and marine ecosystems, 3) proximity to areas of population and to areas with scientific research institutions and 4) natural and social history of the area including traditional use patterns be taken into account as well.

In addition, man's use of these coastal marine ecosystems was discussed. A bibliography of published sources of descriptive information about these coastal marine ecosystems is included, along with a list of some current research institutions and marine resource projects in the area.

Three levels of information about these coastal marine ecosystems are ultimately required for a complete scientific understanding of these ecosystems. These include A) identification of the systems, B) structure, including descriptive information about the system, and C) function, including physiological and ecological principles underlying the system. Methods were suggested by which the first two types of information could be obtained in any of these areas. It was suggested that the third type of information might best, at least initially, be obtained near sites of research institutions which have the equipment and personnel support needed for this kind of research. Finally, some sites of representative ecosystems in the Lesser Antilles and adjacent regions are discussed.

There is no one method by which all potential "representative" sites will be determined. Political, social and economic criteria must be examined once the relevant ecological criteria have been used to assess potential sites. If the MAR program hopes to understand man's relationship with the tropical

marine ecosystems it must not only evaluate available information and continue to support the type of programs of which this publication is a part but must also encourage the necessary cooperative management of a multi-island, multinational reserve as is envisioned for the Lesser Antilles.

At present the Virgin Islands National Park is the only Biosphere Reserve unit in the region. It should continue to serve as a nucleus of information and information gathering techniques for the marine ecosystems of the region. It is a member of the Virgin Islands Resource Management Cooperative. The VIRMC member institutions should maintain contact with the other scientific institutions and scientists in the Lesser Antilles region to foster exchange of needed information to assess the marine ecosystems of the region.

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Table 1 - Inventory of Coastal Marine Ecosystems: Level of Information
(adapted from Ogden and Gladfelter, 1983)

Partially known

British Virgin Islands

Netherlands (Windward)

Antigua

Barbuda

St. Kitts-Nevis

Anguilla

Montserrat

St. Lucia

St. Vincent

Grenada

Well known

Trinidad-Tobago

U.S. Virgin Islands

Netherlands (Aruba, Bonaire,
Curacao)

Guadeloupe

Martinique

Barbados

Table 2 - Principle Economic Uses of Coastal Marine Ecosystems

(adapted from Putney, 1982)

Island(s)	Features of Important Economic Value		
	Tourism	Fisheries	Salt Production or Mariculture
Tortola	sailing, beaches	fish	mangroves
Virgin Gorda	sailing,reefs beaches	fish	mangroves
Anegada	beaches,reefs, sailboat races wrecks	fish, lobster conch	mangroves salt ponds turtle nesting
Anguilla	beaches,reefs sailboat races sailing	fish, lobster conch	salt ponds
St. Barthel- emy	sailing	conch lobster	
Saba		fish lobster	
St. Kitts		fish	salt ponds
Nevis		fish, lobster conch, turtle	
Montserrat		fish, lobster conch	
Barbuda	beaches,reefs caves,wrecks	fish,lobster	mangroves,turtles
Antigua	beaches;reefs sailboat races sailing	fish,conch lobster	mangroves,turtles
Guadeloupe	beaches,reefs sailing	fish,conch lobster, turtle	mangroves,turtles
Dominica		fish	
Martinique	beaches,reefs wrecks	fish,lobster conch,turtle	mangroves,turtles salt ponds
St. Lucia	beaches	fish,lobster	mangroves

Table 2 - cont.

