FISHERY MANAGEMENT PLAN

FOR

CORAL AND CORAL REEFS

of the

GULF OF MEXICO AND SOUTH ATLANTIC

GULF OF MEXICO FISHERY MANAGEMENT COUNCIL
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APRIL, 1982

1.0 PREFACE

This fishery management plan for coral and coral reefs is unique in many respects and should be approached with that understanding. The management unit is composed of some 400 species, many of which have no common names. Much of the descriptive material is necessarily technical. Data on growth and potential production are scant, and a maximum sustainable yield is incalculable. Harvest presently is at a very low level, and the principal value of this resource is determined to be in non-consumptive uses. Such uses include the use of coral as habitat by many other important recreational and commercial species of fish and shellfish. The coral reefs are also important economically to the tourist and recreational industry as a major attraction for divers and other nonconsumptive users. Because the growth of many corals is slow (Oculina thickets may be a century old) the "fishery" in many instances must be considered as a nonrenewable resource.

Corals in the FCZ, which includes much of the Florida reef tract, were protected by a federal agency until 1979 when a court ruling restricted this authority. Although harvest of coral and destruction of reefs is at a low level at this time, large scale harvest of corals could begin as it becomes generally known that this resource is no longer protected by law.

The thrust of this plan therefore is to conserve this resource at the present low level of harvest.

1.1 Preparation

The initial draft of this plan was prepared in 1979 by the Center for Natural Areas under contract to the Gulf of Mexico and South Atlantic Fishery Management Councils (Contract No. C-97-6A).

List of Preparers:

Center for Natural Areas:

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Each of the listed people contributed to the drafting of the fishery management plan. Since this is truly a cooperative effort coordinated by the Councils, no individuals can be listed as authors of separate sections or chapters.

Appreciation is extended to the several federal and state agencies, academic institutions, and individuals who contributed helpful information, advice, and suggestions.

Special appreciation is extended to the members of the Special Coral Scientific and Statistical Committee, the Coral Advisory Subpanel and Jennifer Wheaton Lowry, whose suggestions, insights, and data facilitated preparation of this plan.

Cover drawing of Eusmilia fastigiata by Chuck Messing.

1.2 Review

List of Agencies, Organizations, and Persons to whom Copies of the Statement are Sent:

Department of the Interior
Department of State
Department of Agriculture
Department of Transportation
Department of Energy
Environmental Protection Agency
Florida, Alabama, Louisiana, Mississippi, Texas, Georgia, South Carolina and North Carolina state agencies
All fishery management councils
Southeastern Fisheries Association
Florida League of Anglers
Gulf States Marine Fisheries Commission
Sea Grant Advisory Services:

Texas	Georgia
Mississippi-Alabama	South Carolina
Florida	North Carolina
Louisiana	

Bureau of Land Management, New Orleans Office
Organized Fishermen of Florida
Southern Offshore Fishermen's Association
Texas Shrimp Association
Louisiana Shrimp Association
State Coastal Zone Agencies
Marine Sanctuary Office, Department of Commerce
Sport Fishing Institute
Marine Wilderness Society
Environmental Defense Fund
Florida Marine Life Association
Audubon Society of Florida
Audubon Society of Texas
Houston Sportsman Club
Houston Audubon Society
Houston Regional Group of the Sierra Club
Lone Star Chapter of the Sierra Club
Harbor Branch Foundation

Environmental Impact Statement for The Fishery Managment Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic

( ) Draft (x) Final Environmental Statement

Responsible Agencies:

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1. Name of Action: (x) Administrative

2. Description of Action:

The proposed action is to adopt and implement a fishery management plan for coral and coral reefs within the geographical area of authority of the South Atlantic and Gulf of Mexico Fishery Management Councils. The primary objective of this plan is to optimize benefits while conserving the management unit. This goal is supported by specific objectives to generate sufficient data to assess the feasibility of harvest of coral, to minimize adverse human impacts, to provide special management to particular habitat areas, to increase public awareness of the resource, and to provide a coordinated management regime. This fishery plan covers over 400 species of coral distributed throughout the management area. The size and diversity of this unit is exceedingly complex, including species ranging from shallow water, muddy sediment sea whips to deepwater precious corals, and from hard bottom solitary species to outer bank reef corals. Among the most significant and unique stocks are the Flower Garden Banks on the Texas/Louisiana outer continental shelf and the Florida reef tract. Elsewhere, much of the coral occurs in hard bottom communities where it contributes habitat and food to many other species, with established recreational or commercial value, e.g., snapper, grouper, shrimp. In certain areas, particularly southern Florida, corals also help support important businesses such as diving and charter-boats.

3. Date by Which Comments Must Be Received: SEP 1 0 1983

This integrated document contains all elements of The Fishery Management Plan and Environmental Impact Statement. To aid the reviewer a table of contents for the EIS elements is provided separately referencing corresponding sections of the FMP.

4. Table of Contents

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2.0 SUMMARY

2.1 The Fishery

The fishery for coral and coral reefs as addressed in this plan is located in the Gulf of Mexico, and the waters of the Atlantic Ocean from the Texas-Mexico border through North Carolina.

2.2 The Management Unit

The management unit consists of the coral and coral reefs of the fishery conservation zone (FCZ) of the Gulf of Mexico and South Atlantic Fishery Management Councils. Management measures in this plan will be recommended to adjacent states where appropriate.

2.3 The Species Included

Included in this management unit are:

A. Corals: the corals of the class Hydrozoa (stinging and hydrocorals) and the class Anthozoa (sea fans, whips, precious corals, sea pen and stony corals).

B. Coral Reefs: the hard bottoms, deepwater banks, patch reefs and outer bank reefs as defined in this plan.

2.4 Problems in the Fishery

1. Degradation of the stocks through natural and man-made impacts.

2. Limited scientific information on many species and many sections of the management unit, which includes the inability to assess the impact of coral harvest.

3. Susceptibility to stress because of corals being located at the northern limit of their distribution.

4. Inability of corals to escape stress because of their sedentary nature.

5. Complexity and inconsistency of management regimes.

6. Lack of adequate public understanding of the importance of coral and coral reefs.

7. Present lack of jurisdiction over most coral and coral reefs by a federal agency which has traditionally executed authority and jurisdiction.

2.5 Statement of Maximum Sustainable Yield, Optimum Yield, Expected Domestic Annual Harvest, and Total Allowable Level of Foreign Fishing

2.5.1 Maximum Sustainable Yield

With the existing data, a single maximum sustainable yield (MSY) for the entire management unit is incalculable. An estimate of MSY for select species at Biscayne National Park gave an MSY range of 0.0026 to 0.0158 kg/m^2/yr for three hard corals and 0.0026 to 0.0132 kg/m^2/yr for six soft coral genera. Those estimates are based on mortality and living tissue biomass data that are subject to widespread speculation (see FMP Section 5.4.9 and Tables 5-18 and 5-19).

2.5.2 Optimum Yield

OY for all corals is the level of harvest specified or as may be authorized pursuant to the permitting criteria established in this plan. Based on available data it is the Councils' intent to allow the existing level of legal, reported harvest consistent with the objectives of this plan.

OY for stony corals is to be zero (0) except as may be authorized for scientific and educational purposes. The current and expected level of harvest for this purpose is estimated to be about 140 kilograms per year.

OY for octocorals is the amount of harvest which is authorized pursuant to this plan. It is to be all octocorals (except sea fans) that are harvested by U.S. fishermen. Octocorals, except for sea fans, are identified as presently being harvested without apparent stock damage (Section 8.2.6). Present and expected directed level of harvest is estimated to be about 5,845 colonies, 1,463 of which come from the FCZ.

Because of the value of some species of octocorals as a source of hormones, there exists the potential for localized or even widespread overfishing. For this reason, the Councils are proposing that the condition of the stocks and the harvest be monitored so that the Secretary of Commerce may take appropriate action should there be an impending threat of overfishing.

2.5.3 Estimated Domestic Annual Harvest

The Estimated Domestic Annual Harvest (EDAH) is to be equal to OY.

2.5.4 Total Allowable Level of Foreign Fishing

The Total Allowable Level of Foreign Fishing (TALFF) is to be zero.

2.6 Specific Management Objectives

PRIMARY MANAGEMENT OBJECTIVE

Optimize the benefits generated from the coral resource while conserving the coral and coral reefs.

SPECIFIC MANAGEMENT OBJECTIVES

1. Develop scientific information necessary to determine feasibility and advisability of harvest of coral.

2. Minimize, as appropriate, adverse human impacts on coral and coral reefs.

3. Provide, where appropriate, special management for coral habitat areas of particular concern (HAPCs).

4. Increase public awareness of the importance and sensitivity of coral and coral reefs.

5. Provide a coordinated management regime for the conservation of coral and coral reefs.

2.7 Management Measures

1. Catch Limitations

A. Total Allowable Level of Foreign Fishing - none. The expected domestic annual harvest will equal the optimum yield.

B. Types of Catch Limitations:

(1) Prohibit the taking of stony corals and sea fans (Gorgonia flabellum or G. ventalina) or the destruction of these corals and coral reefs in the FCZ of the Gulf and South Atlantic Fishery Management Councils' geographical area of authority, except as provided for in this plan.

(2) Stony corals and sea fans taken incidentally in other fisheries must be returned to the water in the general area of capture as soon as possible. An exception is provided for the groundfish, scallop, or other similar fisheries, where the entire unsorted catch is landed. In such instances the stony corals and sea fans may be landed but may not be sold.

(3) Should harvest of octocorals become accelerated which in the Councils' judgement is threatening the habitat in localized or widespread areas, the Councils may request the Secretary to take available measures designed to eliminate such threat of damage to the resource and fishery habitat. On the advice of its Scientific and Statistical Committee or other sources that one or more species of octocorals may be endangered from widespread or localized depletion from overharvest or threat of overharvest, the Councils may notify the Secretary of the threat and recommend that he take one or more of the following actions.

a. Restrict by regulation amendment or through promulgation of emergency regulations the harvest of one or more species of octocorals to a recommended level or amount.

b. Restrict by regulatory amendment or through promulgation of emergency regulations the area from which one or more species of octocorals may be taken.

c. Restrict by regulatory amendment or through promulgation of emergency regulations the method of harvest by which one or more species of octocorals may be harvested.

d. Utilize any procedures other than regulatory amendment or promulgation of emergency regulations which may be within the realm of authority of the Secretary and which will achieve the results of action proposed in options (a) through (c) above.

2. Permits

Establish a permit system for:

A. the use of toxic chemicals in taking fish or other marine organisms which inhabit coral reefs,

B. for taking prohibited corals for scientific and educational purposes.

3. Time and Area Restrictions

See Section 13.5 for special regulations applicable in habitat areas of particular concern.

4. Types of Vessel, Gear, and Enforcement Devices

Prohibit the use of toxic chemicals in taking fish and other marine organisms which inhabit coral reef areas except under permit as may be specified in this or any other fishery management plan.

5. Identify habitat areas for corals which may be threatened or subject to degradation and provide a management program for them. These habitat areas of particular concern (HAPCs) are recognized as providing habitat to valuable or special assemblages of corals or coral reefs. Some of these areas are presently under jurisdiction of management programs, some are under consideration for inclusion in such programs, and others are presently without management. Identified coral habitat areas of particular concern:

A. Measures proposed for the coral HAPCs:

(a) East and West Flower Garden Banks (nominated National Marine Sanctuary). Within the HAPC defined as being that portion within the 50 fathom contour, the taking of all corals is prohibited except as authorized by permit. The use of bottom longlines, traps and pots, and bottom trawls, and anchoring by vessels 100 feet or more in registered length are prohibited within the HAPC.

(b) Florida Middle Grounds - the northernmost hermatypic (shallow reef-type) coral community in the Gulf of Mexico. The taking of all corals is prohibited except as authorized by permit. Within the HAPC defined in Section 12.4, Measure 5b, the use of bottom longlines, traps and pots, and bottom trawls is prohibited.

(c) Oculina Bank - Within the four by 23 nm HAPC of Florida's central eastern coast as defined in Section 12.4, Measure 5c, the use of bottom trawls, bottom longlines, dredges, fish traps and pots is prohibited in order to protect the coral from damage.

B. Coral HAPCs presently under management programs:

(a) Dry Tortugas (Fort Jefferson National Monument). Management is provided by the National Park Service.

(b) Looe Key Reef National Marine Sanctuary. Designated in 1981, this sanctuary consists of five square nautical miles. Sanctuary regulations prohibit or regulate anchoring, coral collection and damage, wire trap fishing, lobster fishing, tropical specimen collecting, spearfishing, and discharge of certain substances.

(c) Biscayne National Park. Management is provided by the National Park Service (Department of Interior).

(d) Key Largo Coral Reef National Marine Sanctuary. Designated in 1975, this sanctuary consists of a one hundred square nautical mile section of the upper Florida reef tract. Regulations prohibit, among other activities, removal or destruction of hard and soft corals within the boundaries of the sanctuary.

(e) Gray's Reef National Marine Sanctuary. Designated in January, 1981, this diverse coralline hard bottom encompasses about 17 square miles off Sapelo Island, Georgia. Regulations prohibit alteration of seabed, discharge of certain substances, bottom trawling and dredging, wire fish trapping, and marine specimen collecting.

2.8 Special Recommendations

1. Recommended that the Secretary establish a communication program to inform the public of the reasons for coral management and regulations which protect corals and coral reefs.

2. Recommended that the Secretary establish a procedure to coordinate coral management activities in the FCZ and territorial sea within the Councils' geographical area of authority.

3. Recommended that the states and NMFS monitor at least at the present level of effort the condition of the octocorals and report damage or threat of damage to their habitat. The Councils believe under existing monitoring regime, these agencies can effectively carry out this request without a significant increase in current expenditure.

2.9 Data Needs for Management

The Councils identified the following needs for data and research:

1. Determine and monitor level of harvest of octocorals.
2. Survey of distribution and abundance of corals in the management area.
3. Study of growth, mortality, reproduction and other biological data on which to base MSY.
4. Effects of other fisheries and fishing gear on coral.
5. Effects of natural and human impact on coral.
6. Analysis of import and domestic price structure of harvested corals.
7. Comparison of value of coral in its nonconsumptive use vs. harvested coral.

3.0 CONTENTS

4.0 INTRODUCTION

While the scientific literature provides only limited data on coral growth, most researchers agree that growth of many species of coral is very slow. The natural beauty of coral specimens makes them vulnerable to unregulated harvest by commercial and amateur collectors.

Among the states only Florida provides some protection to living stony corals and two species of sea fans. It is of limited effect because the prohibition of possession is restricted to uncured specimens, and curing can be a simple, on-board process of dipping in bleach.

Harvest of corals in federal waters was regulated by the Bureau of Land Management (BLM) under the Outer Continental Shelf Lands Act until September, 1979, when in United States v. Alexander, the Court held that BLM's authority was restricted to activities connected to the administration of mineral leases. This action has recently left most coral and coral reefs in the FCZ without management or protection. This includes much of the Florida reef tract which lies just beyond the state's territorial sea. This lack of protection to this valuable resource is not yet generally known, but harvest and destruction of the coral reefs could legally occur at any time.

The Fishery Conservation and Management Act (FCMA) of 1976 (Public Law 94-265), signed into law April 13, 1976, provides for exclusive United States fishery management authority over fishery resources inhabiting the fishery conservation zone (FCZ) that area bounded by the seaward limit of state jurisdiction and an equidistant line 200 nm or 370 km from shore with exceptions for international treaties. The responsibility to prepare fishery management plans (FMPs) was vested in a network of eight Regional Fishery Management Councils. The FCMA also delegated research and enforcement duties to the National Marine Fisheries Service in the U.S. Department of Commerce and enforcement powers to both the U.S. Coast Guard and NMFS.

The Gulf of Mexico and South Atlantic Fishery Management Councils determined that a need does exist for immediate management of corals and that this may best be provided in the development of a joint fishery management plan, the thrust of which is:

1. To provide immediate protection to what is, for the most part, an unprotected and important nonrenewable resource.

2. To acquire additional information on the resource.

3. To prevent any sudden devastation of the resource that could be brought about by:

   (a) Sudden intensive harvesting.

   (b) Sudden intensive destruction of the resource by man, e.g., a quantum jump in the use of roller rig trawls or bottom longlines.

The fishery for coral as addressed in this plan is located in the waters of the U.S. Gulf of Mexico and Atlantic Ocean from the Texas-Mexican border through North Carolina. The management unit includes the coral and coral reefs of the FCZ (see definition in Table 5-1) under the jurisdiction of the Gulf of Mexico and South Atlantic Fishery Management Councils. Management measures in this plan will be recommended to adjacent states where appropriate.

The Councils' primary management objective is to optimize benefits generated from the coral resource while conserving the coral and coral reefs.

Very little published data exist on many aspects of corals and coral reefs in the management area. Most existing data and many on-going studies tend to concentrate on a limited number of species in a very few localities within the area. Hence, much of the study area and many specific subjects are unavoidably lightly addressed in this plan. Certain biological, socio-cultural, and economic data are especially limited. While many people recognize the existence of numerous valuable consumptive and nonconsumptive uses of the resources, that recognition is based largely upon intuitive observations rather than hard research data.

The existence of these data gaps is reflected and documented throughout the FMP. In attempting to utilize the best available data several sections of the plan rely heavily upon informal interviews with knowledgeable professionals, users, and user groups. While this approach has contributed to the preparation of the FMP, it has also emphasized the need to develop more and better data to fulfill the management objectives (Section 12.1) of the FCMA and the two Councils.

5.0 DESCRIPTION OF STOCKS COMPRISING THE MANAGEMENT SYSTEM

To clarify the presentation of Sections 5.1 and 5.2 of the FMP, corals have been divided into deep-water and shallow-water species, with the 200 m (660 ft) isobath or depth contour arbitrarily chosen as the dividing line since it approximates the edge of the continental shelf.

This fishery management plan manages the following species: the corals of the class Hydrozoa, (stinging and hydrocorals), and the class Anthozoa (sea fans, whips, precious corals, sea pen and stony corals). Figure 5-1 illustrates several of the more commonly observed and/or researched corals.

Table 5-1. Definitions of selected terminology used throughout this FMP.

Coral: Species belonging to the Orders Stolonifera, Telestacea, Alcyonacea (soft corals), Gorgonacea (horny corals, sea fans, sea whips), and Pennatulacea (sea pens) in the Subclass Octocorallia; Orders Scleractinia (stony corals) and Antipatharia (black corals) in the Subclass Zoantharia; and the Orders Milleporina (fire corals, stinging corals) and Stylasterina in the Class Hydrozoa.

Phylum Coelenterata
- Class Hydrozoa
  - Order Milleporina (fire, stinging corals)
  - Order Stylasterina (hydrocorals)
- Class Anthozoa
  - Subclass Octocorallia
    - Order Stolonifera
    - Order Telestacea
    - Order Alcyonacea (soft corals)
    - Order Gorgonacea (horny corals, sea fans, whips, precious red coral)
    - Order Pennatulacea (sea pens)
  - Subclass Zoantharia
    - Order Scleractinia (stony corals)
    - Order Antipatharia (black corals)

Stony Corals: For the purpose of this plan, includes species belonging to the Class Hydrozoa (fire corals and hydrocorals) and Class Anthozoa, Subclass Zoantharia (stony corals and black corals).

Octocorals: For the purpose of this plan, includes species belonging to the Class Anthozoa, Subclass Octocorallia (soft corals, horny corals, sea fans, sea whips, sea pens, and others).

Hermatypic (Corals): Corals that contain symbiotic, unicellular zooxanthellae in their endodermal tissue. Always found in shallow (0 to 100 m; 0 to 330 ft), warm (15 to 35°C; 60 to 95°F), sun-lit waters. Usually colonial but may be solitary. Often referred to collectively as reef corals, however some species are small and are never found on reefs. Within the discussion in Sections 5.1 through 5.2 on shallow-water corals, this definition has been qualified to exclude some corals with aberrant zooxanthellae relationships, e.g., facultatively symbiotic species (Boschma, 1925; McCloskey, 1970; Duclaux and Lafargue, 1973) and those which appear capable of "bank-building" without the benefit of symbionts (Avent, et al., 1977).

Ahermatypic (Corals): Corals that do not have zooxanthellae. Their distribution is not restricted by depth, temperature, or light penetration. Found from 0 to 5,880 m (0 to 19,000 ft), and 0 to 35°C (32 to 95°F). Both colonial and noncolonial (i.e., single polyp) species in about equal number. Although often referred to as "deep sea" or "solitary" (see next definition) corals, they often occur in shallow water and many are colonial. Their distribution overlaps that of the hermatypes and is exclusive in waters deeper than about 100 m (330 ft).