Islands	Features of Important Economic Value		
	Tourism	Fisheries	Salt Production or Mariculture
Barbados	beaches, reefs caves	fish	
St. Vincent		fish	
St. Vincent Grenadines	beaches, reefs sailing	fish, lobster conch, turtle	turtles
Grenada Grenadines	beaches, reefs sailing	fish, lobster conch, turtle	turtles
Grenada	beaches, wrecks sailing	fish, lobster conch, turtle	mangroves, turtles
Bonaire	reefs	fish	mangroves, salt ponds
Curacao	reefs	fish	mangroves
Aruba	beaches, reefs	fish	mangroves, salt ponds

Table 3 - Fisheries of the Caribbean Coastal Zone; number refers to priority order
 (adapted from Ogden and Gladfelter, 1983)

	seaweeds	sea urchins	conch	shrimp	lobster	reef fish	mangrove fish	pelagic fish	aquarium fish
Netherlands Antilles						1			2
Trinidad/Tobago				2				1	
Barbados	4	2				1		3	
Guade Loupe			2		3	1	4		
USVI/BVI			4		2	1			3

Table 4
 Institutions and Projects Involved in Research about Marine Ecosystems
 in the Lesser Antilles and adjacent regions

Guadeloupe:	Centre Universitaire Antilles-Guyane UER Sciences Exactes et Naturelles Laboratoire de Biologie et Physiologie Animales B.P. 592 97167 Pointe-a-Pitre cedex Guadeloupe, F.W.I.
St. Lucia:	Seamoss Mariculture Project (Mr. A. Smith) c/o Goodwill Fisherman's Co-op Jetty Street Vieux Fort, St. Lucia
	Ocean Research and Conservation Association Inc. 3455 Cadboro Bay Road Victoria, B.C. V8R 5K7 Canada (cetology, phycology, geology)
Barbados	The Bellairs Research Institute of McGill University St. James, Barbados
	Biology Department University of the West Indies P. O. Box 64 Bridgetown, Barbados
Trinidad	Institute of Marine Affairs P.O. Box 3160, Carenage Post Office Trinidad
Netherlands Antilles	CARMABI P.O. Box 2090 Curacao
	Afdeling Milieubeheer Geneeskundige en Gezondheidsdienst Piscaderaweg 49 Zaquito, Curacao (Dept. Environ. Manag., Sanit. and Health)
	Dienst Landbouw, Veeteelt en Visserij Cas Cora, Curacao (Dept. Agric., Livestock and Fishery)

Table 4 - cont.

Foundation for Aquaculture
c/o Dienst Landbouw, Veeteelt en Visserij
Bonaire

Karpata Ecological Center
P.O. Box 151
Bonaire

Virgin Islands: West Indies Laboratory
Teague Bay
Christiansted, St. Croix

Eastern Caribbean Natural Area Management Program
c/o West Indies Laboratory (see above)

Caribbean Research Institute
College of the Virgin Islands
St. Thomas

Island Resources Foundation
P.O. Box 33
Red Hook Center, St. Thomas

Table 5 - Priority Areas for Protection of Representative Samples of
Lesser Antillean Ecosystems

(adapted from Putney in Wood, 1984)

<u>Areas</u>	<u>Ecosystems</u>			Comments
	<u>Coral Reefs</u>	<u>Seagrass Beds</u>	<u>Mangroves</u>	
Parc National Guadeloupe	x	xxx	xxx	proposed
Barbuda	xxx	xxx	xxx	public land
SE Peninsula St. Kitts	x	xxx	x	private land
Anegada	xxx		x	
xxx	relatively large area			
x	medium to small area			

Table 6 - The Largest Remaining Contiguous Areas of Relatively Unaltered
Ecosystems

(adapted from Putney, 1982)

Living Reefs

SITE	ISLAND	LENGTH(km) ¹
Southeastern Coast	Martinique	84
Northern, eastern and southern reefs	Barbuda	77
Horseshoe Reef	Anegada	63
Northern and eastern reefs	Antigua	58
Grand Cul-de-Sac Marin	Guadeloupe	33
Eastern and southern reefs	Barbados	44
Northeastern reefs	Sint Maarten	25
Southwestern reefs	Sint Maarten	23
Southeastern Coast	Anquilla	17

Seagrassbeds

SITE	ISLAND	SIZE(ha)
Southwestern Shelf	Barbuda	19,800
Northwestern Shelf	Sint Maarten	11,600
Grand Cul-de-Sac Marin	Guadeloupe	6,700
Southwestern Shelf (2 patches)	Sint Maarten	3,600
Northwestern Shelf (2 patches)	Nevis	3,300
Southern Shelf	Nevis	2,400
Southeastern Peninsula (5 patches)	St. Kitts	1,200

¹ continuous, with no more than a 2 km gap

APPENDIX Ia - MARINE ECOSYSTEMS OF CURACAO AND BONAIRE
(Mr. Tom van't Hof)

Curacao

Coral reefs, mangroves or seagrass beds in a "natural" state are non-existent in Curacao. Most or all of the inter bays have some mangrove belt and/or seagrass beds, but I do not consider them "outstanding examples of representative marine ecosystems".

As to coral reefs I believe Curacao offers outstanding examples of fringing reefs with a history of traditional use. These reefs are of great biological, scientific, educational and economic significance. The accessibility of these fringing reefs is a unique feature which greatly increases their recreational potential, but at the same time enhances their vulnerability. I suggest two areas of interest: Kaap St. Marie to Westpunt and Bapor Kibra to Oostpunt (Fig. 1).

The area of Bapor Kibra to Oostpunt coincides with Curacao Underwater Park and is, except for two small harbor/industrial areas in Caracasbaai and Fuikbaai, in an unaffected state. The area is moderately exposed to wave action (increasing towards Oostpunt) and this is responsible for a very characteristic coral community of the shallow submarine terrace (0-9 m depth) consisting of Acropora palmata, head corals and gorgonians with high cover and very little vertical zonation. The drop-off zone and reef slope are zoned sensu Bak (Stud. Geol., 4, 1977). Also 22% of reef length in this area consists of steep submarine cliffs. Fishing has been the only traditional use of the area.

Types of fishing include trolling (mainly pelagic fish), bottom fishing (reef fish; reef fish compose 10-15% of total catch in Curacao), spearfishing and very limited trap fishing.

The area of Kaap St. Marine to Westpunt is far more sheltered (increasing shelter to the west). Coral communities of the submarine terrace are rather different from those of the east. Mostly a zoned terrace is found with an Acropora palmata zone, a zone with dispersed head corals, gorgonians and patches of Acropora cervicornis, and towards the drop-off a zone with moderate cover of Montastrea annularis, gorgonians, Agaricia agaricites and patches of Madracis mirabilis.

In the western part of this area the Acropora palmata zone is often completely lacking. Again fishing has been the only traditional use of the area. A second marine park is planned including at least part of the area of Kaap St. Marie to West Punt.

Bonaire

Bonaire has two excellent examples of representative ecosystems with a history of traditional use. Bonaire and Klein Bonaire are surrounded by virtually unaffected fringing reefs, which are of great biological, scientific, educational and economic value. The fringing reef around the entire island and around Klein Bonaire should be considered since there are hardly any present uses that affect the reef system. Fishing is the main traditional use of the ecosystem, but with a low and stable population density as compared to Curacao, exploitation of marine resources has always been considerably less than in Curacao.

Differences in the abundance of large piscivorous predators demonstrate this.

The accessibility of the fringing reefs and the physiographic characteristics of the island provide tremendous opportunities for recreation and tourism. This potential has been developed in the past decade which resulted in Bonaire becoming one of the favorite destinations for North American divers. The possible effects of this rapidly increasing recreational use has yet to be assessed, but can be controlled if necessary since the reefs obtained the status of a national marine park.

Lac Bay (Fig.2) is a shallow clear-water lagoon of about 8 km² along the east coast of Bonaire. The lagoon is bordered by extensive mangrove vegetation (Rhizophora mangle and Avicennia germinans). The greater part of the bottom is covered with Thalassia testudinum and to a lesser extent with Syringodium filiforme. There is an influx of oceanic water across the coral barrier that separates Lac from the ocean and an outward flow through a narrow canal in the north-eastern corner. Lac has traditionally been fished for conch (Strombus gigas), reef fish (using small fish traps) and turtles. Mangrove wood has been used for charcoal burning and boat building. Present use consists mainly of trap fishing and recreation. Conch has been overfished to the extent that no individuals over 15 cm length were found. Lac is presently being restocked with juvenile conch raised in the laboratory.