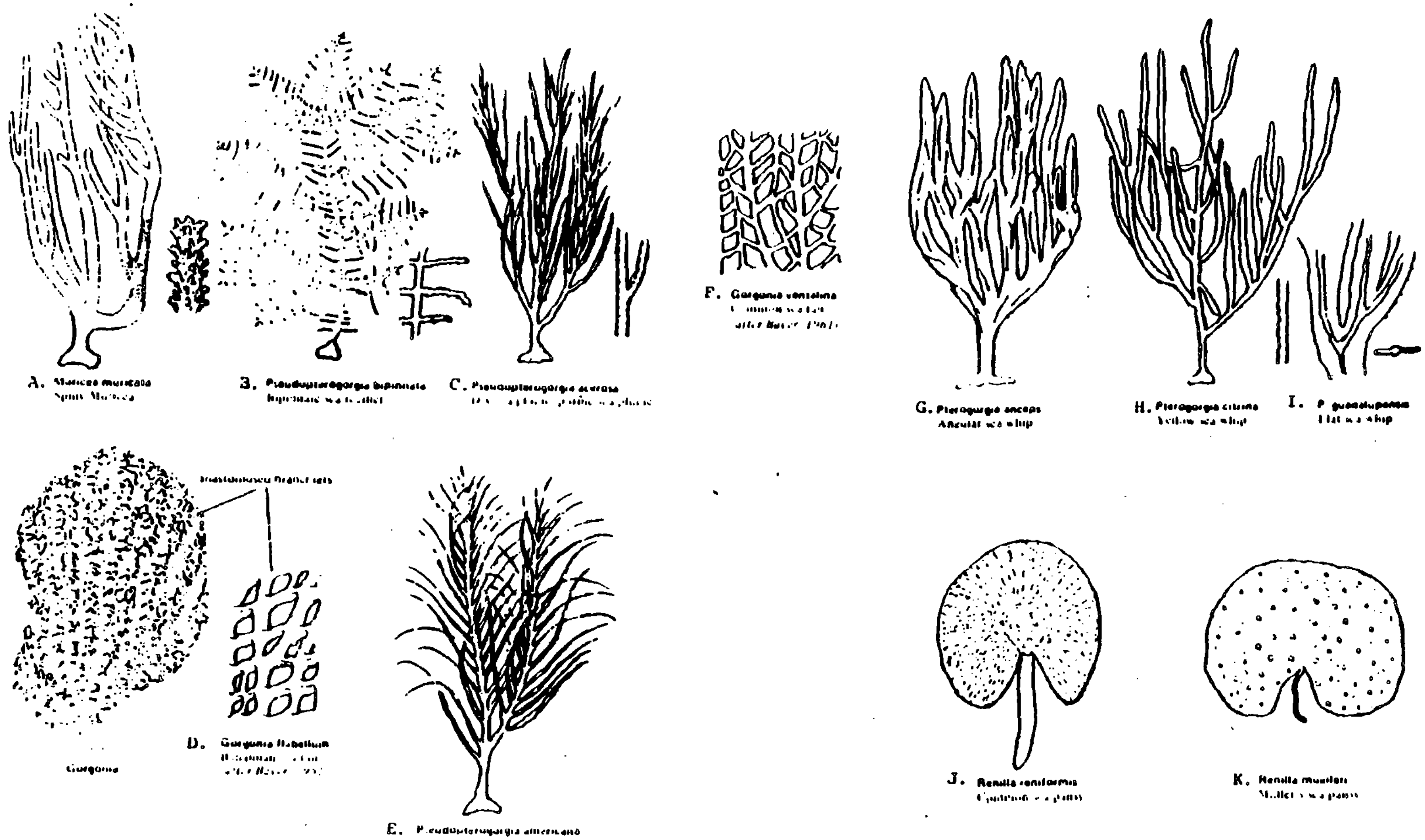


FIG. 5-1. Line drawings of selected corals from the management area. A. Muricea muricata; B. Pseudopterogorgia bipinnata; C. Pseudopterogorgia acerosa; D. Gorgonia flabellum; E. Pseudopterogorgia americana; F. Gorgonia ventalina; G. Pterogorgia anceps; H. Pterogorgia citrina; I. P. guadalupensis; K. Renilla muelleri. (A-K from Voss 1976.)

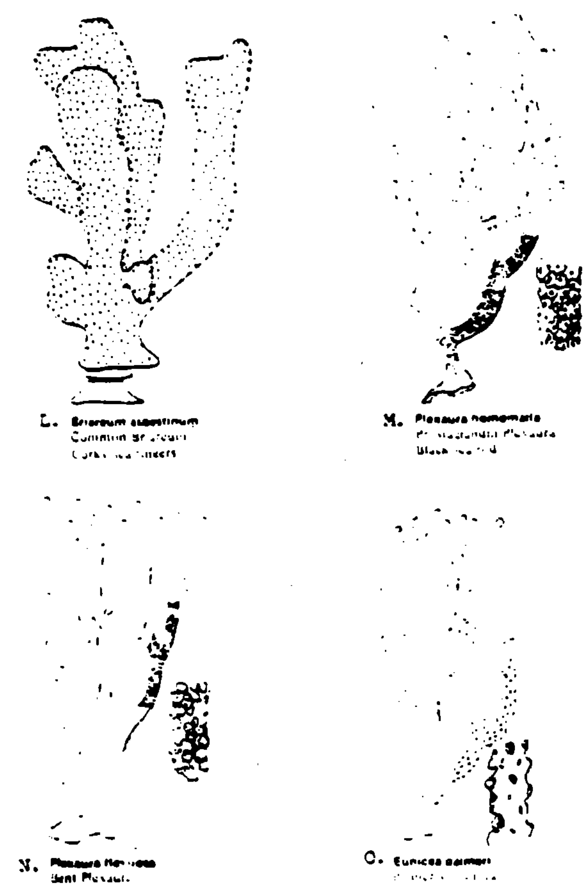


FIG. 5-1, cont. Line drawings of selected corals from the management area. L. Briareum asbestinum; M. Plexaura homomalla; N. Plexaura flexuosa; O. Eunicea palmeri. (L-O from Voss, 1976.)

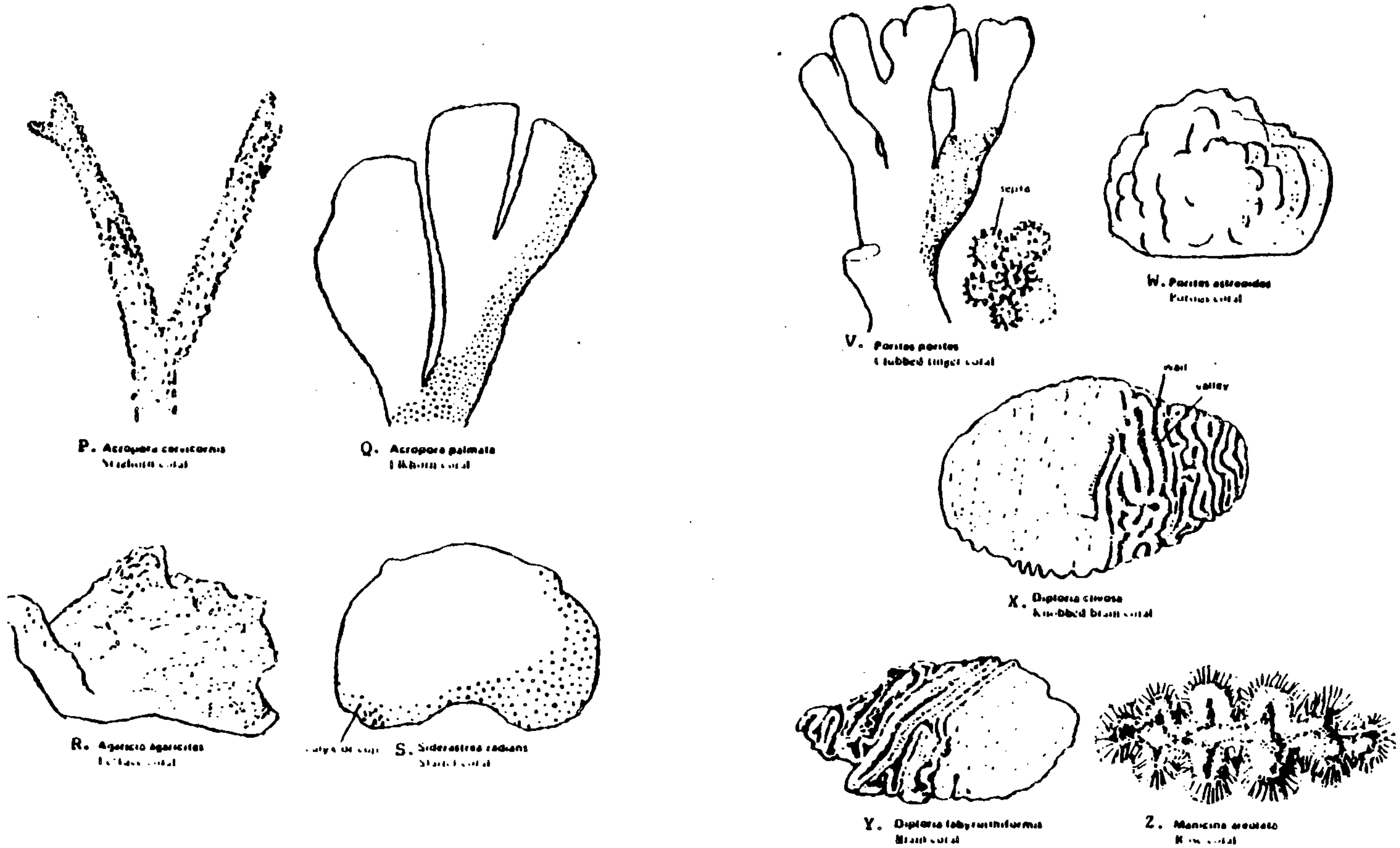
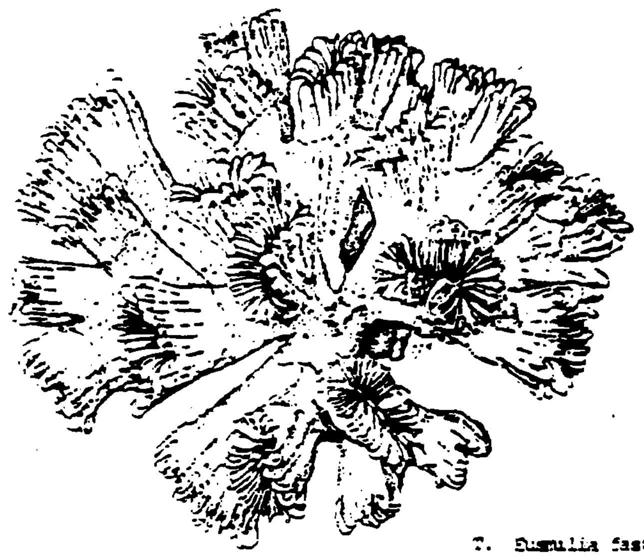
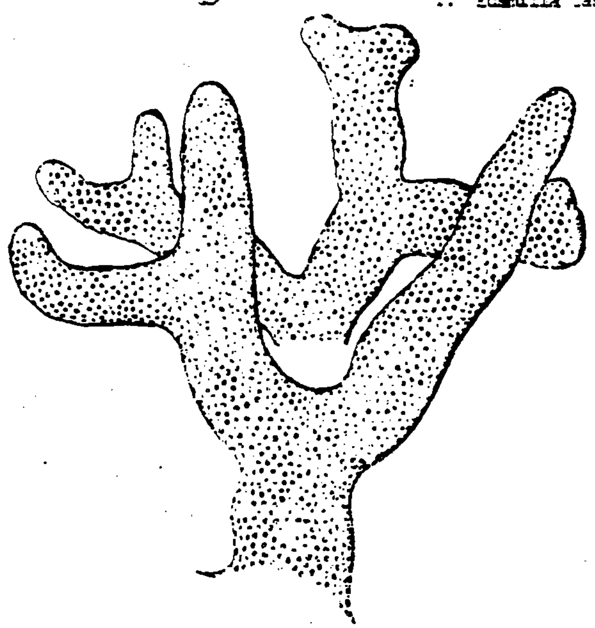


FIG. 5-1, cont. Line drawings of selected corals from the management area. P. *Acropora cervicornis*; Q. *Acropora palmata*; R. *Agaricia agaricites*; S. *Siderastrea radians*; V. *Porites porites*; W. *Porites astreoides*; X. *Diploria clivosa*; Y. *Diploria labyrinthiformis*; Z. *Manicina areolata*. (P-A from Voss, 1976).



T. Eusmilia fastigiata



U. Porites porites

FIG. 5-1, cont. Line drawings of selected corals from the management area. T. Eusmilia fastigiata; (from Messing in Taylor, 1977); U. Porites porites, formerly P. clavaria; (from Rathbun, 1887).

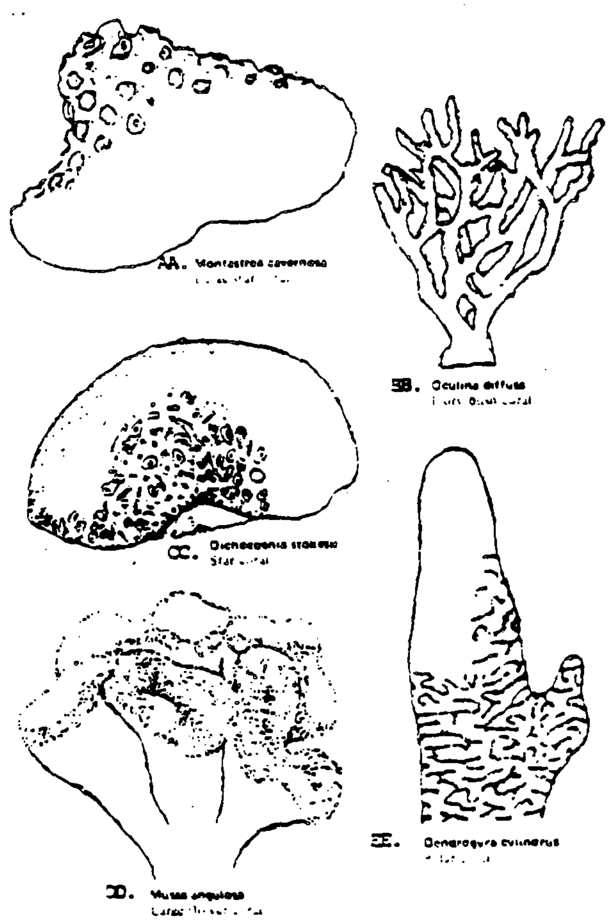


FIG. 5-1, cont. Line drawings of selected corals from the management area. AA. Montastraea cavernosa; BB. Oculina diffusa; CC. Dichocoenia stokesii; DD. Mussa; EE. Dendrogyra cylindrus. (AA-EE from Voss, 1976).

Solitary corals: A coral organism composed of a single polyp.

Colonial corals: A coral organism with more than one polyp and which may be part of a coral reef or some other another coral assemblage. This may also be referred to as a colony, unit, or individual coral.

Coral Reefs: For purposes of this FMP, coral reefs are defined as the hard bottoms, deepwater banks, patch reefs and outer bank reefs as described below:

1) Patch reef: Irregularly distributed clusters of corals and associated biota located in the management area only along the seaward (southeast) coast of the Florida Keys. Occur as dome-type patches on the leeward side of outer bank coral reefs (see definition below) or as linear-type patches that parallel bank reefs in acuate patterns. The latter support flora and fauna, including elkhorn coral (*Acropora palmata*), which more nearly resembles the bank reefs. Patch reefs include hermatypic reef-building corals plus ahermatypic species. Most patch reefs occur 3 to 7 km (1.6 to 3.8 nm) offshore between Miami and the Dry Tortugas on the inner shelf (less than about 15 m or 49 ft depth). Vertical relief ranges from less than 1 m to over 10 m (3 to over 33 ft).

2) Outer bank reefs: Includes ahermatypic and hermatypic species in a complex assemblage often with greater vertical relief than patch reefs. Located in the Florida reef tract primarily shoreward of the 18 m (60 ft) isobath and on two hard banks (East and West Flower Gardens) on the Texas-Louisiana shelf in much deeper water. Biota always exhibits zonation, with the number and type of zones dependent upon the height of the coral substrate, the location of the reef, and the stresses present. Also referred to as the "outer reef arc" (Davis, 1928) and a "fringing barrier" (Milliman, 1973).

3) Hard bottoms: Coral communities lacking the density, reef development, and coral diversity of patch and outer bank reefs. Some hard bottoms are more appropriately termed hard banks, organic banks or simply banks since they may occur atop "topographic highs" in the Gulf of Mexico. Hard bottoms may include some hermatypic corals. Widely distributed in the management area. Biota usually include a thin veneer of live corals, often covering a rock outcrop or a relic reef, and associated benthos (e.g., sponges, tunicates, holothurians) in an assemblage with low relief. Also called live bottoms (Struhsaker, 1969), hardgrounds, or pinnacles (when found in a nonbank setting). Hard grounds is not used herein since the term connotes a particular geological sediment structure rather than a biotic community.

4) Deepwater banks: A structure composed primarily of surface-hardened crusts of submarine muddy to sandy carbonate sediments supporting a comparatively diverse assemblage of benthic animals. The ahermatypic corals (*Enallopsammia profunda* and *Lophelia prolifera*) may provide framework and promote entrapment and accumulation of sediments and skeletal debris. Similar structures may be called haystacks, deep sea mounds, or lithoherms.

5.1 Species or Groups of Species and Their Distributions

5.1.1 Shallow-water Species

5.1.1.1 Octocorallia (sea fans, sea whips, etc.)

The shelf waters of the southern and southeastern United States contain a considerable diversity of octocorals (see Appendix A). Among those listed for the shelf regions of the western Atlantic by Bayer (1961), only 19 have not been reported from the management area (four species are reported which require confirmation). However, 36 species of primarily deeper-dwelling species have been added to

Bayer's list since 1961, bringing the total shelf octocoral fauna of the present study area to 113 species. Of that total, 18 species appear to be endemic, and an additional three species find their principal distribution here (Table 5-2).

Octocorals in the Gulf of Mexico can be divided into three groups: 1) a deepwater element, most notably from the Paramuriceidae; 2) a disjunct Carolinian element, represented by the genera Leptogorgia and Muricea; and 3) tropical Atlantic and Caribbean species or forms (see Appendix A). The north and northwestern Gulf of Mexico (Texas to Florida) lacks the latter, but has a well-developed deepwater fauna which becomes locally prominent on the continental shelf. The paramuriceids and the ellisellids are more common there than elsewhere.

The region from North Carolina to south Florida contains no distinctive octocoral elements. Typical there are Leptogorgia virgulata, L. setacea, Lophogorgia hebes, Muricea pendula, and Titanideum frauenfeldii, all of which are represented in the Gulf of Mexico as Carolinian fauna.

The area from Palm Beach south to the Dry Tortugas contains a tropical Atlantic fauna, which appears to be fairly homogeneous. Some faunal differences occur along the Florida reef tract in response to water temperature ranges, substrate availability, and other variables.

The distribution of octocorals in the Gulf of Mexico has been thoroughly investigated by Giammona (1978) and summarized in Appendix B. Cairns (1977a) published a field guide to the more common gorgonians of the Gulf of Mexico, Caribbean, and Florida.

5.1.1.2 Milleporina and Scleractinia (the fire corals, stinging corals, and stony corals)

Sixty-eight species of stony corals are known from the continental shelves of the study area (Appendix C), 62 of which have been noted from the Florida Keys and the Dry Tortugas alone. This is a remarkably high number, considering that the most diverse locale in the Caribbean (Jamaica) lists only 66 species (Goreau and Wells, 1967; Wells and Lang, 1973). Twelve Jamaican species are absent from Florida waters and an additional seven species are known from the Florida reef tract but not Jamaica: Madracis asperula, Oculina tenella, O. robusta, Cladocora debilis, Caryophyllia horologium, Flabellum fragile, and Favia gravida. The latter species had been considered as endemic to Brazil until their identification from Florida by Jaap (1979, personal communication) and Avent, et al. (1977), respectively. Three colonial scleractinians are endemic to the study area, and two more have their main distribution here. Most of these are members of the Oculinidae and include those listed in Table 5-3.

Unlike octocoral distribution, stony corals show little separation by subregion (Appendix C). The only notable stony coral group other than the oculinids are the occasional specimens of Madracis myriaster, M. asperula, and M. bruegemanni found in the Gulf of Mexico. Madracis mirabilis is also apparently quite common in the Gulf and south Atlantic regions. There are several other species of stony corals found in the Florida Keys or on the west coast of Florida and the Tortugas which are typical Caribbean forms. The data show that for the most part, the outlying areas of the Gulf of Mexico and the southeastern coast of the U.S. are accurately described as sparsely developed extensions of the scleractinian fauna found in the Florida Keys and the Dry Tortugas.

5.1.1.3 Antipatharia (black corals)

Black corals are not well represented in the management area with the exception of Cirripathes sp. (probably C. lutkeni) which occurs on shelf-edge hardbanks (usually below 60 to 80 m) throughout the Gulf of Mexico (Bright and Rezak, 1976), and rarely in the Florida Keys (Goldberg, 1979, personal communication). The species appears to be quite common below 20 m (66 ft) on the southeast Florida coast (Goldberg, 1973a). An unidentified species of Antipathes has been recorded from the northern Gulf (Bright, 1978). Additional records are listed in Table 5-4.

Table 5-2. Endemic elements of the octocoral fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southern United States.

Telestacea	Alcyonacea	Gorgonacea (Scleraxonia)	Pennatulacea
Telesto flavula	Pseudodrifa nigra	Anthopodium rubens	Virgularia presbytes
T. sanguinea		Anthothela tropicalis	Stylatula antillarum
T. fruticulosa		*Titanideum frauenfeldii	Acanthoptilum agassizii
*T. nelleae		(Holaxonia)	A. oligacis
		Thesea citrina	
		T. plana	
		Swiftia casta	
		Trichogorgia viola	
		Eunicea palmeri	
		Eunicea knighti	
		Muricea pendula	
		Leptogorgia medusa	
		*Lophogorgia cardinalis	

* indicates species with principal distribution within study area but also reported from Cuba.

Table 5-3. Endemic elements of the scleractinian fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southern and southeastern United States. (References as listed)

Oculina robusta Pourtalès.	West coast of Florida. Recorded from the Dry Tortugas (Pourtales, 1871). Hourglass and the Florida Middle Grounds 8 to 55 m (26 to 180 ft) (Jaap, 1979, personal communication).
Oculina tenella Pourtalès.	Same geographical distribution as above, 36 to 73 m (117 to 240 ft).
Oculina varicosa Lesueur.	Rare off Florida Keys at 72 to 90 m (236 to 295 ft) (Pourtales, 1871; Verrill, 1901). Found at Looe Key from 5 to 30 m (16 to 100 ft) (Antonius, et al., 1978). Common on the continental shelf and shelf edge north of Palm Beach (Avent, et al., 1977; Reed, 1978, personal communication). Known as far north as Cape Hatteras, North Carolina from subtidal to 152 m in depth (Reed, 1980b). Also known from Bermuda in 5 to 22 m (16 to 72 ft) (Verrill, 1901). Ludwick and Walton (1957) include a questionable report of this species from the northern Gulf of Mexico.
Oculina arbuscula Verrill.	Cape Hatteras, North Carolina, to Charleston, South Carolina (McCloskey, 1970). Reportedly common off Savannah, Georgia, 3 to 25 m (10 to 82 ft). Porter (1978, personal communication) reports this species from Bermuda.
Flabellum fragile Cairns.	Eastern Gulf of Mexico and the Florida Keys (Cairns, 1977b).
Caryophyllia horologium Cairns.	West Florida coast (Cairns, 1977b) and Florida Keys (Cairns, 1979, personal communication), 55 to 91 m (180 to 300 ft).

Table 5-4. Shallow-water Antipatharia from the continental shelves of the southern United States.

SPECIES	LOCATION/DEPTH	REFERENCE
Cirripathes desbonni (D. & M.)	Sand Key, 81 m (267 ft) Jeff's Reef (Vero Beach, Florida), 80 to 90 m (265 to 300 ft).	Pourtales, 1878; Reed, 1979, personal communication; Goldberg, 1979, personal communication.
Antipathes pennacea (Pallas)	Crocker Reef, Florida, 28 m (93 ft).	Goldberg, 1979, personal communication.
	Alligator Light, Florida, 29 to 38 m (96 to 125 ft).	Opresko, 1974.
Antipathes lenta Pourtales	Carysfort Reef - Dry Tortugas, Florida, 45 to 67 m (149 to 221 ft).	Opresko, 1972.
Parantipathes columnaris (Duch.)	Dry Tortugas, Florida, 183 m (604 ft); East Flower Garden Bank, 91 m (300 ft).	Cairns (1979, personal communication; Smithsonian Institution records).