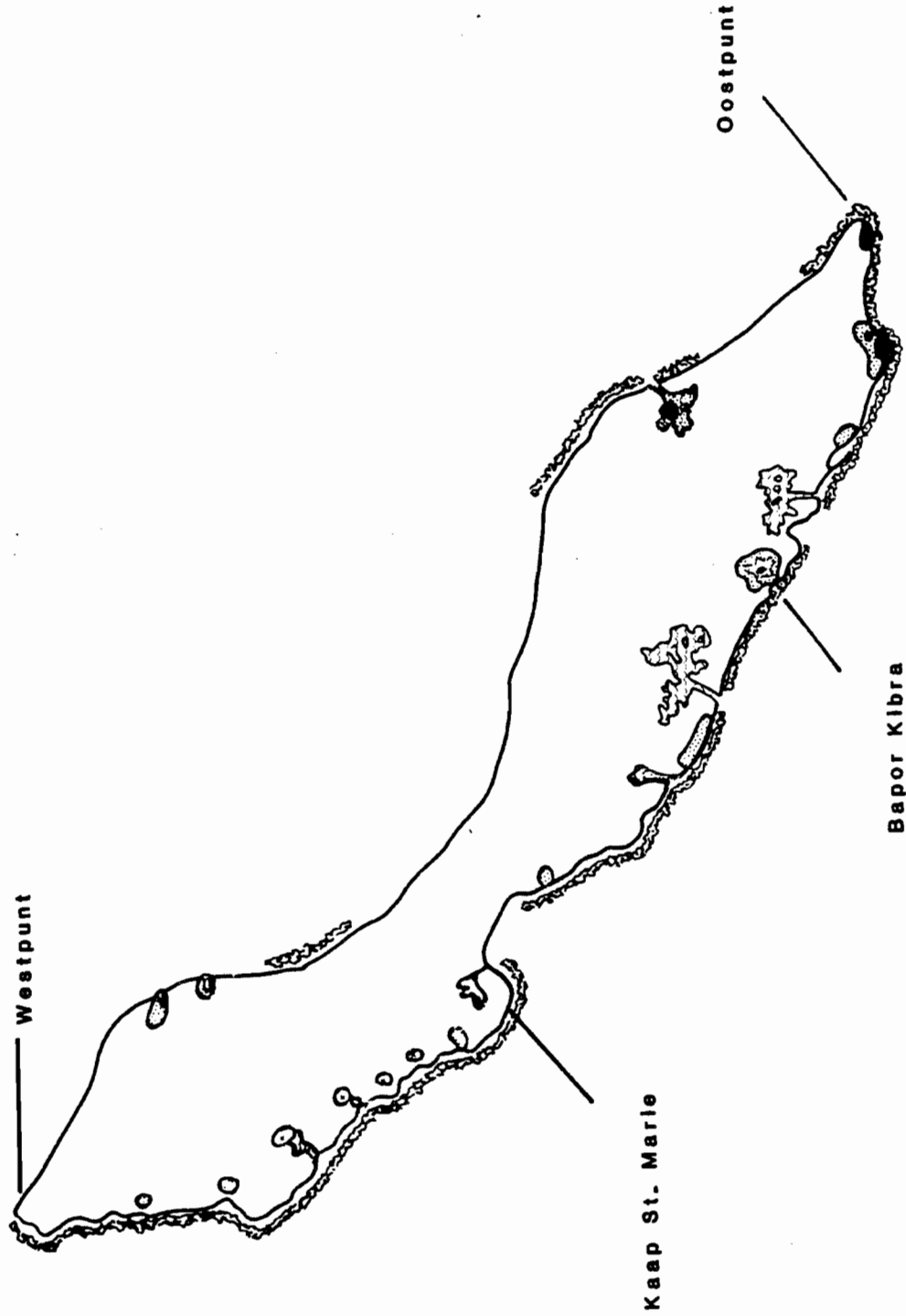
Lac is a unique example of close proximity of the three

ecosystems mangroves, seagrass beds and coral reefs where interactions between these systems can be studied. It has suffered only minimal levels of interference. The mangroves and seagrass beds of Lac were demonstrated to be of major significance as nurseries for at least 9 species of commercially important reef fish.