5.1.1.4 Stylasterina

Some Stylasterina have been reported in waters less than 200 m (660 ft) deep (Boschma, 1957): Stylaster duchassaingi P. from Dry Tortugas at 78 m (257 ft); S. punctata P. northwest of Dry Tortugas at 185 m (600 ft); Distichopora foliacea P. from Key West at 183 m (595 ft) and off Vaca Key (Marathon) at 152 to 244 m (500 to 720 ft); and Pliobothrus symmetricus P. from American Shoal at 179 m (585 ft). Each of these records probably represents unusually shallow occurrences of deeper water species.

5.1.1.5 Potential Commercially Important Shallow-water Species

Within waters shallower than 200 m (660 ft), corals have been identified as having potential commercial value, defined herein as a monetary value for use in research, industry (e.g., jewelry), or unusual art value. Although nearly all corals could conceivably be, and have in the past, been marketed as curios, only species with major potential for exploitation are acknowledged as commercially important.

At least nine species of soft corals are currently being harvested for use in marine aquaria. These are Leptogorgia virgulata, Briareum asbestinum, Telesto riisei, Renilla mulleri, Diodogorgia nodulifera, Nicella schmitti, Swiftia exserta, Lophogorgia cardinalis, and Lophogorgia hebes. Approximately 25 percent of this current harvest comes from the FCZ while 75 percent is taken from state waters according to members of the Councils' advisory panels.

Species which have had commercial value in the past are Plexaura homomalla (black sea rod), Cirripathes lutkeni (black coral), and Manicina areolata (rose coral). As detailed in Appendix D, these species could continue to have value in pharmacology research, jewelry, and tropical fish businesses, respectively. Dendrogyra cylindrus (pillar coral) is used in Haiti in the jewelry and furniture businesses but is uncommon in U.S. waters (see Gelster, 1972, for ecology).

5.1.1.6 Protected Shallow-water Species

Aside from state and federal laws and regulations protecting corals in general, 14 species have been identified as worthy of special protection (Table 5-5). Antonius, et al. (1978) noted that pillar coral (*Dendrogyra cylindrus*) has been recommended for listing as an endangered species under the U.S. Endangered Species Act; no formal action has yet been taken on that motion (Roe, 1979, personal communication). A conference sponsored by the Atlantic Reef Committee on June 15, 1979, determined the species to be threatened in the management area but not endangered throughout its range (defined by the Endangered Species Act as worldwide for invertebrates). Jaap (unpublished) produced a summary document on systematics, distribution, stratigraphy, and ecology of the pillar coral for the meeting. The Florida Committee on Rare and Endangered Plants and Animals (a private group that supplies information to state agencies) has listed as endangered throughout the Florida reef tract (in all unprotected areas, i.e., outside Biscayne National Park and other areas) an additional 13 species.

All of the corals listed as continental shelf fishery resources in the Fishery Conservation and Management Act of 1976 that may occur in the management area are found deeper than the 200 m (660 ft) contour.

Table 5-5. Corals categorized as endangered by the Florida Committee on Rare and Endangered Plants and Animals.*

Common Name	Scientific Name
Elkhorn coral	*Acropora palmata* (Lamarck)
Staghorn coral	*Acropora cervicornis* (Lamarck)
Fused staghorn coral	*Acropora prolifera* (Lamarck)
Pillar coral	*Dendrogyra cylindrus* Ehrenberg
Large flower coral	*Mussa angulosa* (Pallas)
Flower coral	*Eusmilia fastigiata* (Pallas)
Lettuce coral	*Agaricia agaricites* (Linnaeus)
Starlet coral	*Siderastrea siderea* (Ellis and Solander)
Brain coral	*Diploria clivosa* (Ellis and Solander)
Brain coral	*Diploria labyrinthiformis* (Linnaeus)
Brain coral	*Diploria strigosa* (Dana)
Small star coral	*Montastraea annularis* (Ellis and Solander)
Large star coral	*Montastraea cavernosa* (Linnaeus)
Brain coral	*Meandrina meandrites* (Linnaeus)

* Although this Committee (FCREPA) is a private group of scientists and conservationists, the lists they prepare do contribute to efforts by the Florida Game and Fresh Water Fish Commission (GFWFC) in their own Endangered Species Program. However, since the GFWFC addresses only vertebrate animals, the FCREPA list constitutes the only state listing of marine invertebrates, including corals. These species are not necessarily rare or endangered at this time.

Source: Layne, 1979, personal communication; Simon, 1979, personal communication).

5.1.2 Deepwater Corals

As a group, deepwater corals (found deeper than 200 m or 660 ft) are among the most poorly understood corals considered in this plan. Field and laboratory observations of deepwater species are lacking. Collecting expeditions have been fair to adequate; the best available sources of data are the coral specimens scattered at research institutions such as the Florida Department of Natural Resources Marine Lab, the Smithsonian Institution, the Museum of Comparative Zoology at Harvard, the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences, and Texas A&M University. Cairns (1979) has comprehensively reviewed the deepwater Scleractinia but the deepwater Gorgonia remain relatively unstudied, especially outside the Gulf of Mexico; Giammona (1978) has surveyed octocorals in the western Gulf.

The work of Cairns (1979) on deepwater scleractinian coral zoogeography revealed seven species to be endemic (i.e., limited) to the temperate region off the eastern United States. Five of those species have a primarily warm temperate distribution (Concentrotheca laevigata, Cyathoceras squiresi, Thecopsammia socialis, Bathypsammia tintinnabulum, and B. fallosocialis), two are found in cold temperate waters (Enallopsammia profunda and Dasmosmilia lymani).

Generally, Caribbean waters have more deepwater species than adjacent waters. Forty-two species of scleratinians are known in the Gulf of Mexico. In the warm temperate western Atlantic, 28 species occur. Of those species, 14 are tropical and do not occur north of Cape Hatteras, seven are endemic to the temperate region north of Florida and Cuba, and seven species are more cosmopolitan. North of Cape Hatteras, 12 species have been reported, six of which also occur in warm temperate waters. Distribution maps and tables of these corals are included in Cairns (1979).

Giammona (1978) studied the taxonomy and distribution of octocorals in the Gulf of Mexico, emphasizing the Texas continental shelf region but also covering waters deeper than 220 m (660 ft). Brief taxonomic descriptions are written for 58 species and distributional maps are presented for 152 species. Gorgonian palaeontology was also discussed.

In light of the inadequate data base, separate sections discussing the other major taxonomic groupings of deepwater corals are not attempted. Appendix E, however, provides a species list including orders and families of the deepwater corals from the management area.

5.1.2.1 Distributions

Within the management area there are at least 183 species of corals collected from deeper than 200 m (660 ft) (Appendix E). Although information from deepwater collections is far from complete, the areas of highest coral concentration along the Atlantic coast appear to be between the 600 and 800 m (1,960 to 2,600 ft) contours of the continental slope where deepwater banks are found (see Table 5-1 and Section 6.2.1.3). Although a complete listing of coral species associated with such structures is impossible at present, at least 23 species of coral have been collected from them (see Appendix F), including some species of potential commercial value (see Appendix D).

5.1.2.2 Potential Commercially Important Deepwater Species

Due to the distance from shore and the inconvenience of collecting corals in waters deeper than 200 m (660 ft), projections of commercial value must be based on use of similar species elsewhere, especially Hawaii.

Eight deepwater corals found off the Gulf of Mexico and south Atlantic U.S. coasts have been identified as having potential commercial value. The skeletons of each species are very hard and amenable to cutting and polishing for jewelry. As described in Appendix D, these corals are: the precious red corals Corallium medea and C. niobe; the bamboo corals Acanella eburnea, Keratoisis flexibilis, K. ornata, and Lepidisis caryophyllia; the black coral Leiopathes glaberrima; and the hydrocoral Distichopora foliacea.

In addition to these eight species, an additional seven have been noted in Appendix E as having some possible commercial market. Those seven species include six gold corals (gorgonians) and one hydrocoral, all with potential value in jewelry manufacture. None of these species are presently exploited due to the risky and expensive nature of deepwater harvesting. Collections by submersible, as employed in the Hawaiian precious coral industry, have not been applied to the western Atlantic or Gulf of Mexico stocks.

5.1.2.3 Protected Deepwater Corals

No deepwater species have been listed as endangered or threatened by the Endangered Species Act nor are any under consideration for listing (Roe, 1979, personal communication).

Of the seven deepwater species recognized in Appendix D as having commercial potential, Corallium (precious red coral) and Keratoisis (bamboo coral) are listed as fishery resources in the Fishery Conservation and Management Act of 1976.

5.2 Abundance and Present Condition

5.2.1 Shallow-water Species

Information concerning relative abundance of shallow-water corals must be gleaned from a large number of papers, reports, and personal unpublished observations of specific coral habitats and communities. Since these studies/observations were almost always conducted at different times by different investigators using different methods, the composite data base incomplete and inconsistent and does not provide a thorough assessment of the present condition of the coral stock.

However, available data do allow an overview of the resourse. For purposes of discussing relative abundance of shallow-water corals, the management unit may be subdivided into seven regions based on general species compositions (see Figures 5-2 and 5-3). Each of these regions is discussed individually below. As an overview of major shallow-water coral communities surveyed in the following, Figure 5-4 locates the major hard bottom and coral reef areas of the Gulf of Mexico and south Atlantic.

5.2.1.1 North Carolina to Cape Canaveral

The coral fauna along the edge of the continental shelf from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, remains imperfectly known. Studies by Menzies, et al. (1966) and Macintyre and Milliman (1970) indicate that Pleistocene algal accumulations account for the ledges, small terraces, and slight rises of the continental margin off North and South Carolina, while oolitic deposits predominate in the more southerly sector. O. varicosa is present on the inner and mid-shelf (3 to 40 m) as small discrete colonies (<30 cm diameter, usually <15 cm), and on the outer shelf and upper slope to depths of 152 m either as individual colonies (1 to 2 m diameter), thickets, or banks. Distribution is unknown from Cape Canaveral through north Florida except mention by Macintyre and Milliman (1970) of large clusters off north Florida. It seems possible that further study will reveal a patchy distribution of Oculina communities elsewhere in this region.

Corals on the outer continental shelf proper are characterized by patches of low relief hard bottoms also referred to as "live bottoms" (Struhsaker, 1969). Hard-bottom communities throughout this shelf area have been reviewed by Continental Shelf Associates (1979). NOAA's Office of Coastal Zone

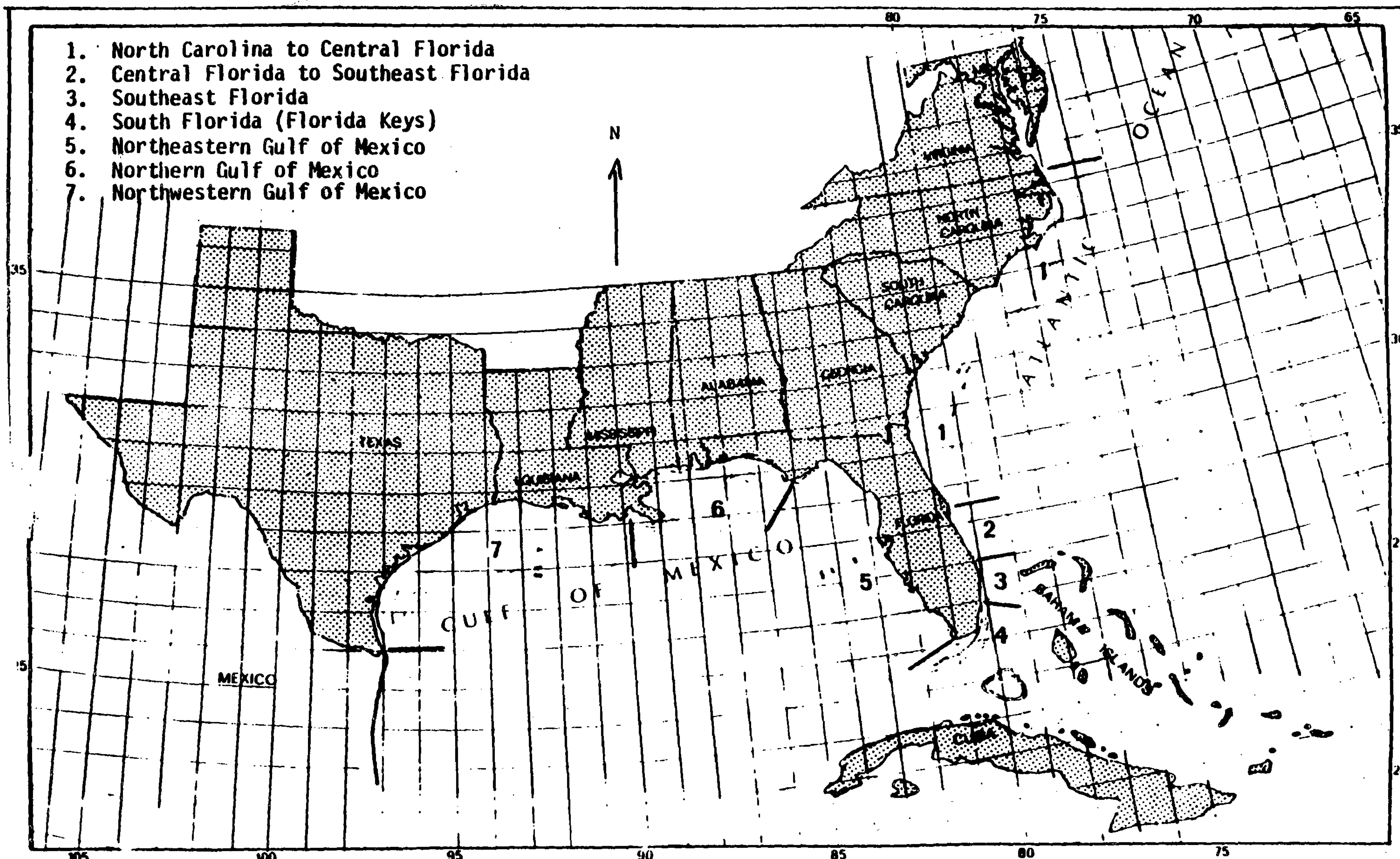


FIGURE 5-2. Shallow-water (less than 200 m or 660 ft.) coral regions discussed in Section 5.ii.

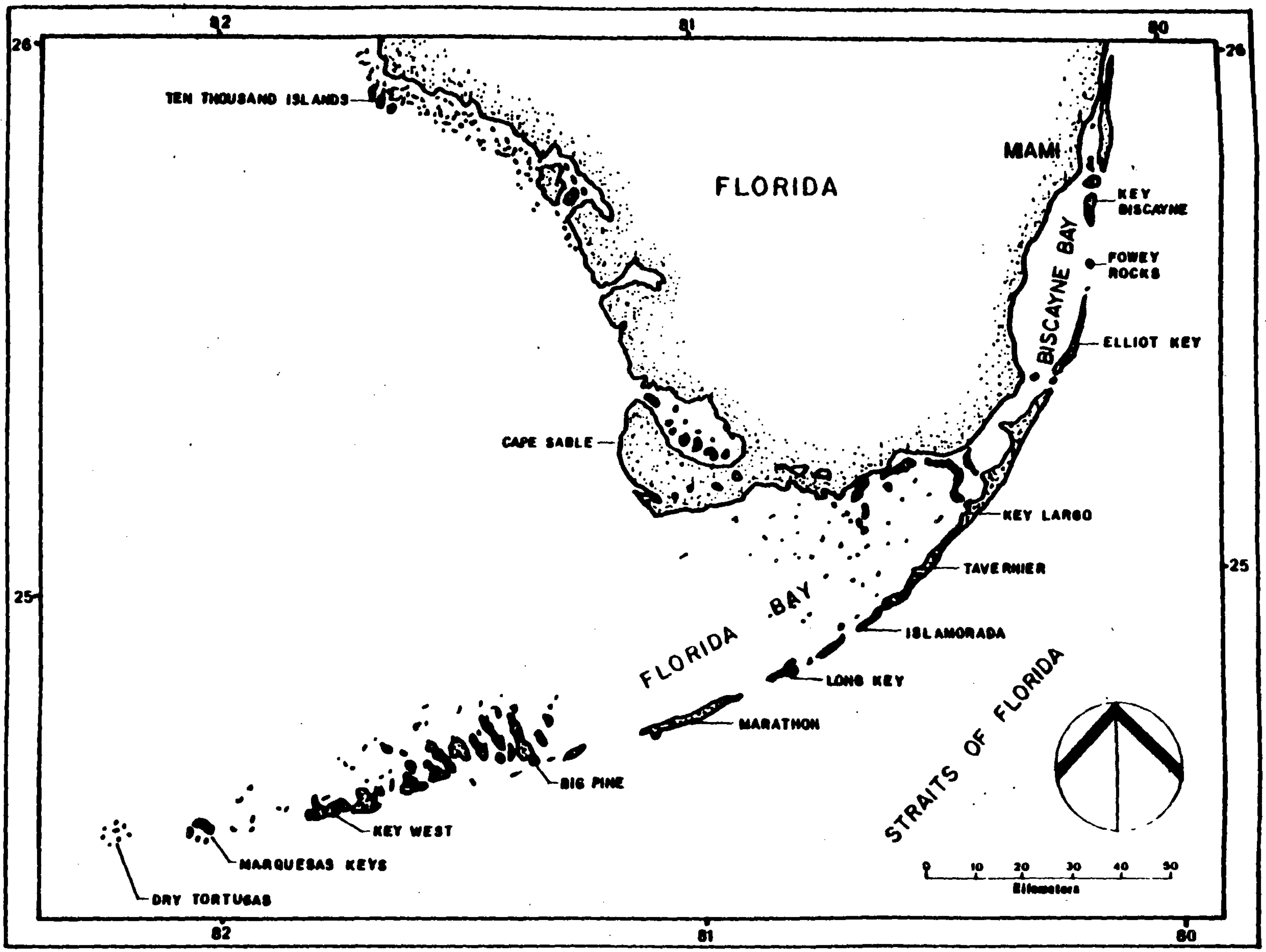


FIGURE 5-3. South Florida and the Florida Keys orientation map.

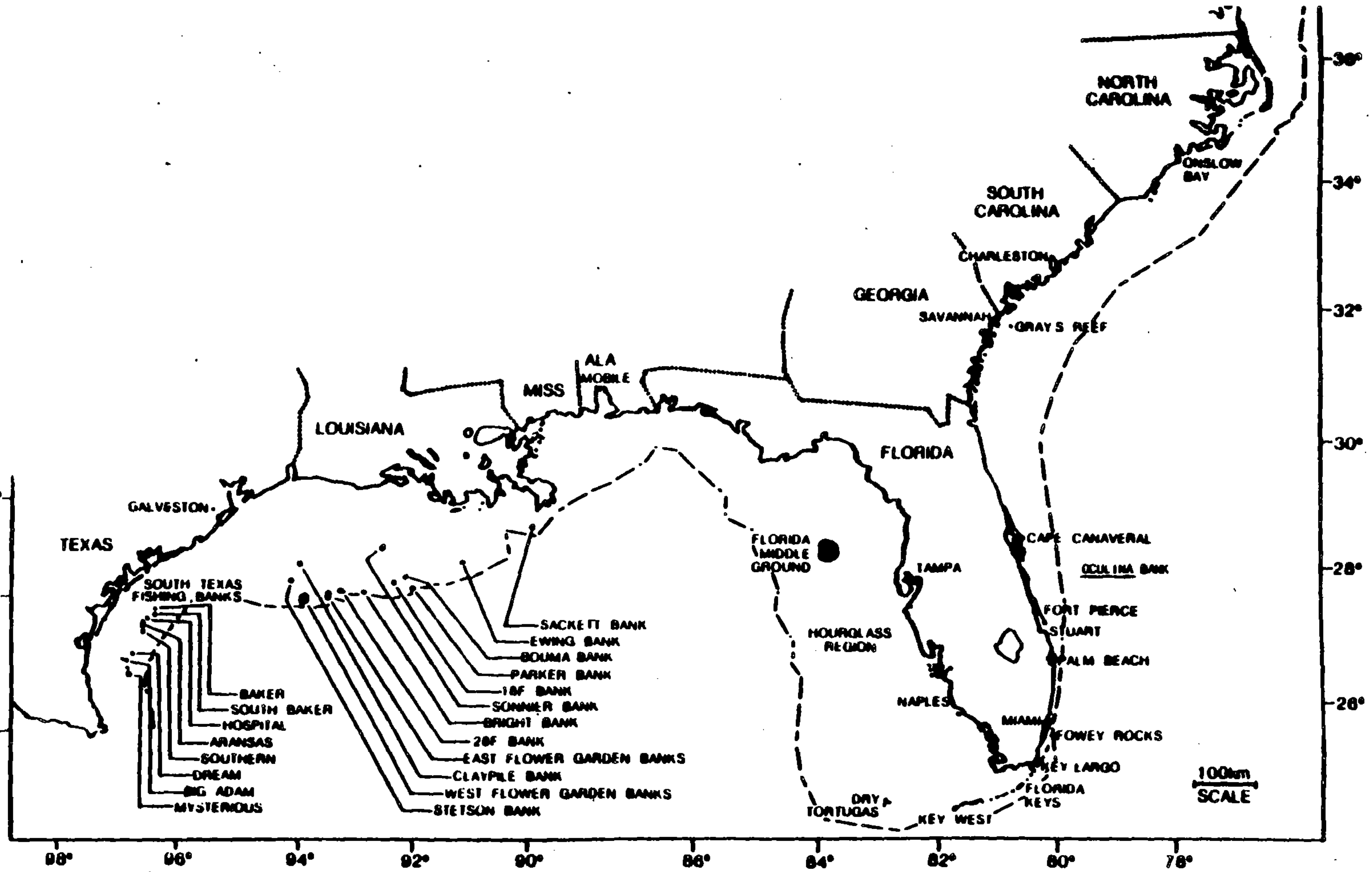


FIGURE 5-4. Distribution of hard banks and prominent hard bottoms in the Gulf of Mexico and south Atlantic regions. Hatched line denotes edge of the continental shelf at 200m (660 ft.).