Although Lac is part of the Bonaire Marine Park it is continually threatened by development for touristic purposes. Lac cannot sustain any large-scale developments. Lac can sustain low to intermediate levels of traditional resource exploitation such as trap fishing, conch fishing and mangrove harvesting.

Figure 1
Resource Data Map of Curacao (from ECNAMP)

CURACAO	
6. IMPORTANT MARINE HABITATS	
	Wetland
	Saltpond
	Seagrass bed
	Living reef
Source: Bakhuis, 1979 Bak, 1979.	



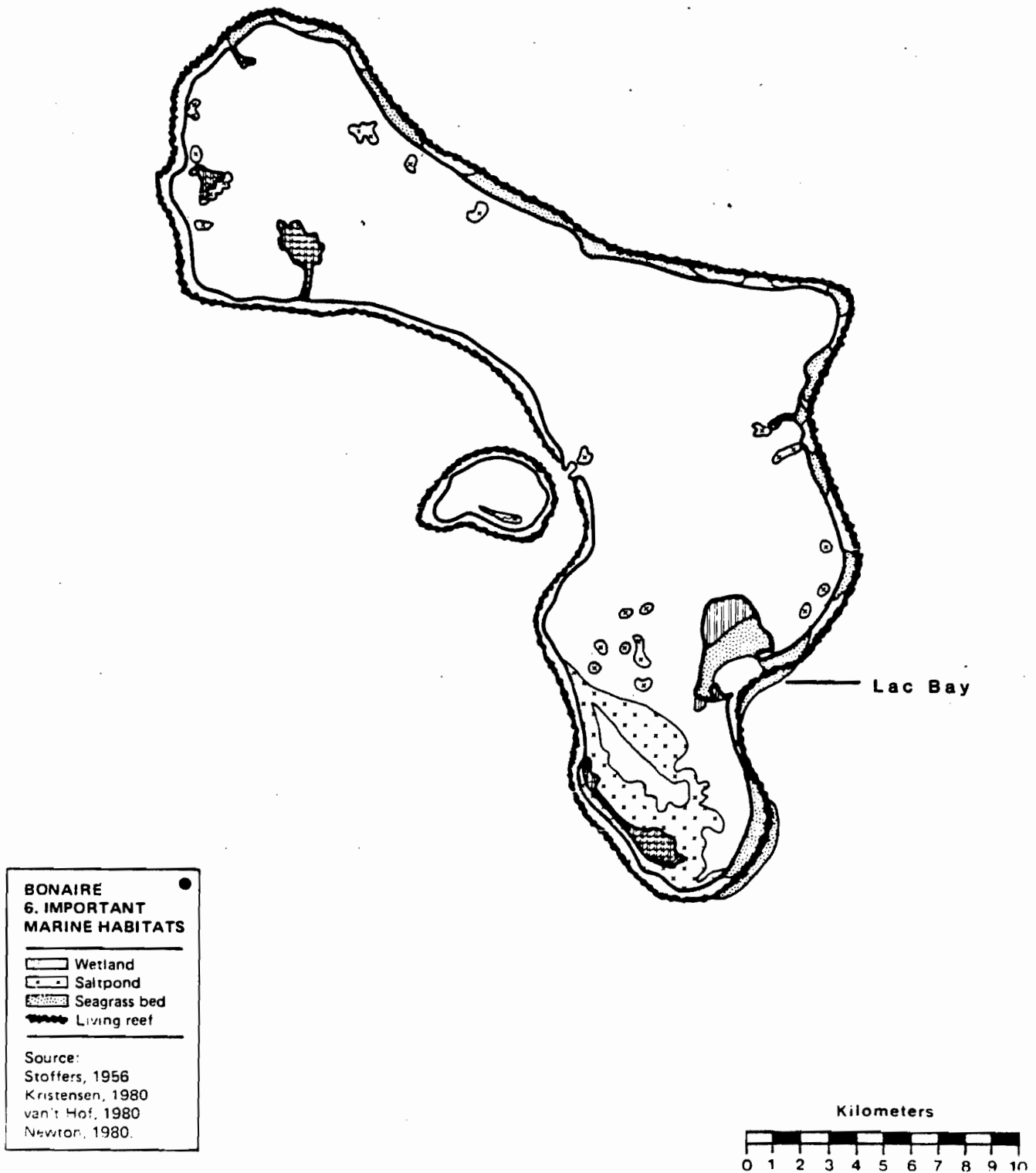


Figure 2

Resource Data Map of Bonaire (from ECNAMP)

APPENDIX Ib - MARINE ECOSYSTEMS OF ST LUCIA (Mr. A. Smith)

A. Coral reefs

These are in a comparatively early stage of development because of ongoing coastal erosion. They are restricted in distribution and therefore of great importance where found.

Acropora palmata reefs

Fig. 3 (1) Atlantic side of Pigeon Island causeway; no personal information on exploitation.

" (2) Maria Islands reefs; see enclosed report (1).
Pot-fishing, spearfishing for fish and lobster.

" (4) Laborie Bay; exploitation as for Maria Islands.

Deeper reefs

Fig. 3 (3) Anse Gallette; low level of spearfishing and pot-fishing, regular dynamiting for fish, some data available on this area (2,3).

The most extensive reef development is in the area of Soufriere and the Pitons. It should be noted that the tourist industry in S. Lucia is in its infancy and would best be developed in the direction of recreational diving. Such development is only possible if the reefs in this particular area are protected. At the present rate of destruction this option will not be available for much longer.

Fig. 3 (5) North side of Gros Piton; colonization by reef species, hermatypic corals and gorgonians on boulders, sloping gradually to sand at 15 m depth. Extensive spearfishing, pot-fishing, with occasional dynamiting.

- Fig. 3 (6) South face of Petit Piton; Shallow slope on east end of face. Extensive pot-fishing with pots regularly retrieved from deep water by dragging towards shore up the reef face, with obvious destruction of corals. Western end of the face showing less damage; frequently vertical below 20 m depth mostly appearing 'natural', as impressive examples of wall communities.