Management (1979d) cited reports that three to 30 percent of the shelf region is covered by "live bottom" habitats. These areas are inhabited by tropical and subtropical fishes, coralline algae, sponges, hydroids, and various species of other invertebrates and coral. They have been described at depths of 20 to 40 m (66 to 132 ft) from Onslow Bay, North Carolina, by MacIntyre and Pilkey (1969) and Huntsman and MacIntyre (1971). Figure 5-5 depicts the distribution of the stump coral, Solenastrea hyades (Dana), and the starlet coral, Siderastrea siderea (Ellis and Solander), in the bay. Four other species of scleractinians were noted: Balanophyllia floridana Pourtales; Phyllangia americana Milne-Edwards & Haime; Astrangia danae Agassiz (= A. astreiformis M.-E. & H.); and the eye coral, Oculina arbuscula Verrill. Additional scleractinian records for the North Carolina continental shelf include a number of small, mostly solitary species: Rhizosmilia maculata (reported as Bathycyathus maculatus), Dasmosmilia lymani; Rhizotrochus fragilis (reported as Monomyces fragilis); Paracyathus defilipii; and Cladocora sp. (Cerame-Vives and Gray, 1966).

Reports from South Carolina and Georgia waters (Powles and Barans, 1979; Reed, 1978, personal communication, respectively) indicate that the coral fauna is largely the same as off North Carolina, except that coral patches are even more sparsely distributed (Barans, 1978, personal communication). One particularly interesting hard bottom community known as Gray's Reef occurs approximately 33 km (18 nm) east of Sapelo Island, Georgia (Figure 5-4; Section 6.3). This complex rises from a depth of 22 m (72 ft) to a crest at 18 m (59 ft). It is approximately 6 km (3.2 nm) long and 2 km (1 nm) wide. The geology of Gray's Reef has been studied by Hunt (1974), but nothing has been published regarding its coral fauna. Although the area is not a true coral reef (see Table 5-1), a number of corals and their associates are found there. Porter (1978, personal communication) noted that the biomass is dominated primarily by a large pink ascidian (probably Eudistoma sp.), secondly by the gorgonian Leptogorgia sp. (probably L. virgulata), and thirdly by scleractinians, Oculina varicosa identified by J. K. Reed and eye coral, Oculina arbuscula. If confirmed, this identification extends the range of O. arbuscula from Charleston to Savannah (McCloskey, 1970). Other species noted by Porter include stump coral (Solenastrea hyades), star coral (Montastraea annularis, uncommon), Cladocora arbuscula, Astrangia (astreiformis = danae), and Phyllangia americana.

Bayer (1961) stated that the shelf octocoral fauna from the east coast of Florida north of Cape Canaveral is indistinguishable from the fauna from Georgia and the Carolinas. Reports from North Carolina (Menzies, et al., 1966; Cerame-Vives and Gray, 1966), South Carolina (Powles and Barans, 1979), and Georgia (Reed, 1978, personal communication) appear to confirm this conclusion for both octocorals and scleractinians (Appendices A and C).

5.2.1.2 Central Florida to South Florida (Cape Canaveral to Palm Beach)

This shelf region (Figure 5-2) represents a transitional zone for coral fauna and deserves special consideration. The shelf edge contains a conspicuous band of pinnacles, benches, mounds, and troughs (here collectively referred to as hard bottoms) which are often capped by the ivory tree coral, Oculina varicosa Lesueur. Although the species occurs at least as far north as Cape Hatteras, North Carolina (Reed, 1980b), its structural development is greatest in this region; thickets 1-2 m (3-6 ft) high are found on pinnacles with up to 25 m relief (Avent, et al., 1977; Reed, et al., in press). A major portion of the shelf edge is littered with Oculina debris (Macintyre and Milliman, 1970).

The Oculina community harbors a rich vertebrate and invertebrate fauna which includes other scleractinians (Astrangia astreiformis, Balanophyllia floridana, Cladocora debilis, Paracyanthus pulchellus, and Coenocyathus species) and octocorals (Telesto nelleae, and Titanideum frauenfeldii) (Avent, et al., 1977). Two hundred species of molluscs, 47 species of amphipod crustaceans, 21 species of echinoderms, and 50 species of decapod crustaceans have been found directly associated with Oculina varicosa (Reed, et al., in press).

Although shelf-edge Oculina communities seem not to persist south of Jupiter, Florida, the species is found on coquinoid rock ledges scattered over the shallow shelf south to St. Lucie Inlet and Stuart, Florida (27° 10'N) where Oculina is associated with decidedly Carolinian octocorals such as Lophogorgia and Leptogorgia spp. In spite of the Antillean ecological character of other groups which persist north to Cape Canaveral (Avent, et al., 1977; Briggs, 1974), the scleractinian and octocorallian fauna become Antillean only south of St. Lucie Inlet (in a similar fashion to the Mollusca studied by Work, 1969). The coquinoid ledges here possess the same species noted above, but mixed with tropical genera such as the Diploria (brain coral), Isophyllia (cactus coral), Montastraea (star coral), and the octocorals Eunicea, Pseudopterogorgia, and Gorgonia (Reed, 1979, personal communication).

5.2.1.3 Southeast Florida Coast (Palm Beach to Fowey Rocks)

South of 27° north latitude to near Miami, the continental shelf narrows to 3 to 5 km (1.6 to 2.7 nm) and the warm waters of the Florida current become the most dominant hydrographic feature (Lee and McGuire, 1972). Thus, in the vicinity of Palm Beach, Florida, Carolinian corals are replaced by a diverse hard-bottom community, tropical in character, zoogeographically similar to that of the Florida Keys, but less well developed than the majority of the Florida reef tract.

The hard-bottom community found in this region is dominated by gorgonian corals. The antipatharian black coral Cirripathes lutkeni is prominent below a depth of 22 m (72 ft) but the scleractinians are less abundant at the northern end (Wheaton-Smith and Jaap, 1976) and in the vicinity of Miami (Courtenay, et al., 1975) than in the central Florida coastal region (Goldberg, 1973a,b). The underlying substrate is a Holocene elkhorn coral, Acropora palmata, and staghorn coral, A. cervicornis, relic reef which lies 15 to 30 m (50 to 100 ft) below present sea level. The reef apparently has not been active for the last 7,000 years (Lighty, et al., 1977). Presently, the dominant hermatypes are the large star coral Montastraea cavernosa, the small star coral M. annularis, the lettuce coral Agaricia lamarcki, and the brain coral Diploria clivosa. Other stony corals known from the southeast Florida coast are summarized in Appendix C.

The deeper zones of this community (20 to 30 m; 66 to 100 ft) are characterized by the presence of the scleraxonian gorgonian Iciligorgia schrammi as described by Goldberg (1973a). Wheaton-Smith and Jaap (1976) and Courtenay, et al. (1975) have confirmed the existence of the same zonation off Palm Beach and Miami Beach, respectively. Other octocorallians from this area are summarized in Appendix A.

5.2.1.4 Florida Keys (Fowey Rocks to the Dry Tortugas)

With the exception of reefs of Bermuda and the northern Bahamas, the Florida Keys represent the northernmost limit of coral reefs in the western Atlantic. Many well developed patch and outer bank reefs, such as Carysfort Reef and Key Largo Dry Rocks, occur shoreward of the 18-m (60-ft) isobath and are dominated by Acropora palmata (elkhorn) and Millepora complanata (encrusting fire coral) at the crest, followed by A. cervicornis (staghorn), Montastraea annularis (small star coral), and M. cavernosa (large star coral), in successively deeper zones (Shinn, 1963). There is little specific information on the distribution and abundance of corals on these reefs in spite of their position as the northernmost Acropora reefs in the western Atlantic. The outer bank reefs of Biscayne National Park to the north have been described by Voss, et al. (1969) but quantitative data on distribution and abundance of corals on a single reef were not included. Ongoing research at the Park should fill this data gap (Jaap and Wheaton Lowry, in preparation; Tilmant, 1979, personal communication).

The only outer reef system presently described in detail is Looe Key Reef, in the lower Florida Keys (Antonius, et al., 1978). Hence, although Looe Key is only one of many outer bank reefs, most of this discussion is limited to this representative area. The reef crest at Looe Key is dominated by

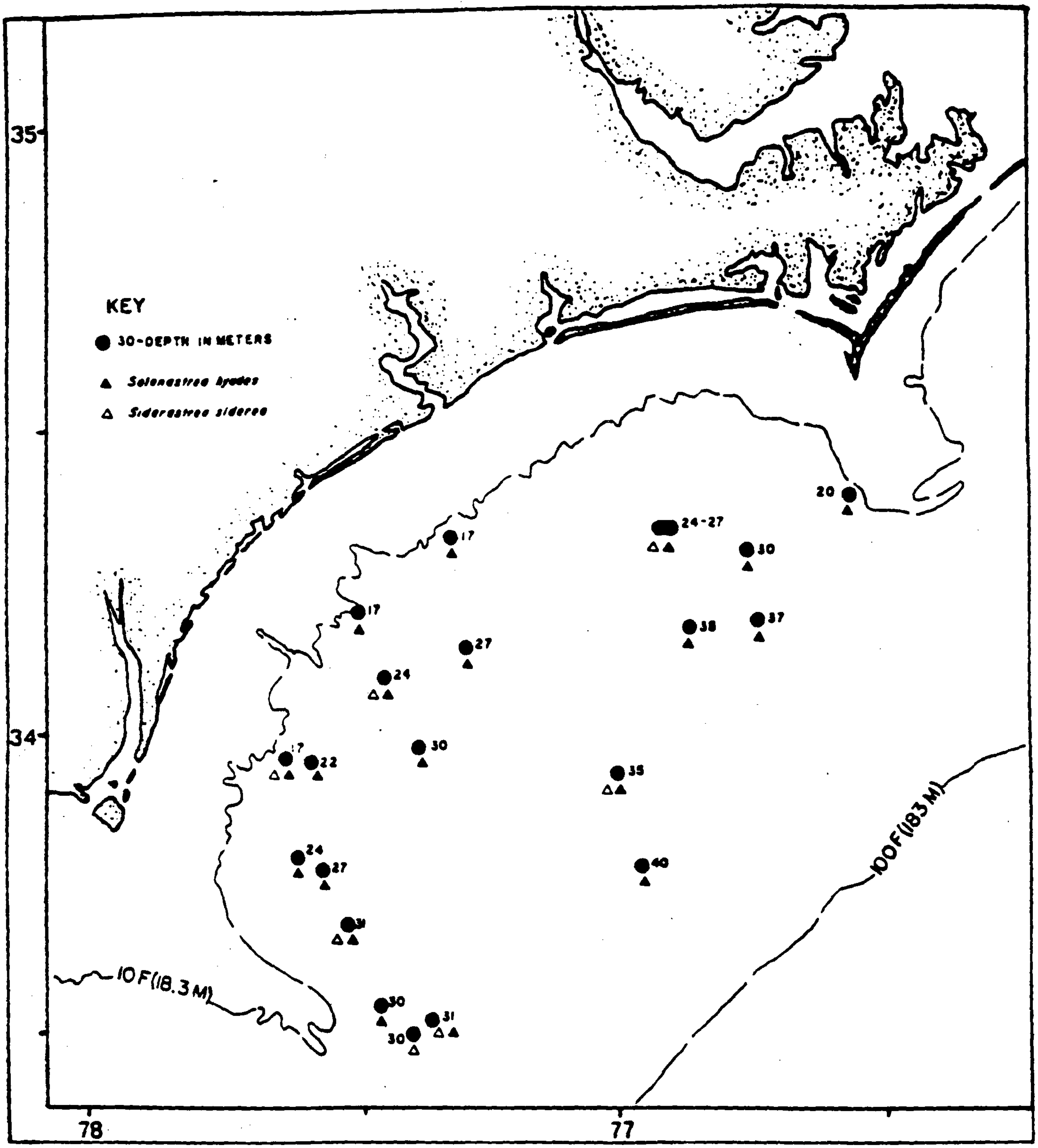


FIGURE 5-5. Areas of tropical reef corals in Onslow Bay, North Carolina (after Huntsman & Macintyre, 1971).

Millepora complanata (encrusting fire coral); Acropora cervicornis (staghorn) is not prevalent. The crest is transected by valleys, some of which extend seaward as a system of spurs and grooves (S & G) perpendicular to the Keys' general coastline. The S & G system at Looe Key is roughly 800 m (2,600 ft) long, 300 m (990 ft) wide, and slopes sharply from the surface to a sand bottom at 9 to 11 m (29 to 36 ft). The spurs are composed of a framework of A. palmata (elkhorn) capped by colonies of very large, living Montastraea annularis (small star coral), Diploria strigosa (brain coral), and Colpophyllia natans (moon coral). Montastraea cavernosa (large star coral) becomes dominant at the deeper ends of the spurs. Montastraea spp. and Acropora palmata are numerically dominant on the spurs, accounting for 54 percent of the scleractinians. The gorgonian fauna are dominated primarily by Pseudopterogorgia americana and Gorgonia ventalina which comprise 19 percent of the fauna. Secondary dominants are Plexaura flexuosa, Pseudopterogorgia acerosa, Muricea atlantica, and Erythropodium caribaeorum which account for an additional 18 percent of the gorgonians found in this zone.

The end of the spur and groove zone at Looe Key is marked by a sandy plain at 10 to 12 m (33 to 40 ft), which grades into a deeper reef zone, particularly toward the west. A second tier of deep spurs and grooves continues to a depth of 30 to 35 m (100 to 115 ft). Octocorals such as the rough sea plume (Muriceopsis flavida; eleven percent of deep reef gorgonians) are common but are replaced by Psuedopterogorgia bipinnata (the bipinnate sea feather) and Iciligorgia schrammi (13 percent) with increasing depth. The scleractinians of the deep reef are similar in composition to the shallower zones but contain a relatively greater abundance of branching forms such as Eusmilia fastigiata (star or flower coral), Porites porites, and Madracis spp. (finger coral). The larger scleractinians of the deep reef are Agaricia (lettuce coral) and Mycetophyllia.

The zone landward of the reef crest at Looe Key is the reef flat zone. Coral diversity there is limited and individuals present are usually small and encrusting. Dominant species include the mustard hill coral Porites astreoides (27 percent of reef flat Scleractinia), the brain coral Diploria clivosa (17 percent), the fire coral Millepora squarrosa (14 percent), and the starlet coral Siderastrea siderea (11 percent). Gorgonians are the most conspicuous element here and consist principally of two species, Gorgonia ventalina (common sea fan; 27 percent) and Pterogorgia citrina (yellow sea whip; 43 percent).

Antonius, et al. (1978) also described the patch reef zone closest to Looe Key. This area contains the same scleractinian species as described for the reef flat, except that an increased abundance of Acropora cervicornis is noted. Twenty-six species of gorgonians were found in this zone, but only one species, Pseudoplexaura flagellosa (flagellate false Plexaura; nine percent), accounted for more than six percent of the individuals.

Patch reefs of the Florida Keys have received the most comprehensive treatment as far as ecology and systematics of corals in the management area are concerned. Comparisons between reefs and areas, however, are complicated by environmental variables which fluctuate with the location of the patch. Wave and current exposure, exposure to Florida Bay water thermohaline and turbidity fluctuations, distance from shore, and depth all play a role in quantitative and qualitative coral development. Generally, patch reefs found in the lagoon between the outer reefs and the Florida Keys may include star corals Montastraea spp., fire corals Millepora spp., regular finger coral Porites porites (P. furcata or P. divaricata), mustard hill coral P. astreoides, starlet coral Siderastrea spp., brain coral Diploria clivosa, and staghorn Acropora cervicornis. Acropora palmata (elkhorn) is almost always absent. Antonius, et al. (1978) found that five species composed 50 percent of the stony corals found on the patch reefs at Looe Key; Millepora complanata, the star corals Dichocoenia stellaris, Siderastrea siderea, and Montastraea annularis accounted for eight to ten percent each, while staghorn coral Acropora cervicornis dominated with 15 percent of the total.

Inshore waters in the immediate vicinity of the Keys are dominated by hardy corals (including the brain coral Diploria clivosa, Favia fragum, Porites porites, P. astreoides, Siderastrea radians, S. siderea, rose coral Manicina areolata, and Cladocora arbuscula), which appear to have a greater tolerance to silt, thermohaline changes, and unconsolidated bottom (Vaughan, 1919; Kissling, 1965). Voss and Voss (1955) have described such an environment in the vicinity of Soldier Key, the northernmost of the Florida Keys, as have Turmel and Swanson (1976) at Rodriguez Bank, near Tavernier, Florida. The dominant scleractinian in both locations is Porites porites (Porites divaricata), found in a distinct seaward band associated with the coralline alga Goniolithon sp. and turtle grass Thalassia testudinum.

Quantitative information dealing with distribution and abundance of gorgonians is available for several back reef areas in the Florida Keys. Opresko (1973) has analyzed gorgonian data for Boca Chita Pass, Soldier Key, and Red Reef (Table 5-6 and Section 5.4). The first two locations lie on the seaward side of Biscayne Bay and are subject to fluctuations in salinity, temperature, and turbidity. Boca Chita Pass is the least oceanic in character and not surprisingly possesses the lowest diversity and density of gorgonians. Red Reef is a lagoonal patch reef located on Margot Fish Shoal, approximately 4 km (2 nm) east of Elliott Key and about 3 km (1.6 nm) west of the outer reef arc (Long Reef) (Figure 5-6); this location displayed the greatest diversity and density of the areas studied by Opresko (Table 5-6).

Comparative information is available for the gorgonian fauna on other lagoonal patch reefs. Bagby (1978) has studied three sites off Key Largo, Florida, chosen to provide a view of the influence of increasing oceanic conditions. The patches, hereafter referred to as Five, Seven and Nine Kilometer Reefs, are named for their respective distances from Key Largo, Florida. Nine Kilometer Reef is immediately shoreward of the outer reef arc just south of Molasses Reef (Figure 5-6). Table 5-6 compares distribution and abundance records of gorgonians from both Opresko (1973) and Bagby (1978). It is apparent that Pseudopterogorgia americana (slimy sea plume) and P. acerosa (porous false Plexaura) are the most widespread species, being found at every station. In agreement with the conclusions of Opresko (1973), P. acerosa is most common inshore, while P. americana is more dominant at offshore patch reef stations. Equally widespread, but numerically less dominant, are the species Plexaurella dichotoma (double-forked Plexaurella) and Plexaura flexuosa (sea rod). The former is present at all stations but is abundant only at Soldier Key and Five Kilometer Reef. Two species, Eunicea succinea (amber Eunicea) and Pterogorgia citrina (yellow sea whip), are distributed in abundance at both Soldier Key and Nine Kilometer Reef, but not in intermediate areas. Pseudoplexaura porosa was dominant on Five Kilometer Reef and Plexaura homomalla (black sea rod) was of considerable importance on Red Reef, but neither was prominent elsewhere in the areas studied.

Species with patchy or widespread distributions are apparently the rule rather than the exception. Goldberg (1973a) noted that offshore patch reefs near the 9 m (30 ft) isobath off the southeast Florida coast could be dominated by either Pseudopterogorgia americana or P. acerosa. Plexaura flexuosa was equally abundant along with Eunicea calyculata (warty Eunicea) and Muricea muricata (spiny Muricea). Reefs at 14-to 20-m (46-to 66-ft) depths off Palm Beach are dominated by Plexaura flexuosa and Pterogorgia citrina (Wheaton-Smith, 1976). Plexaura flexuosa and Pseudopterogorgia americana dominated the shallow reefs at Long Key, Dry Tortugas (Wheaton Lowry, in preparation). Thus, any or all of these species can be found prominently on inshore or offshore reefs, in shallow water or on outer reefs at depths up to 20 m (66 ft). Their relative abundance on a given reef must therefore be interpreted with caution.

Shallow patch reefs near the outer reef tract display a number of clear-water indicator species. Gorgonia ventalina (common sea fan), Muriceopsis flavida (rough sea plume), Briareum asbestinum (corky sea finger), and Pseudopterogorgia bipinnata all fall in this category, in decreasing order of consistency (Opresko, 1973; Bagby, 1978). However, only the sea fan G. ventalina showed any correlation between abundance and reef position. At Red Reef and Five Kilometer Reef, this species accounted

TABLE 5-6. Comparative dominance diversity of Gorgonacea in shoal waters of the Florida Keys. A - after Opresko (1973), B - after Bagby (1978).

A.

SOLDIER KEY

SPECIES	% OF POP.	CUMULATIVE %
Eunicea succinea forma succinea	41.2	41.2
Pterogorgia citrina	37.3	78.5
Pseudopterogorgia acerosa	4.7	83.2
Plexaurella dichotoma	4.5	87.8
Eunicea calyculata	3.3	91.0

Colonies Sampled: 703
No. of Species : 16
Colonies/m^2 : 11.3

BOCA CHITA PASS

SPECIES	% OF POP.	CUMULATIVE %
Pseudopterogorgia acerosa	45.1	45.1
P. americana	12.6	57.7
Muricea atlantica	9.9	67.6
Pterogorgia anceps	9.9	77.5
Muricea elongata	7.2	84.7

Colonies Sampled: 111
No. of Species : 10
Colonies/m^2 : 6.9

RED REEF

SPECIES	% OF POP.	CUMULATIVE %
Briareum asbestinum	21.4	21.4
Plexaura homomalla	14.3	35.7
Pseudopterogorgia bipinnata	13.0	48.6
Erythropodium sp.	12.2	60.9
Plexaura flexuosa	7.9	68.8

Colonies Sampled: 736
No. of Species : 26
Colonies/m^2 : 27.1

B.

KEY LARGO PATCH REEF (5km)

SPECIES	% OF POP.	CUMULATIVE %
Pseudoplexaura porosa	13.2	13.2
Pseudopterogorgia americana	12.0	26.0
Briareum asbestinum	8.8	34.9
Plexaura flexuosa	7.5	42.3
Plexaurella dichotoma	7.1	49.4
Muriceopsis flavida	7.1	56.5

Colonies Sampled: 949
No. of Species : 33
Colonies/m^2 : 26.4

KEY LARGO PATCH REEF (7km)

SPECIES	% OF POP.	CUMULATIVE %
Muriceopsis flavida	27.3	27.3
Pseudopterogorgia bipinnata	26.9	54.2
P. americana	13.5	67.7
Gorgonia ventalina	6.4	74.2
Briareum asbestinum	4.2	78.4

Colonies Sampled: 1138
No. of Species : 25
Colonies/m^2 : 31.6

KEY LARGO PATCH REEF (9km)

SPECIES	% OF POP.	CUMULATIVE %
Eunicea succinea (both forms)	42.6	42.6
Gorgonia ventalina	12.8	55.4
Pseudopterogorgia americana	11.2	66.6
Muriceopsis flavida	10.6	77.1
Pterogorgia citrina	9.8	86.9

Colonies Sampled: 634
No. of Species : 20
Colonies/m2 : 16.7

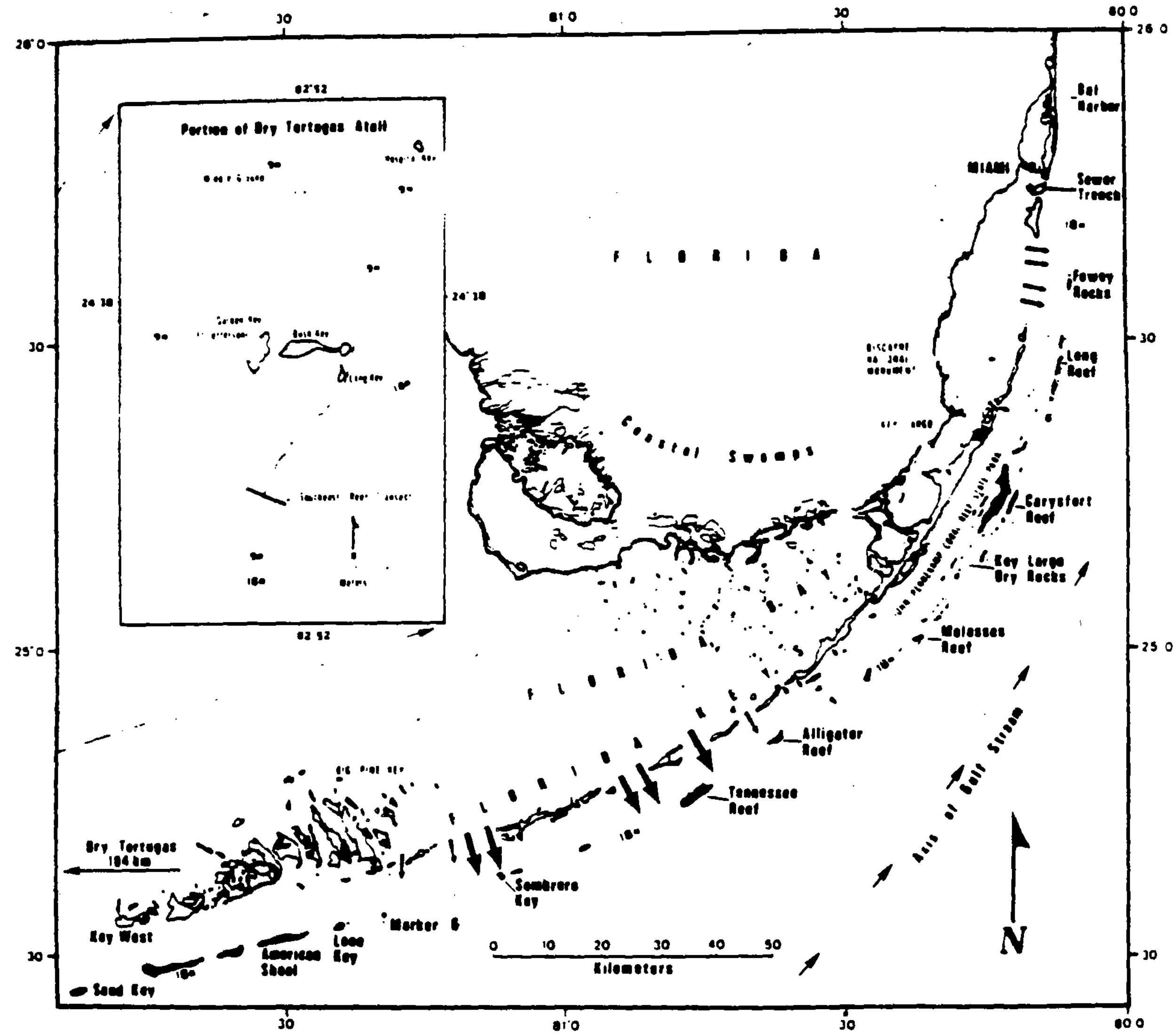


FIGURE 5-6. The Florida Keys with localities mentioned in the text. Arrows indicate major passes for bay water exchange (after Shinn et al., 1977).

for 2.7 to 4.1 percent of the total fauna. At Seven Kilometer Reef this figure increased to 6.4 percent, and at Nine Kilometer Reef it increased again to 12.8 percent.

5.2.1.5 Northeastern Gulf of Mexico

This region includes the waters off the west coast of Florida from the Everglades north to Cape San Blas on the Florida Panhandle (Figure 5-2). From the standpoint of coral communities, the best known and most important area in this region is a 1,536 km^2 (338 nm^2) hard bottom northwest of Tampa known as the Florida Middle Grounds (Figure 5-4). The Florida Middle Grounds is characterized by steep-profile limestone escarpments and knolls rising 10 to 13 m (33 to 43 ft) above the surrounding sand and sand-shell substrate, with overall depths varying from 26 to 48 m (85 to 157 ft) (Smith, 1976). Brooks (1962) attributed the relief to underlying Pleistocene relic reefs which flourished during the last inter-glacial epoch.

At present, live corals contribute little to the configuration of the area (Smith, 1976), so that it is best to use the term hard bottom rather than coral reef to describe it. This point is underscored by the absence of the hermatypic star and brain corals Montastraea and Diploria (Smith, et al., 1975) characteristic of the Flower Garden Reefs described in Section 5.2.2.7 below.

The dominant scleractinians in the Florida Middle Grounds include Madracis decactis, Porites divaricata, Dichocoenia stellaris, D. stokesii, and Scolymia lacera. Octocorals, a relatively minor component of other Gulf reefs considered below, are prominent on the Middle Grounds; dominant forms include Muricea elongata (orange Muricea), Muricea laxa (delicate Muricea), Eunicea calyculata (warty Eunicea), and Plexaura flexuosa (sea rod) (Grimm and Hopkins, 1977). Additions to the latter paper have been made by Wheaton Lowry (in preparation) and are included in Appendix A. It is of interest to note that several genera of octocorals (Plexaura, Eunicea, Pseudopterogorgia, etc.) usually considered typical of tropical areas occur this far north.

A species zonation pattern exists on the Florida Middle Grounds with overlap between adjacent zones. Grimm and Hopkins (1977) describe a Muricea-Dichocoenia-Porites zone at 26 to 28 m (85 to 92 ft). From 28 to 30 m (92 to 100 ft) the dominant forms are Dichocoenia (eye coral) and Madracis. Millepora (fire coral) dominates from 30 to 31 m (100 to 103 ft) but becomes codominant with Madracis from 31 to 36 m (103 to 118 ft).

A second shelf region with notable coral communities is bounded by the waters off Tampa Bay on the north and Sanibel Island on the south and has been investigated and reported by the Florida Department of Natural Resources in their Memoirs of the Hourglass Cruises. The so-called "Hourglass region" (Figure 5-4) consists of a variety of bottom types. Rocky bottom occurs at the 18 m (59 ft) contour where sponges, alcyonarians, and the scleractinians Solenastrea hyades (stump coral) and Cladocora arbuscula are especially prominent (Joyce and Williams, 1969). Smith (1976) noted additional "patch reefs" (hard bottoms according to the definitions in Table 5-1) which occur off Sarasota, Florida. Cairns (1977b) published an analysis of the ahermatypic stony corals of the Hourglass samples; Jaap is currently preparing a report on the other scleractinians. While it is apparent that the distribution of corals in this region is irregular, a considerable diversity of scleractinians and octocorallians occur here and are listed among those recorded from the eastern Gulf of Mexico (see Appendices A and C). Dominant species were Siderastrea radians, Cladocora arbuscula, Solenastrea hyades, Phyllangia americana, Oculina diffusa, and Oculina tenella; twelve other species were rare (Jaap, 1979, personal communication).

As in the Florida Middle Grounds the Hourglass region octocoral fauna include Carolinian and West Indian species. This Leptogorgia/Lophogorgia assemblage is found in some abundance to the vicinity of Naples, Florida, (Wheaton Lowry, in preparation) and persists sporadically to Cape Sable, Florida (Tabb and Manning, 1961).

In addition to the Florida Middle Grounds and Hourglass areas, the eastern Gulf region also includes abundant hard bottom communities (Causey, 1979, personal communication). Woodward-Clyde Consultants (1979) described the biological associations of these areas, in which *Oculina robusta* is particularly abundant.

5.2.1.6 Northern Gulf of Mexico

This region is bounded on the east by Cape San Blas, Florida, and on the west by the Mississippi Delta (Figure 5-2). The shallow nearshore zone in this area appears to be a transition zone between hard-bottom communities to the east and southeast and localized hard-bank communities to the west. The area is influenced by the Mississippi River outflow. Although some corals [*Manicina areolata* rose coral; 34 m (112 ft) depth; Jaap, 1979, personal communication] and inshore hard bottoms have been reported 3 to 11 km (1.6 to 5.9 nm) offshore between Panama City, Florida, and the Choctawatchee Bay entrance (Brooks, 1974), most coralline areas are restricted to the outer edge of the continental shelf in this region.

The shelf edge lying in the area between the Mississippi Delta and northwest Florida contains a number of discontinuous mounds, hills, and pinnacles at depths of 80 to 168 m (262 to 550 ft). Ludwick and Walton (1957) studied a section of these prominences off Mobile, Alabama, (depth, 80 to 110 m or 262 to 360 ft; mean temperature, 18.3°C or 63°F) which were found to be Pleistocene rock composed chiefly of calcareous algae. Their relief averaged 9 m (30 ft) above the surrounding terrain, and although no evidence of modern reef construction was found, a number of scleractinians and octocorals (in addition to the antipatharian *Cirripathes* sp.) were obtained by dredge and grab (Table 5-7).

Table 5-7. Shelf-edge corals from the northern Gulf of Mexico. (After Ludwick and Walton, 1957)

Octocorallia	Scleractinia
Nidalia occidentalis Gray	**Oculina varicosa* Lesueur (reported as *O. disticha*)[1]
Neospongodes agassizi Deichmann	**Madracis mirabilis* D. & M.[2]
**Nicella guadalupensis* D. & M.	**Bathycyathus* sp.
Riisia paniculata D. & M.	*Anomocora fecunda* Pourtales
Ellisella sp. (*funiculina*?)	*Balanophyllia* sp.
**Thesea rubra* Deichmann	*Deltocyathus agassizi* Pourtales
Villogorgia nigrescens D. & M.	*Desmophyllium cailleti* D. & M.

* Indicates most commonly encountered species.

[1] Probably *O. robusta*

[2] Perhaps *M. decactis* or *M. asperula*

Additional species of Octocorallia from this region are listed in Appendix A from Bayer (1961) and Giammona (1978), but with no indication of whether they are associated with hard-bottom communities. Cairns (1977a) had published a field guide and taxonomic key to the commoner octocorals of the Gulf of Mexico, Caribbean, and Florida.

5.2.1.7 Northwestern Gulf of Mexico

The principal communities in the northwestern Gulf of Mexico (west of the Mississippi River Delta) are localized on the hard banks occurring on the shelf (see Figure 5-4). Numerous other banks are being discovered as topographic studies continue on the Gulf shelf. These banks usually originate in waters 40- to 100-m (131- to 330-ft) deep and include filamentous and leafy algae (Bright, 1977; Giammona, 1978). Bright (1977) had grouped these banks into three categories based on their biota and depth of origin, as described in Table 5-8 and Figures 5-4 and 5-7. Only East and West Flower Garden Banks in group 3 peak at depths less than 25 m (82 ft); the other banks peak at 58 to 70 m (190 to 230 ft). Biota on these banks fall into at least six biotic zones, combinations of which are found on different banks (Bright, 1977).

Table 5-8. Classification of Gulf of Mexico banks based on depth of origin. (After Bright, 1977).

Group 1 - Origin between 50 and 60 m (163 to 196 ft) contours

Stetson Bank	Claypile Bank
Sonnier Bank (Three Hickey Rock)	32 Fathom Bank

Group 2 - Origin between 60 and 80 m (196 to 262 ft) contours

Mysterious Bank	North Hospital Bank
Blackfish Ridge	Aransas Bank
Big Adam Rock	South Baker Bank
Small Adam Rock	Baker Bank
Dream Bank	29 Fathom Bank
Southern Bank	Fishnet Bank
Hospital Bank	

Group 3 - Origin between 100 and 200 m (330 to 660 ft) contours

East Flower Garden Bank	Ewing Bank
West Flower Garden Bank	Parker Bank
Bright Bank	18 Fathom Bank
Bouma Bank	28 Fathom Bank

Two banks (Stetson and Sonnier) in the first group (those originating between the 50 to 60 m [163 to 196 ft] contour) are dominated by the fire coral *Millepora alcicornis* and various sponges (Giammona, 1978; Bright, 1977). Stetson Bank, in particular, has been described in some detail by Bright and DuBois (1974) (Figure 5-8). This bank occupies about 4 ha (10 acres) of bottom composed primarily of a soft claystone which rises from a mud bottom at roughly 49 m (161 ft) to a peak at about 20 m (66 ft). A wide variety of benthic organisms are common on the bank, including the sponge *Neofibularia* sp. and the rock-boring bivalve *Jouannetia quillingi*.

Few scleractinian and no gorgonian corals are found at Stetson Bank. *Stephanocoenia michelinii* (also reported as *S. intersepta* by some researchers) occurs with occasional encrustations of *Madracis decactis* (Bright and DuBois, 1974). Edwards (1971) reported the presence of *Siderastrea* sp. (starlet coral), and the star coral *Montastraea annularis*, brain coral *Diploria strigosa*, and *Madracis asperula* on Stetson Bank, but these were not encountered by the former authors despite extensive SCUBA and submersible operations. E. A. Shinn (personal communication) reports *Millepora* sp. as having been fairly common there in 1973.

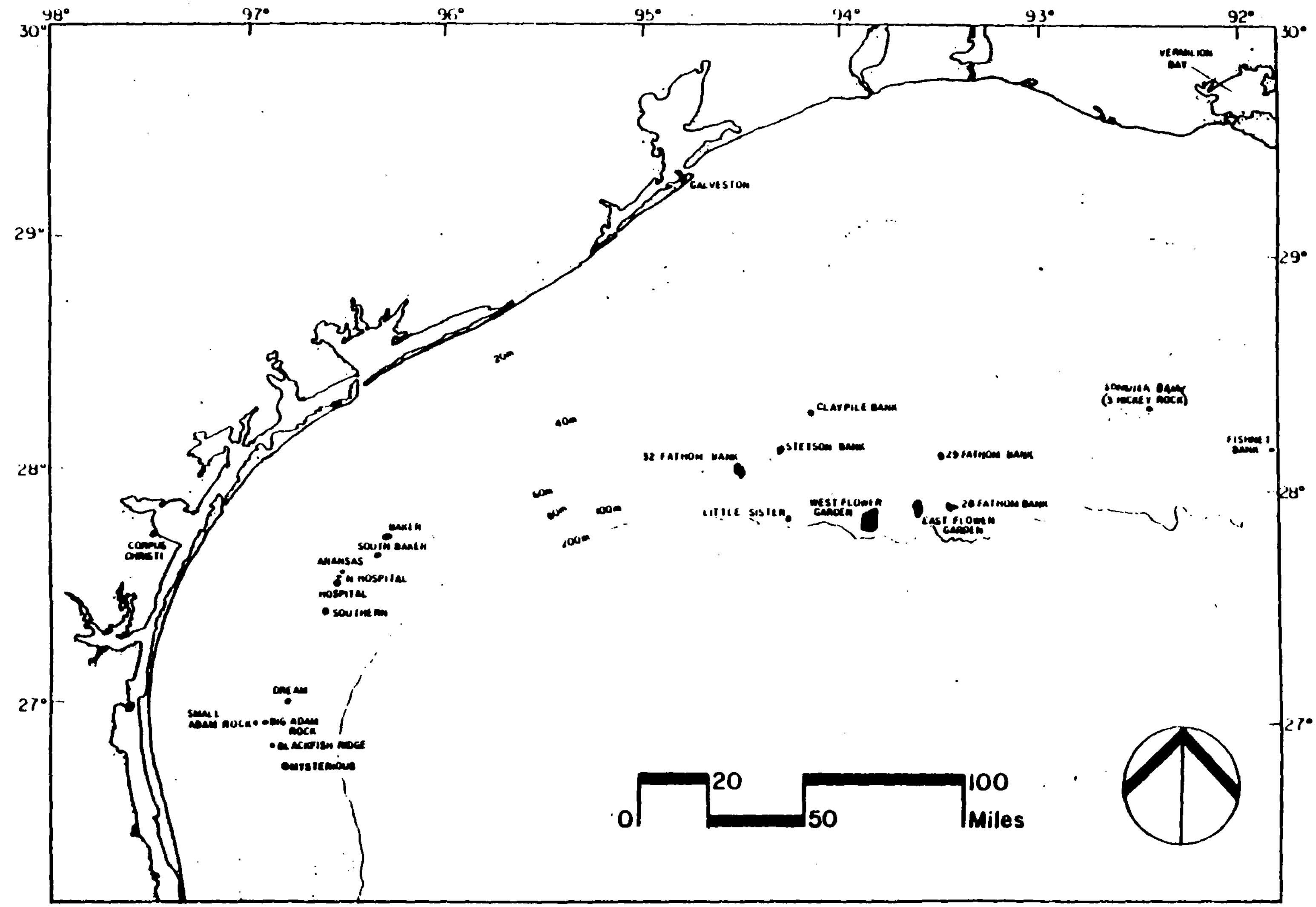
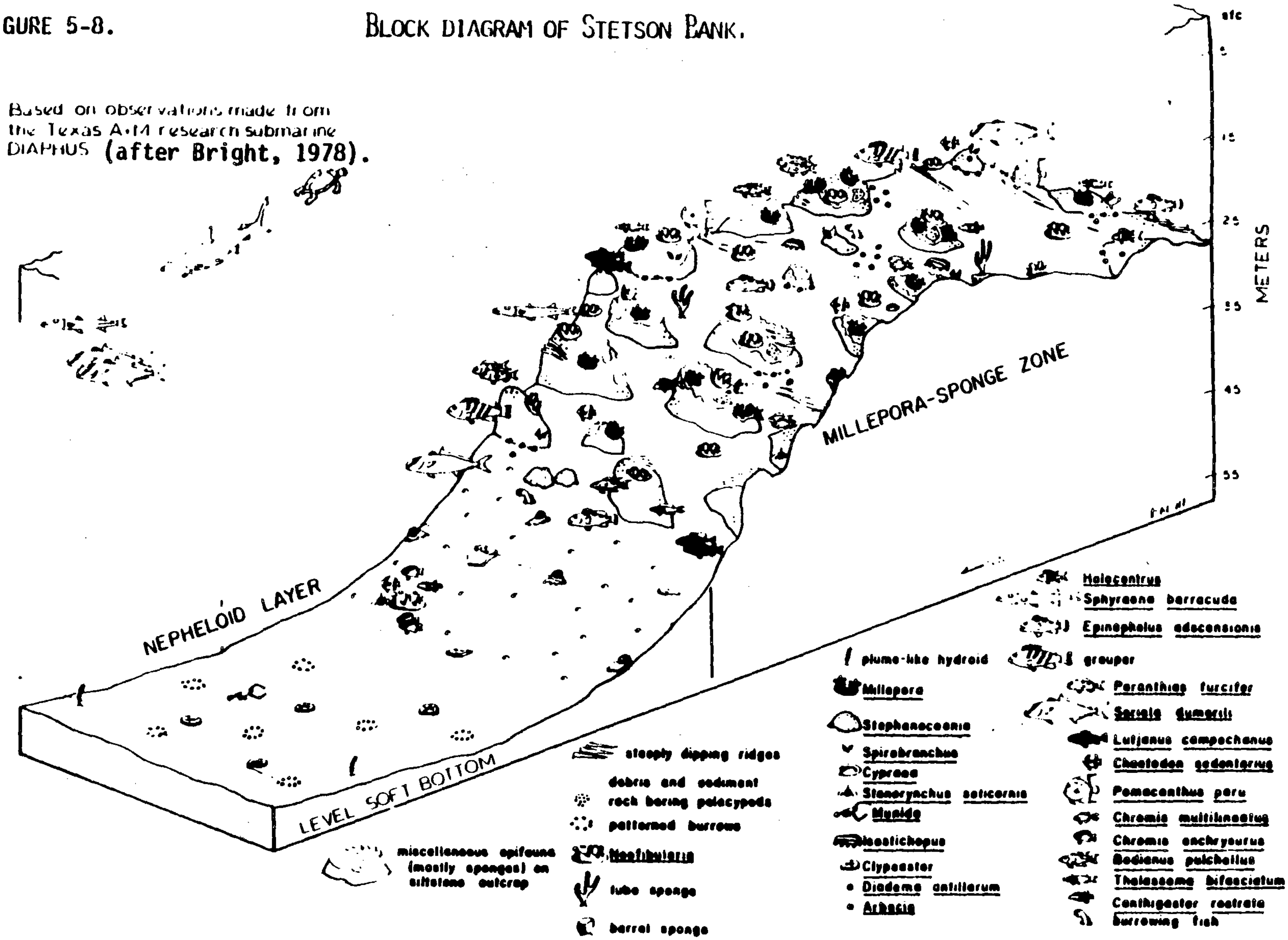


FIGURE 5-7. Major Texas-Louisiana outer continental shelf fishing banks (Bright and Rezak, 1978).

FIGURE 5-8. BLOCK DIAGRAM OF STETSON BANK.

Based on observations made from the Texas A&M research submarine DIAPHUS (after Bright, 1978).



Another bank within Group 1 is the Sonnier Bank (formerly known as the Three Hickey Rock). This bank is a mid-shelf structure composed of siltstone outcrops. The peak at 20 to 21 m (66 to 69 ft) is almost entirely encrusted with Millepora sp. (fire coral) which persists to 40 m (132 ft) along with the sponges Neofibularia nolitangere and Ircinia sp. Although a specimen of Agaricia sp. (lettuce coral) was recovered at 52 m (170 ft), the only common scleractinian was Stephanocoenia sp. at 36 to 41 m (118 to 135 ft) (Figure 5-9).

The base of Sonnier lies at about 52 m (170 ft), where rubble gives way to a mud bottom at 58 m (190 ft). The antipatharian black corals Cirripathes sp. and Antipathes sp. were noted from 47 to 58 m (153 to 190 ft) adjacent to the bank but not on it. Bright (1978) considers the structure, environment, and biota of Sonnier to be similar to Stetson Bank (described above).