- " (7) Rchette Point, north side of Soufriere Bay: a small but outstanding area. No evidence of destruction or exploitation, apparently in a 'natural' state and worthy of preservation at least as a diving attraction.
- " (8) Anse Chastanet reefs; the best-developed reefs around St Lucia, beginning within 30 m of shore at 5 m depth extending offshore to steep faces with abundant reef species. Severe exploitation through pot-fishing, gill-netting, removal of gorgonians in shallow water for 'brown coral', antipatharians from deeper water for 'black coral', and hermatypic species to be bleached as souvenirs. Also evident is physical damage by visiting divers as this is the most frequented reef on the island. Legislation for conservation urgently required.

B. Mangroves

South-east coast mangrove heavily exploited for charcoal

production; detailed information on this no doubt supplied by Mr. Yves Renard, ECNAMP.

C. Seagrass beds

Personal experience is limited to the south-east coast where a large area of Thalassia/Syringodium exists inshore of the reef that runs between Maria Island and Saltibus Point (3). Maximum depth between 4 and 5 m. Traditional use of the reef involves collection of 'seamoss' for local consumption and export. 'Seamoss' is a collective term for the agarophyte Gracilaria spp., in this case G. crassissima.

Piles of tests indicate a very large harvest of Tripneuste esculentus in the past. The species has been totally absent in recent years (reportedly since the 1980 hurricane) but began to re-appear at the end of 1983. A survey conducted in 1982 indicated approximately 200ha of seagrass within the boundary described above, a significant habitat in the south of the island. Strombus spp. and Cassis spp. were apparently found here in the past but are absent at present. Juvenile lobsters are abundant but the collection of lobsters on the reefs bordering the areas has been so severe that the catch usually involves two to four individuals per pound, sold locally. Methods of cultivation of agarophytes are being developed here.