The second group of banks, of which Southern Bank (Figure 5-10) is typical, does not rise as close to the surface as most banks and is characterized primarily by antipatharians of the genus Cirripathes. Also present are scattered encrustations of coralline algae and gorgonians of the genera Hypnogorgia (Muricea ?) and Thesea (Bright and Rezak, 1976). It is worth noting that nearby Dream Bank (also in group 2) has a more diverse octocoral fauna when compared with the rest of the South Texas Banks. Bebryce cinerea Deichmann, Scleracis guadalupensis Duchassaing and Michelotti, Thesea nivea Deichmann and T. parviflora are all known from here at depths of 63 to 83 m (207 to 271 ft) (Giammona, 1978). In addition, Muricea pendula Verrill has been taken on Baker and Aransas Banks (60 to 62 m; 196 to 203 ft), Nicella flagellum (Studer) is known from Hospital Rock (depth unspecified), and Placogorgia tenuis Verrill has been recovered from South Baker Bank at 76 m (250 ft) (Giammona, 1978). Additional Octocorallia from this region are listed in Appendix A.

Scleractinian corals, while not abundant, are represented by populations of Agaricia sp. (lettuce coral), Madracis brueggemanni, and an unidentified solitary species (Bright and Rezak, 1976). Cairns (1978) lists several additional ahermatypic corals from the shelf banks of this region (see Appendix C). The physical conditions which characterize these hard banks are not conducive to the development of coral communities. The South Texas Banks, in particular, are subjected to frequent intrusions of coastal water masses with their attendant thermohaline fluctuations. Bright and Rezak (1976), for example, state that bottom temperatures can vary from 12 to 16°C (53 to 61°F) and salinities can change abruptly. In addition, the upper levels of the banks are subjected to periodical inundation by turbid water layers which overlie the predominantly soft bottom of the Texas-Louisiana outer continental shelf (Bright, 1977). The community characterized as the "antipatharian zone" is apparently adapted to these conditions although the tops of the banks, which are frequently above the nepheloid layer, are biotically more diverse than the lower parts of the banks (Bright, 1977).

The third group of Gulf banks classified by Bright (1977) are the outer shelf structures originating at depths of 100 to 200 m (330 to 660 ft). These are typified by the East and West Flower Garden Banks except for the large number and diversity of scleractinians which are found in abundance only in their shallowest zones. Located in clear, oceanic waters over 200 km (108 nm) south-southwest of Galveston, Texas, these two banks bear the most complete and complex coral communities on the northwestern Gulf of Mexico continental shelf. Zonation patterns at the banks resembles patterns observed in the Florida reef tract but begins at much greater depths.

Geologically, the Flower Garden Banks are salt-dome structures which have been colonized by coralline algae and reef-building corals (Levert and Ferguson, 1969). Because at least some of the relief has been contributed by hermatypic corals, it seems appropriate to refer to these salt-dome structures as a special variety of coral reef. Accordingly, Bright and Pequegnat (1974) classify the Flower Gardens as a submerged reef-bank with coral prominences cresting at a depth of approximately 20 m (66 ft).

West Flower Garden Bank is composed of large, closely spaced coral heads up to 3 m (10 ft) or more in

FIGURE 5-9. SONNIER BANK

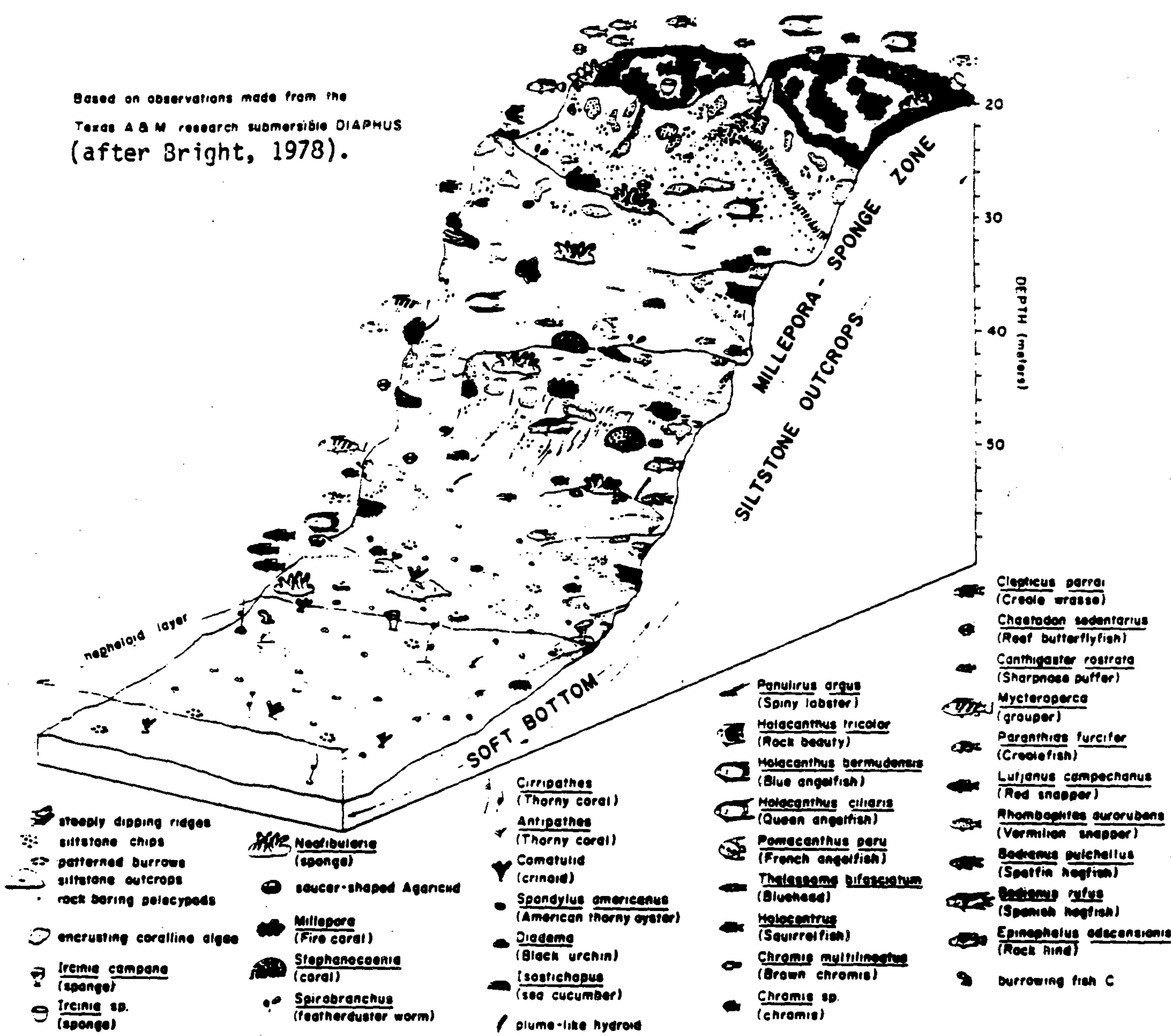
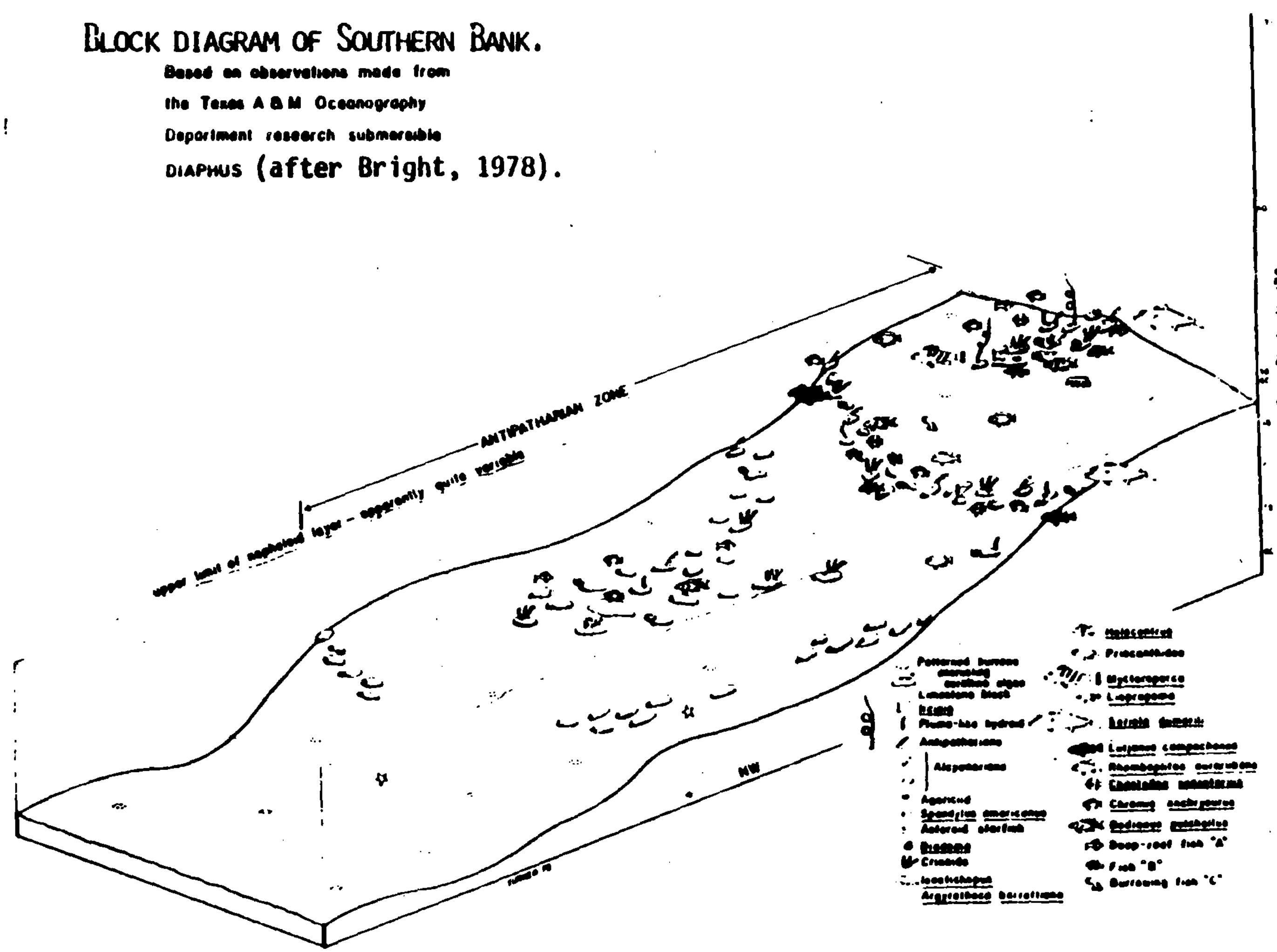


FIGURE 5-10.

BLOCK DIAGRAM OF SOUTHERN BANK.

Based on observations made from the Texas A & M Oceanography Department research submersible DIAPHUS (after Bright, 1978).



diameter. The resultant topography is quite rough with much growth in the form of ledges and overhangs (Bright and Pequegnat, 1974). The principal growth zone of the reef, found over an area of 40 ha (100 a) at a depth of 24 to 49 m (78 to 160 ft), is dominated by Montastraea annularis (small star coral), Diploria strigosa (brain coral), Montastraea cavernosa (large star coral), Colpophyllia natans (moon coral), and Porites astreoides (mustard hill coral), in that order of abundance. Bright and Pequegnat (1974) refer to this as a "Diploria-Montastraea-Porites Zone" (Figure 5-11). The acroporids, the dominant hermatypes in other coral reefs in the southern Gulf and Caribbean, are entirely absent from the Flower Garden Reefs and other localities in the Gulf north of Veracruz, Mexico (Moore, 1958). The reasons for the absence of this and other groups of hermatypic corals may include greater peak depths, the seasonal temperature range between 20 to 30°C (68 to 86°F) (Bright and Pequegnat, 1974), or recruitment difficulties presented by the great distance between the Flower Garden Banks and other coral gene pools of south Florida and the southern Gulf.

East Flower Garden Reef is somewhat smaller (28 ha or 70 a) than West Flower Garden, and has a similar pattern of zonation (Figure 5-12). In addition to the Diploria-Montastraea-Porites zone, however, the eastern bank also possesses a biotic zone of Madracis mirabilis and a zone of fleshy algae on the uppermost peaks (Bright, 1977).

The deeper portions of both banks contain an algal-sponge zone (dominated by coralline algae) followed by a deeper (70 m or 230 ft) antipatharian zone similar to, but deeper than, that found on the south Texas fishing banks described above in group 2 (Bright, 1977). On the Flower Gardens, gorgonian corals of the type characteristic of West Indian reefs are not present on the reef cap (Bright and Pequegnat, 1974). Giammona (1978) lists a number of deepwater gorgonian species taken largely below the zone of active reef growth (Table 5-9).

Table 5-9. Gorgonacea from West Flower Garden and 28 Fathom Banks.

	Depth in m (ft)
Family Gorgonidae	
Leptogorgia virgulata (Lamarck)	82 (270)
Lophogorgia punicea (M.-E. & H.)	?
Family Ellisellidae	
Ellisella atlantica Toeplitz	100 (330)
E. barbadensis (D. & M.)	100-115 (330-375)
Nicella americana Toeplitz	100 (330)
Riisea paniculata (D. & M.)	100 (330)
Family Paramuriceidae	
Callacis nutans (D. & M.)	100 (330)
Trachymuricea hirta Dichmann	105 (345)
Scleracis guadalupensis (D. & M.)	35-50 (115-165)

Giammona (1978) lists four additional species from nearby 28 Fathom Bank taken at 100-106 m (330-348 ft):

Nidalia occidentalis Gray
Bebryce cinerea Deichmann
Siphonogorgia agassizii (Deichmann)
Nicella flagellum (Studer)

Source: Bright and Pequegnat, 1978.

FIGURE 5-11.

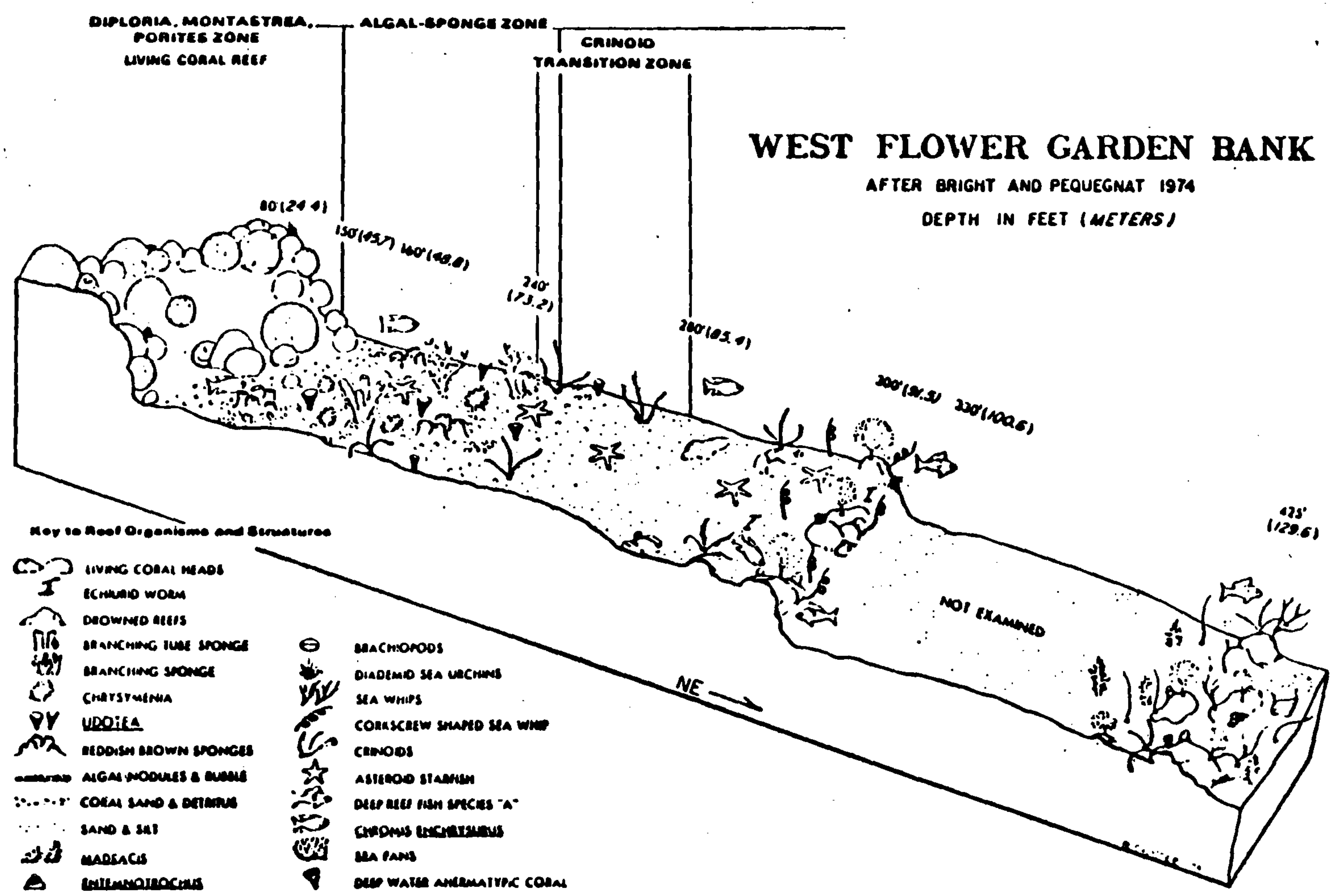
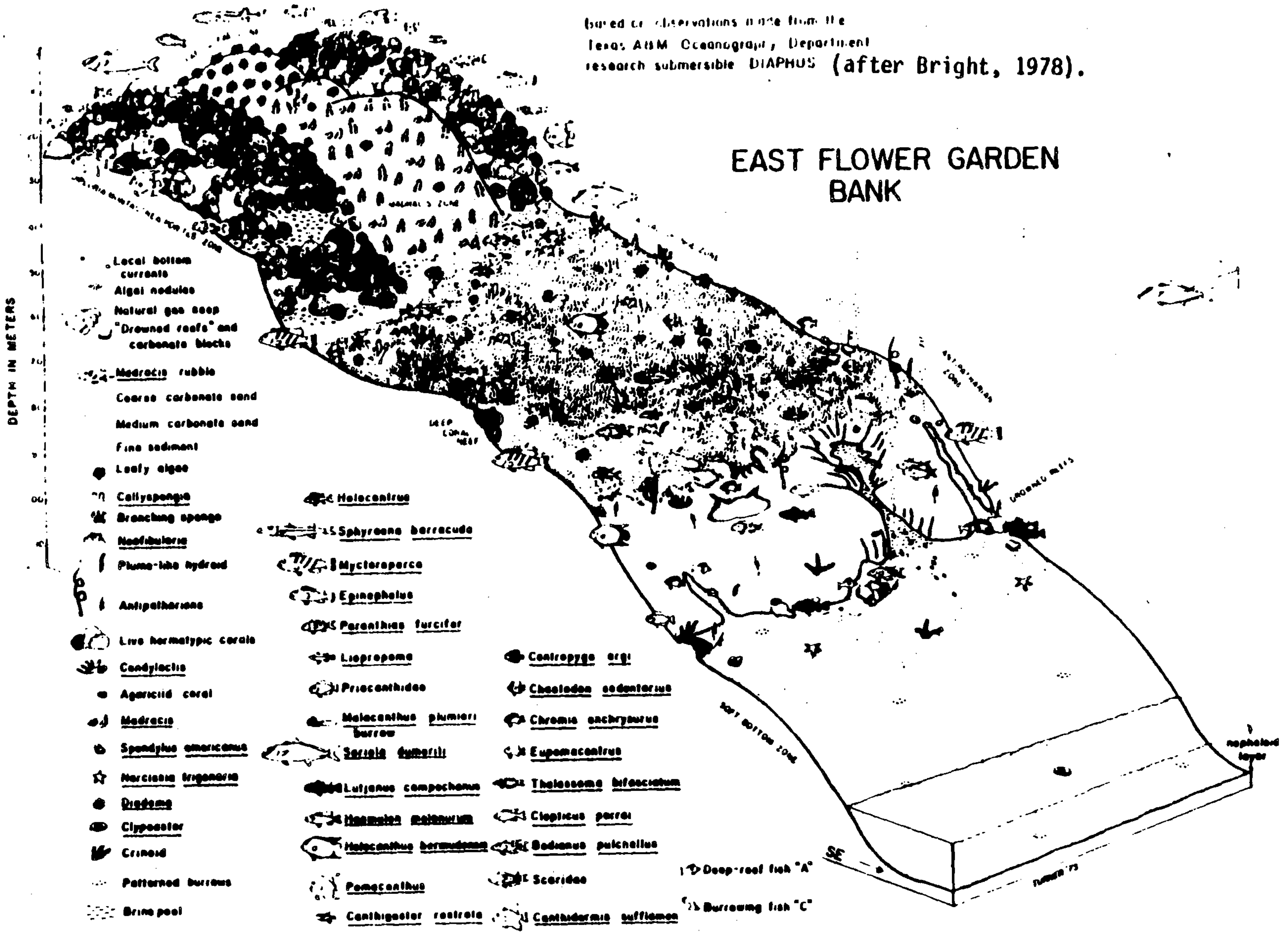

DIPLORIA, MONTASTREA, PORITES ZONE
LIVING CORAL REEF
ALGAL-SPONGE ZONE
CRINOID TRANSITION ZONE
WEST FLOWER GARDEN BANK
AFTER BRIGHT AND PEQUEGNAT 1974
DEPTH IN FEET (METERS)
80'(24.4)
150'(45.7)
160'(48.8)
240' (73.2)
280'(85.4)
300'(91.5)
330'(100.6)
425' (129.6)
NOT EXAMINED
NE
LIVING CORAL HEADS
ECHIURID WORM
DROWNED REEFS
BRANCHING TUBE SPONGE
BRANCHING SPONGE
CHRYSYMENIA
UDOTEA
REDDISH BROWN SPONGES
ALGAL NODULES & RUBBLE
CORAL SAND & DETRITUS
SAND & SILT
MADRACIS
BRACHIOPODS
DIADEMID SEA URCHINS
SEA WHIPS
CORKSCREW SHAPED SEA WHIP
CRINOIDS
ASTEROID STARFISH
DEEP REEF FISH SPECIES "A"
SEA FANS
DEEP WATER AHERMATYPIC CORAL

FIGURE 5-12.



based on observations made from the Texas A&M Oceanography Department research submersible DIAPHUS (after Bright, 1978).