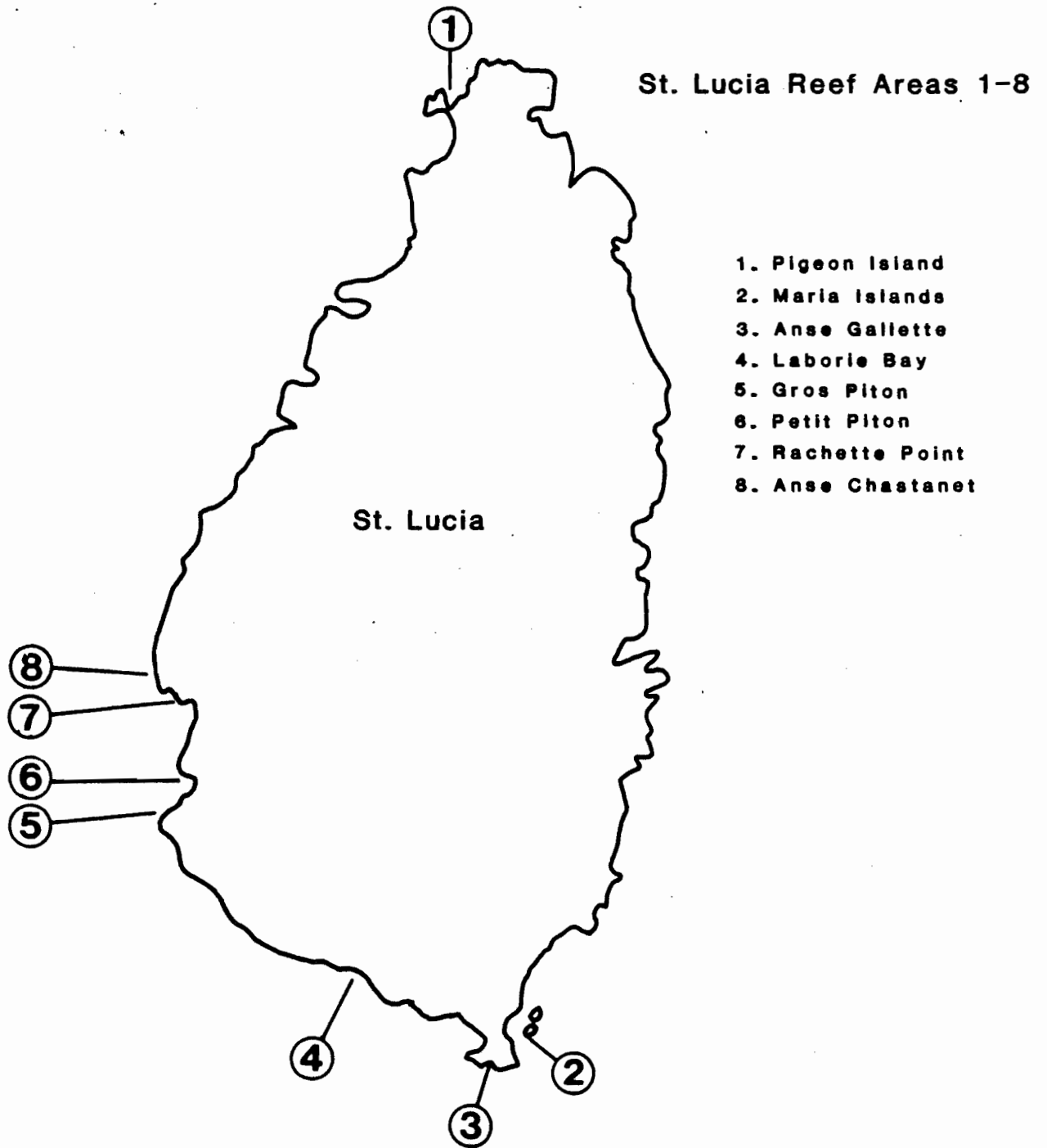


Figure 3