Several other topographic highs on the Louisiana continental shelf also fall in this third group: Bright, Bouma, Ewing, Parker (not figured), and 18 Fathom Banks (Figures 5-13, 5-14, 5-15, and 5-16) (Bright, 1978). All five are shelf-edge features supporting a community structured largely by populations of coralline algae. All possess features of zonation, generally similar to those seen at Flower Garden Banks (except for the noted lack of scleractinian diversity and number). The algal-sponge zone (coralline algae - Neofibularia sp.) at 50 to 70 m (165 to 230 ft), is developed on all five banks, usually associated with Madracis sp. followed by an antipatharian zone at 70 to 80 m (230 to 263 ft) (Cirripathes sp. and Antipathes sp.). In addition to these zones, 18 Fathom Bank is capped with a zone composed of the scleractinians Montastraea cavernosa, Stephanocoenia sp., and Agaricia sp., plus the hydrozoan Millepora sp. (Figure 5-16). This coral zone, the only one of its kind in the banks described here, is found in patches between 43 to 47 m (140 to 154 ft). It is worth noting that lettuce coral Agaricia sp. is also found on Bright and Bouma Banks, M. cavernosa is known from Bright Bank, and the solitary coral Oxysmilia sp. is reported from both 18 Fathom and Ewing Banks (Bright, 1978).

Octocorallians are only preliminarily described for these regions, but 18 Fathom Bank is reported to have four species: Bebryce cinerea, Nicella flagellum, Nidalia sp., and dense populations of a whiplike Ellisella sp. at 62 to 73 m (203 to 240 ft) (Bright, 1978). Nicella schmitti and Nidalia occidentalis are reported from Ewing Bank.

A final Gulf bank not fitting the above biotic classification is Sackett Bank (Bright, 1978). The area in which this bank is located is chronically beset with stresses associated with variations in turbidity and salinity due to its proximity to the Mississippi River. It is not occupied by extensive coral or coralline algae communities, except that at 70 to 80 m (230 to 263 ft), the Cirripathes zone becomes developed (Figure 5-17). At 80 to 88 m (263 to 288 ft), Antipathes sp., Nidalia occidentalis, and unidentified paramuriceid, and the solitary scleractinian Oxysmilia sp. are all found, but disappear below 90 m (225 ft) due to the development of a mud surface.

5.2.2 Deepwater Corals

As noted in Section 5.1.2, information concerning deepwater corals is exceedingly sparse. In most instances, the information is too incomplete to make assessments as to the abundance of the stocks. With respect to the condition of the stock (i.e., mortality versus replacement rates) and overall stock stability, it is not possible to make an informed assessment. In one sense of the word "condition", however, the lack of exploitation and other damaging development activities in deepwater areas (except for limited collection and damage by research dredging) infers that the stocks should be in a pristine state.

For the Gulf of Mexico, the two principal studies of deepwater corals are, Giammona (1978), Cairns (1978); additionally, Moore and Bullis (1960) published a short note on these corals. Cairns described the zoogeography of scleractinians throughout the management area; Giammona reviewed available information on Octocorallia in the Gulf of Mexico (Appendix E relates his distributional information to habitat types); and Moore and Bullis (1960) reported a "deepwater coral reef" between 420 to 510 m (1,350 to 1,700 ft) on the continental slope 70 km (37.8 nm) east of the mouth of the Mississippi River. In the first such area reported from the Gulf (other areas mentioned below have been reported in the Atlantic), a single trawl produced about 100 kg (220 lbs) of corals, including Lophelia prolifera (Pallas) and Caryophyllia sp. (Moore and Bullis, 1960).

In the Atlantic, similar structures have been reported along the margins of the Straits of Florida off Miami, Palm Beach, and points farther north (Squires, 1963; Neumann and Ball, 1970). One such mound observed from a submersible in 825 m (2,700 ft) of water on the Miami Escarpment was described by Neumann and Ball (1970) as "small mounds of muddy sand capped by thickets of branching, deepwater ahermatypic corals." The uncollected species were possibly of the genera Lophelia, Madrepora, and

FIGURE 5-13.

BRIGHT BANK

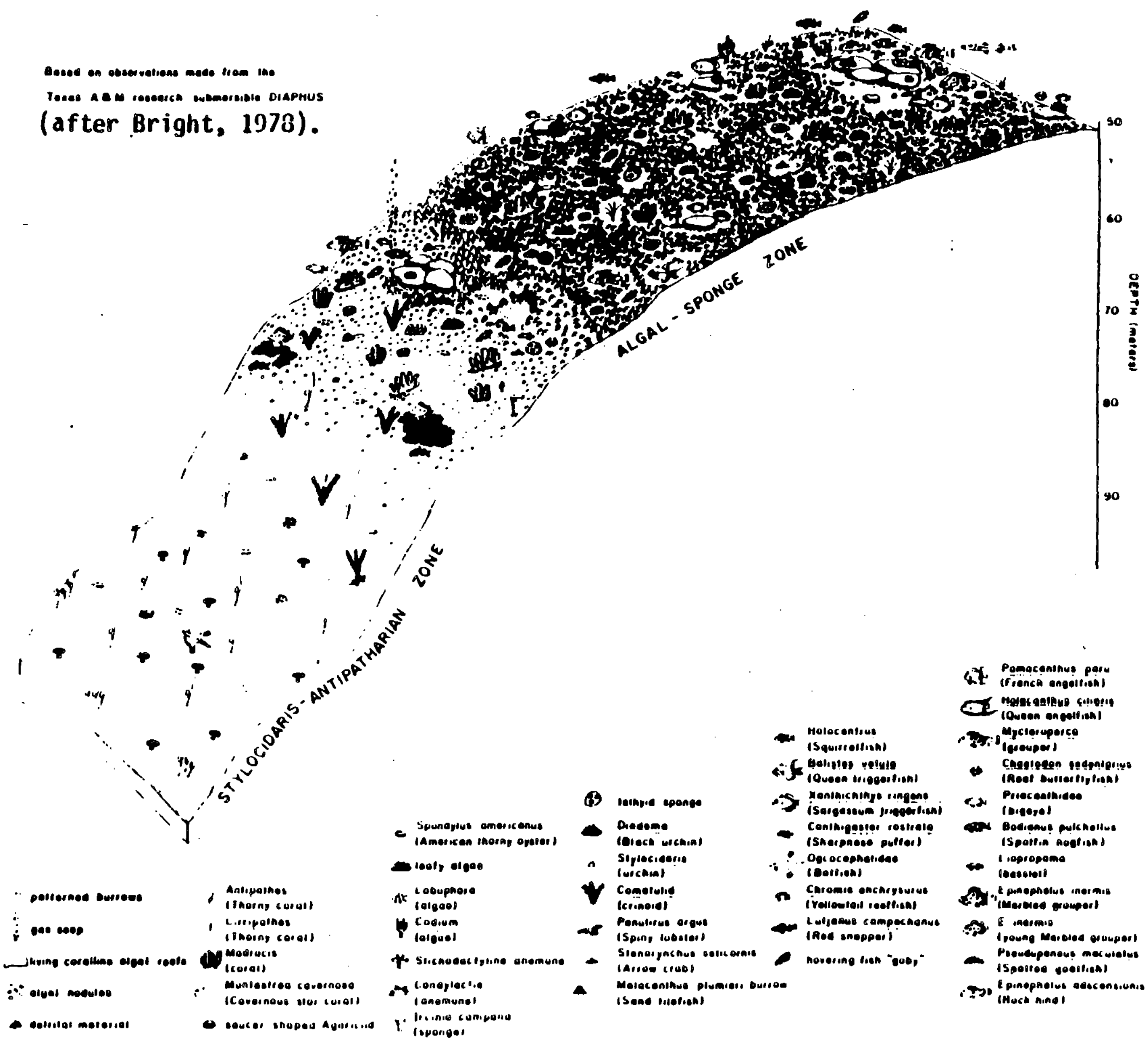


FIGURE 5-14.

BOUMA BANK

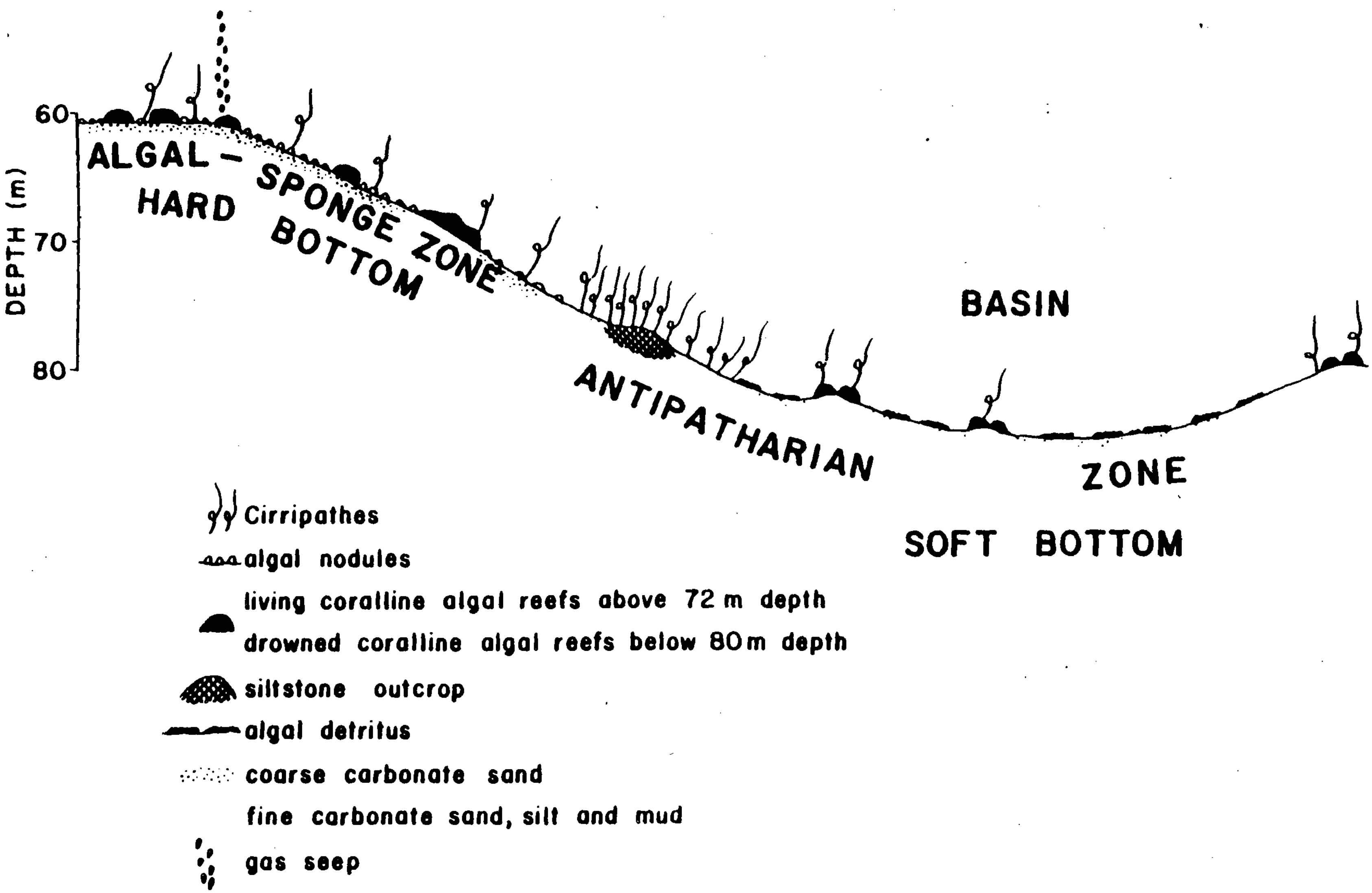


FIGURE 5-15.

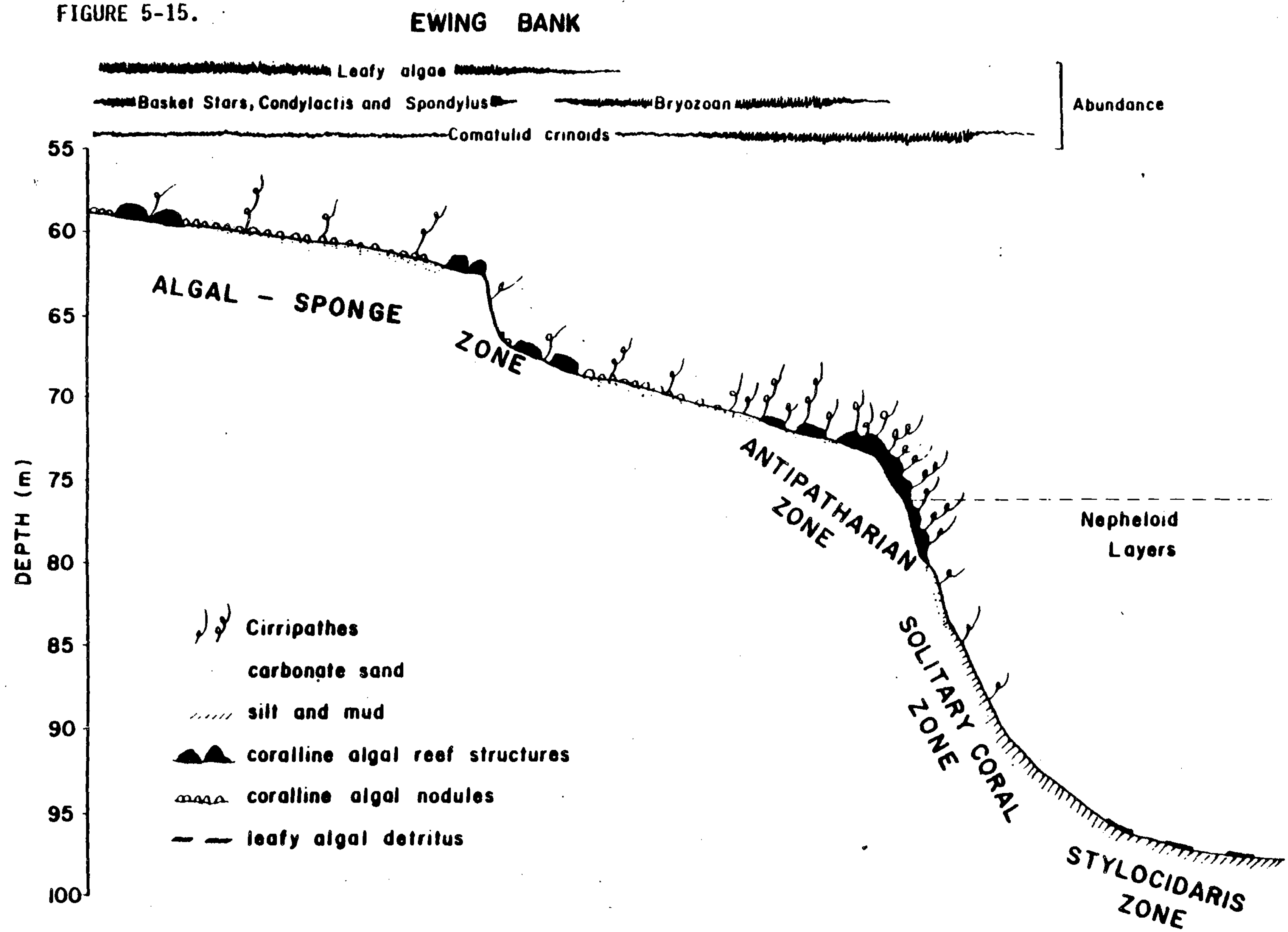

EWING BANK
Leafy algae
Basket Stars, Condylactis and Spondylus
Bryozoan
Comatulid crinoids
Abundance
DEPTH (m)
55
60
65
70
75
80
85
90
95
100
ALGAL - SPONGE ZONE
ANTIPATHARIAN ZONE
Nepheloid Layers
SOLITARY CORAL ZONE
STYLOCIDARIS ZONE
Cirripathes
carbonate sand
silt and mud
coralline algal reef structures
coralline algal nodules
leafy algal detritus

FIGURE 5-16. 18 FATHOM BANK

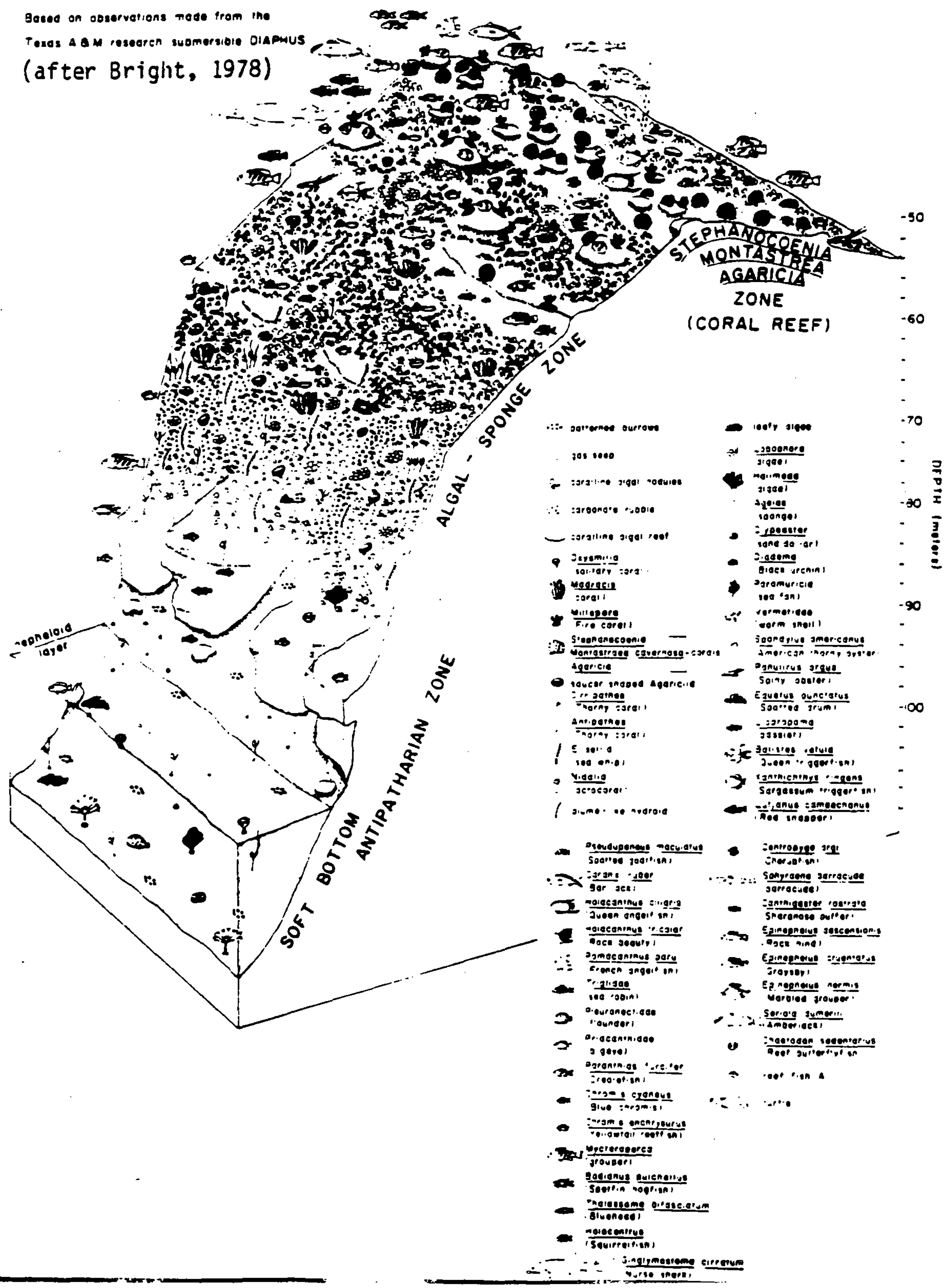
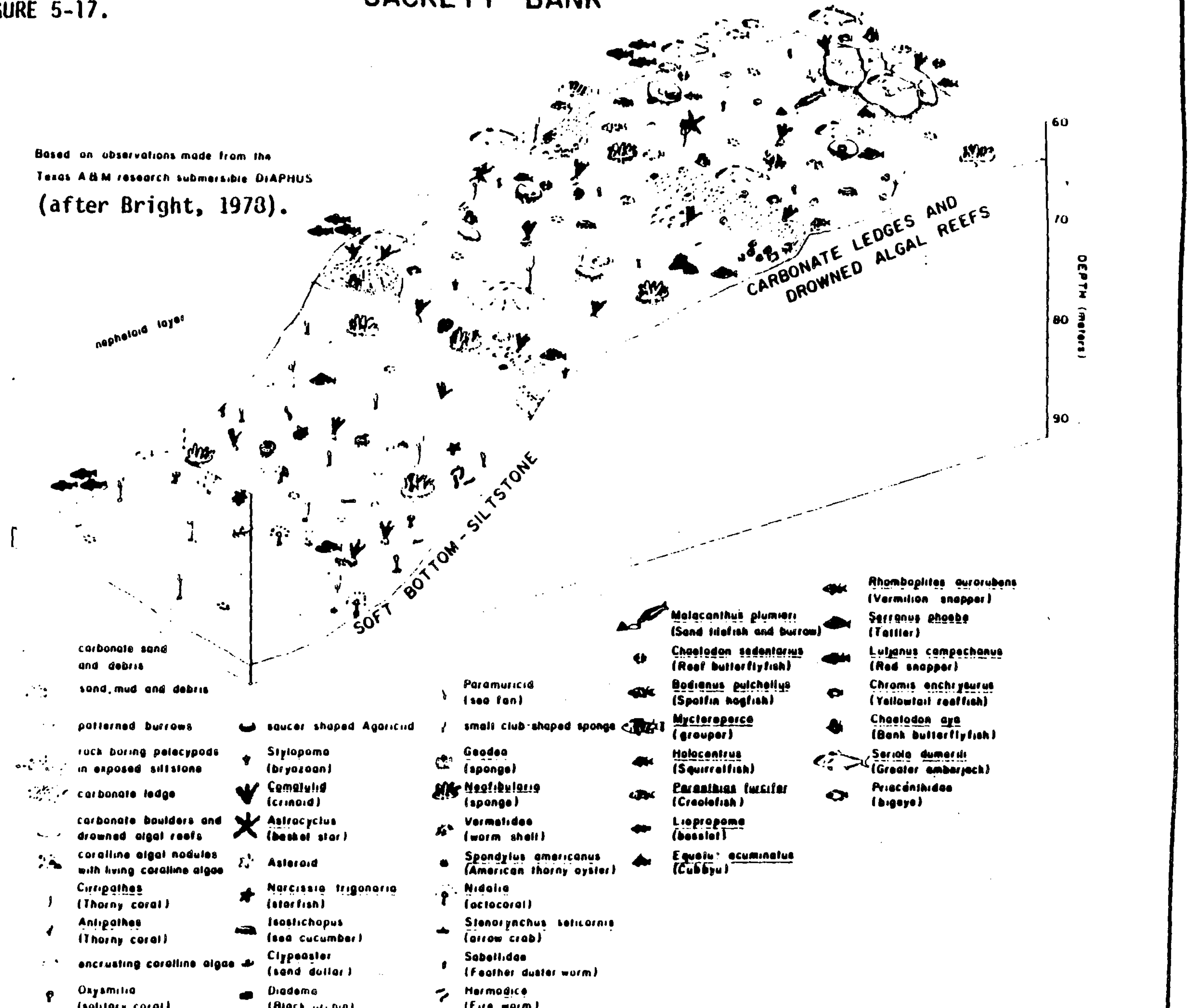


FIGURE 5-17.

SACKETT BANK



Dendrophyllia. Cairns (1979, personal communication) reviewed unworked collections at the Smithsonian Institution and has hypothesized that deepwater banks may possibly occur commonly along the Atlantic continental slope within the coral management area -- particularly around the 600 to 800 m (1,980 to 2,640 ft) depth contour. If this is true, associated deepwater corals including Enallopsammia (which Cairns believes to be the Dendrophyllia reported by earlier investigators) and Lophelia may be relatively abundant in many localized areas.

Also identified within the Atlantic coral management area are "bump areas" (Stetson, et al., 1962; Squires, 1963) located in a broad area about 370 km (200 nm) southeast of Charleston, South Carolina, in 720 to 970 m (2,350 to 3,200 ft) of water. Here, a 5,145 km^2 (1,130 nm^2) area contains thousands of "bumps" (hummocks of low relief) hypothesized to represent accumulations of coral material. As in the Straits of Florida, the corals were predominantly the branching corals Lophelia prolifera and Enallopsammia profunda.

In both the Gulf and Atlantic portions of the management area, solitary corals may also occur along the shelf flank, slope, and plain. Although solitary deepwater corals have occasionally been collected from a single trawl in numbers exceeding several hundred individuals, such collections are rare and fit no discernable pattern.

5.3 Ecological Relationships

Most coral assemblages are so complex that holistic approaches to community metabolism are useful primarily for the purpose of comparison with similar measurements made elsewhere. Therefore, most of the attention on coral reef systems has focused on metabolism and interactions of component parts. Lewis (1977) has reviewed the components which contribute to the well known high production rates on coral reefs.

Although summarized here, supplemental information on ecological relationships is included in Appendices G and H.

5.3.1 Coral Ecosystems as a Special Resource

The importance of coral ecosystems and associated habitats has been well documented by numerous studies, reviews, and symposia (e.g., Jones and Endean, 1973, 1976; Bright and Pequegnat, 1974; Taylor, 1977; Bright, Jaap, and Cashman, 1981). Many of those documents emphasize the complex structure of coral ecosystems, the importance of coral for habitat, the sedentary lifestyle and its implications, the wide geographic and bathymetric distributions, and the many behavioral, physiological, ecological, and physical associations that combine to yield an exceedingly intricate functional unit. The Fishery Conservation and Management Act recognizes these values and listed several corals as continental shelf fishery resources subject to exclusive U.S. use beyond the FCZ.

Ecosystems which include coral (solitary corals, hard bottoms or banks, lithoherms, and coral reefs; see below, Section 6.2.1) often represent unique arrays of plants and animals in a balanced, highly productive system. The key to many of these systems, if there can be one most important link, is often coral itself, since the corals provide habitat and/or food for most of the other members of the ecosystem. Connell (1973) and Grassle (1973) have studied aspects of population ecology and diversity within coral reefs (see below, Section 6.2.1). Individual biotic components have also been studied - among them, microbes (DiSalvo, 1973), algae (Cribb, 1973), holothurians (Bakus, 1973), shrimps and prawns (Bruce, 1976), echinoderms (Clark, 1976), fishes (Goldman and Talbot, 1976), and others. The resultant coral community is exceedingly complex and productive. Helfrich and Townsley (1965), Odum (1971), DiSalvo (1973), Sorokin (1973c), and others have attempted to quantify and qualify the productivity of corals and their associated biota (e.g., microorganisms) compared to other marine and terrestrial communities.

Because of their vast species diversity, trophic complexity, and productivity, mature coral communities possess numerous mechanisms that enable them to resist normal disturbances, especially those biological in nature (Endean, 1976). As classified by Sanders (1968), coral reefs may be termed biologically accommodated communities with interspecific competition and predation major determinants of stability. Shallow reef areas (less than 2 m or 6 ft) may be more appropriately termed physically controlled. Numerous other factors also play major roles in coral health (see below, Section 6.2.2.1 and 6.2.2.2). It is many of those other factors that potentially threaten the continued viability of domestic corals.

The special nature of corals as a fishery is further highlighted by their sedentary attached existence, which separates them from the subjects of many other fishery plans. Protection via escape or camouflage is limited by the design of coral skeletons and polyps. Although some protection is afforded by polyp withdrawl, strict energy budgets restrict the use of such behavior. Hence, in the midst of persistent adversity, (e.g., water pollution, cold temperatures, sedimentation), corals appear precariously susceptible.

Part of the uniqueness of the corals covered by this FMP is their position at the northernmost limits of most hermatypic corals in U.S. waters. Although the Solenastrea (stump coral) and Siderastrea (starlet coral) occur off North Carolina where bottom temperatures reach 10.6°C or 50°F (Macintyre and Pilkey, 1969), the majority of hermatypic corals and coral reef growth is limited to south of Fowey Rocks, Florida, where the temperature minimum has been recorded as 15.6°C or 60°F (Vaughan, 1918). Patch reef, hard bottom, and solitary corals do occur north of Fowey Rocks and off west Florida, but not to the extent seen off the Florida Keys, northeast of Key Largo, or southwest of Big Pine Key (Figure 6-2). Most corals inhabiting our nation's continental FCZ, especially the hermatypic specie which are less temperature tolerant, are at the very limit of their geographical range.

5.3.2 Value as Habitat

Perhaps the most valuable contribution made by corals to the marine environment is as habitat for numerous associated organisms. As described by Jones and Endean (1973, 1976), Antonius, et al. (1978), and many other researchers, a coral assemblage within the management area may support rich populations of invertebrates (corals, sponges, tunicates, echinoderms, crabs, lobsters, gastropods, etc.), vertebrates (primarily fish but possibly turtles, birds, and marine mammals), and plants (coralline algae, fleshy algae, eelgrass, turtlegrass, etc.). Wells (1957) emphasized this habitat value in defining a coral reef as "... fauna and flora ... [that] ... provide the ecological niches essential to the existence of all other reef dwelling animals and plants." Undoubtedly coral is a primary provider of niches. As two examples, consider the utilization by reef fish and spiny lobsters of coral reefs or hard bottom zones. The Florida Sea Grant College (1979) reported an annual commercial catch of reef fish in the Gulf of Mexico of about 19 million pounds (8,482 metric tons); Centaur Associates, Inc. (1979) developed a maximum sustainable yield of 7.3 million pounds (3,259 metric tons) for spiny lobsters for U.S. Gulf and south Atlantic waters. While the total catch cannot be attributed to the presence of coral reefs, the reefs do serve as an important source of habitat for these species.

The habitat diversity within a coral community is usually proportional to ecosystem diversity. Complex reef systems usually provide greater types and quantities of habitat than the more unidimensional hard bottoms. Of considerable significance in assessing value as habitat are the living and nonliving components of the ecosystem. Corals and associated benthos, e.g., sponges, tunicates, and algae, contribute most of the living habitat. Dead corals, perhaps parts of relic reefs, coral limestone, or lithified coral rock, are a most important abiotic component. Regardless of the type of substrate or source of protection, the coral community offers space for organisms ranging from epibenthic invertebrates to large fish. Those animals in turn contribute to the food chains of the entire ecosystem.

Octocorals (specifically gorgonian octocorals) are very important in the ecological balance of the reef ecoysystem. They have numerous interactions with other animals, including: functioning as a hold-fast for numerous other intertebrates; as a substrate for encrusting fire coral (Millepora); a host for parasitic organisms and symbiotic zooxanthellae; a food source for snails and marine worms and a refuge for fish and shrimp. Additionally, octocorals contribute to the general reef build-up, adding over a ton of limestone in the form of spicules per acre per year to a reef habitat (Cairns, 1977).

Data from a recent five-year study at Biscayne National Park (BNP) support the importance of octocoral habitat. Average octocoral density was as high as 58 colonies/m^2 for eight patch reefs studied within BNP (Wheaton Lowry, unpublished) whereas stony coral density averaged only 8.5 colonies/m^2 (Jaap, unpublished). Maximum linear density of octocorals was 544 for 20 m in contrast to a stony coral maximum of only 44 colonies. Tilmant, et al. (1979) reported 214 fish species from these same octocoral dominated reefs. This exceeds 134 species for Tortugas and 146 species for Pennekamp reported by Jones and Thompson (1978). These octocoral dominated reefs are thus rich in reef fish and serve not only as habitat and a focal point for a great number of important species but probably as a recruitment area for the fore reef.

Some coral assemblages in the Gulf of Mexico may be adjacent to habitat for marine turtles that have been acknowledged as threatened or endangered species by the Endangered Species Act of 1973, as amended. A January 17, 1979, listing of protected species [Federal Register 44(2):3636-3654] included the green (Chelonia mydas), Kemp's Atlantic Ridley (Lepidochelys kempii), leatherback (Dermochelys coriacea), hawksbill (Eretmochelys imbricata), and loggerhead (Caretta caretta) sea turtles from the management area.

5.3.3 Economic Values

Due to the Florida law prohibiting coral taking and the subsequent shift of supply to foreign sources, such as the Philippines, India, and Haiti, much of the current economic value derived from corals in the management area comes from the nonconsumptive recreational uses of living corals or collection of other reef resources. However, should these foreign sources decline, the monetary value of corals may rise and increase demand for harvesting corals in the management area.

Throughout the management area but especially in the Florida Keys, dive shops, glass bottom boats, reef fishing tours, snorkel trips, boat ramps, and/or tropical specimen collecting companies, emphasize the importance of corals to many local economies (see Section 10.1). It has been estimated by Davidson (1979, personal communication) that the area from Ohio Key to Sugarloaf Lodge near Looe Key, Florida, generates about eight to ten million dollars annually in marine-related income, much of it coral related. In 1978, the town of Key Largo had 13 dive shops, 22 dive boats, John Pennekamp Coral Reef State Park (including a large boat ramp and hoist, small marina, and numerous daily tours to reefs), 34 boat ramps, and 22 marinas (Office of Coastal Zone Management, 1979b). An estimated 400,000 people, many of whom visit the reefs, visit the park at Key Largo each year through the turnstiles. Park officials estimate total usage including boats from private docks and rentals may double this figure (Gillen, 1979, personal communication). Most of the users who visit the reef concentrate around Dry Rocks, Molasses Reef, and a few other select locations, not the entire park. In the northwestern Gulf of Mexico, divers pay as much as $100 each to visit the Flower Gardens coral reefs by dive boat even though the reefs are over 200 km (about 110 nm) offshore (Blood, 1978, personal communication). Industries such as tropical specimen collecting and glass bottom boat tours are also dependent on corals.

These brief examples, and the more detailed information in Sections 8.0, 9.0, and 10.0, reiterate the dependence of the coastal regions on viable coral ecosystems. Although short-term benefits may be gained by harvesting corals from the reef, extreme care must be taken to protect the long-term viability of the reef and the closely related economics of coastal counties, particularly Monroe County, Florida.

The key fact in the above discussion is the derivation of value from living corals in the natural environment rather than from any collected coral specimens (see Sections 8.1, 8.2 and 9.1 through 9.3). Collection of coral-associated biota constitutes another value that is related to corals. If managed appropriately, both consumptive use of associated biota and nonconsumptive uses of corals and coral reefs should not be detrimental to the environment or any user group's economic well-being. Preservation of existing fisheries that are related to corals should be of vital economic concern. For example, the reef fish and spiny lobster harvests in the Gulf of Mexico FCZ were valued at approximately $9,832,000 (Florida Sea Grant College, 1979) and $8,636,000 (Centaur Associates, Inc., 1979), respectively.

5.3.4 Buffer Values

Coral reefs occurring along southern Florida, and indeed throughout the world, are markedly affected by patterns of water circulation. The most highly developed reefs in the management area are the Florida reefs, confined to the windward or southeastern margins of the land masses (Glynn, 1973; Shinn, 1976). Less developed coral communities and other distinguishable biotic assemblages, e.g., grass beds, frequently occur leeward of the reef barriers (see location of reefs and grass/algae beds in Figure 6-4).

The protection offered by land from cross-platform currents (Ginsburg and Shinn, 1964) is mirrored by the buffer provided islands by relic and/or live coral reefs. Offshore reefs help dissipate storm energies and serve to minimize impacts of storms, wave action, and other physical stresses.

The net result of these two buffering systems is a peculiar, abiotic "symbiosis" -- islands protect corals by shielding away cold water and low salinity flows from the Florida Bay and eastern Gulf and the corals protect land masses and nearshore communities from oceanic effects. As a result, the distribution of coral reefs parallels the distribution of islands (Shinn, et al., 1977).

Protection offered by corals may be crucial to the existence of other shallow-water, continental shelf communities. Coastal Florida, and elsewhere in the management area, is represented by a band of grasses shoreward of the coral reefs. These beds of turtle grass (_Thalassia testudinum_), manatee grass (_Syringodium filiforme_), and shoal grass (_Halodule wrightii_) represent highly productive communities (Helfrich and Townsley, 1965), on which numerous species, e.g., spiny lobster (Herrnkind, 1979, personal communication; Davis, 1979, personal communication) and commercial finfish (Weinstein and Heck, 1979), depend for development and recruitment. Fishes and other species also use the beds as prime foraging grounds. Another coastal community protected to a lesser extent by the corals are mangroves, which along with grass beds, are crucial to nutrient flows in the coastal environment. Lastly, many less developed coral communities, categorized as solitary corals or hard bottoms (see Section 6.1.1.1 and 6.1.1.2), shoreward of the coral reefs are also spared from storm damage. Although not as prominent as massive coral reefs, grass beds, mangroves, and small coral assemblages are all important components of the coastal ecosystem. Without the buffer of coral reefs, those three zones would be exposed to unusually destructive forces. Also, without grass beds and mangroves to assist in filtering sediments, coastal waters would deposit particulates on corals and other bottom dwellers.

5.3.5 Sources of Energy

Scleractinian and alcyonarian corals derive energy from several sources including from sunlight through their photosynthetic, symbiotic zooxanthellae (algae living in the coral tissue), from consumption of zooplankton, from bacteria (which act as biochemical recycling agents), from consumption of detritus, and perhaps even directly from dissolved organics. Antipatharian corals such as _Cirripathes_ apparently rely heavily upon stinging nematocysts to feed upon animal tissues, although plant material has been noted in the gut of black corals. These energy sources are detailed in Appendix G.

5.3.6 Predators and Associations

As described in detail in Appendix H, corals are subject to the ecological pressures of predation (by fish and invertebrates), competition for space, and other interactions with associated organisms. In some instances, such as the symbiotic relationship of corals to zooxanthellae, the association is mutually beneficial. At the other end of the spectrum, however, are predatory pressures such as those applied by certain reef fishes and invertebrates that eat corals.

5.4 Biological Factors and Maximum Sustainable Yield

Maximum sustainable yield (MSY) is the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. Calculation of MSY depends upon catch and effort data, or biological data on growth rates, mortality rates, abundance, density, and biomass among other items.

Two facts concerning this coral FMP -- over 400 species and a lack of data - necessitate grouping similar corals to yield an MSY for a type of coral. Hence, biological factors and MSY are discussed below for two general coral groups: octocorals (gorgonians, precious corals, etc.) and stony corals (fire coral, rose coral, branching corals, brain corals, etc.).

MSY is incalculable except as MSY* at Biscayne National Park (see Section 5.4.9).

5.4.1 Growth and Size

5.4.1.1 Octocorals (Gorgonians, Precious Corals)

The published data on gorgonian growth has been determined from work on the black sea rod (Plexaura homomalla). Kinzie (1974) calculated a range of growth rates of 1.0 to 40 mm (0.05 to 1.6 in) yr^{-1} with a mean increase in height of 20 mm (0.8 in) yr^{-1}. In that same study, Kinzie also noted that colonial growth in terms of height need not be mirrored by growth of new branch tips. Mature P. homomalla colonies are 25 to 35 cm (10 to 14 in) high with multiple branches arising from a single stem (see Figure 5-10); other gorgonians in the management area attain sizes averaging 18 cm (7 in) up to 2.25 m (7.4 ft) (Cairns, 1977a). These measurements parallel data collected by Wheaton Lowry (in preparation) off Biscayne National Park.

Research on the precious black, bamboo, and pink corals (see Table 5-10) has been restricted because of their occurrence in deep waters. Other than Cirripathes lutkeni, which lives at 20 to 174 m (66 to 535 ft), most other corals in this category occur below 200 m (660 ft).

As shown in Table 5-10, growth and size data for the precious corals in the management area is represented only by the work of Goldberg (1977) on Cirripathes lutkeni.

5.4.1.2 Stony Corals (Fire Corals, Branched Scleractinians, Brain Corals, etc.)

Growth data for stony corals is concentrated on the scleractinian species, especially the branched reef corals (Acropora spp.) and the head corals (Montastraea and others). Limited information is available on deepwater species and the hydrocorals. Growth in terms of stock size and number of colonies is not limited to new corals initiated by settling larvae; Shinn (1979, personal communication) and others have noted that many stony corals including the branched corals (Acropora spp.) may regenerate from small pieces remaining after damage to or destruction of a larger colony.

Much of the growth data on the branched scleractinians comes from Acropora palmata (elkhorn), A. cervicornis (staghorn), and A. prolifera (fused staghorn). Generally, these corals have different growth rates dependent upon temperature (A. palmata and A. prolifera), placement in the reef zone

TABLE 5-10. Growth rates and sizes of precious black, pink, and bamboo corals. Data presented for species in the management area and in the Pacific. References as noted.

SPECIES	GROWTH RATE (mm/yr)	COLONY SIZE (Height in m)	GROWTH MEASUREMENT TECHNIQUE	REFERENCE
In Management Area:				
Cirripathes lütkeni (Black coral)	50-100	up to 7	skeletal ring analysis	Goldberg (1977)
Corallium medea (Pink coral)	--	~ 0.5	--	Cairns (1979, personal communication)
Corallium niobe (Pink coral)	--	~ 0.5	--	Cairns (1979, personal communication)
Leiopathes glaberrima (Black coral)	--	up to 1.2	--	Cairns (1979, personal communication)
In Pacific Waters:				
Corallium secundum (Pink coral)	90	up to 0.6	skeletal ring analysis	Grigg (1976)
Gerardia sp. (Gold coral)	--	up to 0.25	--	Western Pacific Fishery Management Council (1979)
Lepidisis sp. (Bamboo coral)	--	up to 0.30	--	Western Pacific Fishery Management Council (1979)

(A. palmata), and geographic area (A. cervicornis) (Gladfelter, et al., 1978). Growth rates of Acropora in the management area and on Caribbean reefs range from 34 to 266 mm per year for A. cervicornis, 47.3 to 105 mm per year for A. palmata, and 59.2 to 81.8 mm for A. prolifera. Those rates are lower if expressed solely for corals in the management area (Table 5-11).

Gladfelter, et al. (1978) found that calcification rates (the amount of calcium carbonate deposited per unit branch perimeter) in Acropora palmata were independent of temperature yet dependent upon zonation; 0.85 g per cm per year in the backreef, 1.66 in the shallow forereef, and 1.35 in the deeper forereef were typical.

The data of Shinn (1966) and Gladfelter, et al. (1978) indicate that Acropora spp. growth rates in terms of linear extension are higher in the warm fall months than in cooler spring months. Similarly, corals in the management area may exhibit slower growth rates than the same species in warmer climates (see, e.g., A. cervicornis data in Table 5-11).

Growth data for other shallow-water scleractinians (brain corals and finger corals) has been summarized by Bright, et al. (1981) and Gladfelter, et al. (1978). Generally, growth rates for these species (see Table 5-12) are only ten to 20 percent that of Acropora spp.

Most growth rates for Montastraea, Porites, and Diploria summarized in Table 5-12 are less than 10 mm (0.2 in) per year, excepting the work of Lewis, et al. (1968) in the Caribbean. Rates between geographic areas are more consistent than observed in Acropora. Also, rates recorded by Gladfelter, et al. (1978) at the backreef (2 m) and deep forereef (10 m) of Buck Island, Virgin Islands, indicated that depth did not affect growth; both portions of the reef had identical average growth rates of 7.6 mm (0.3 in per year based on colonies ranging in size from 9.63 cm^2 to 138 cm^2 (1.5 to 23 in^2).

Highest density bands of Montastraea annularis seem to be deposited in the warmest months of the year (Hudson, et al., 1976).

Although not quantified, several references to Millepora and Manicina aerolata growth rates have conveyed the preliminary conclusion that growth rates on suitable hard surfaces are quite high. Recently discarded bottles, rocks, and other debris may be covered by Millepora alcicornis or other stinging corals within several months to a year. Prior to the existing Florida coral law, several collectors have suggested rapid recolonization in the rose coral M. aerolata in Florida Keys waters. Limited data indicate that growth may be rapid in the first three to four years and much slower thereafter (Vaughn, 1911, 1916).

Data on growth rates of deepwater scleractinians within the management area are practically nonexistent. Hence, to provide a source of comparison, growth data on corals from other geographic areas are presented (Tables 5-13 and 5-14). One species in the tables, Lophelia prolifera, is located in the management area on deepwater banks.

In general, growth rates observed in these limited reports are significantly lower than growth rates reported above for shallow-water corals in the management area. In the absence of area-specific data, the growth and weight information in Tables 5-13 and 5-14 may be assumed to be a fair approximation of deepwater scleractinian growth in the south Atlantic and Gulf of Mexico.

5.4.2 Mortality Rates

Most of the information on natural or human-related mortalities of corals in the management area is in accounts of destruction related to storms, groundings, etc. These qualitative reports relay limited information on death of a coral area (e.g., "many head corals near the grounding were overturned and smashed") and occasionally certain species (e.g., "the 13°C water killed 90 percent of the staghorn

Table 5-11. Growth rates of branched scleractinians (Acroporidae) based on research done on the spe throughout the Caribbean and south Atlantic. References as noted. Growth measured as linear extension, i.e., growth in length.

SPECIES	LOCATION (DEPTH)	GROWTH RATE (mm/yr)	TEMPERATURE RANGE (0°C)	STUDY DURATION	MEASUREMENT TECHNIQUE	CITATION
Acropora cervicornis	Key Largo Dry Rocks (2 m)	109	20 - 30.5	2/61-1/62	Plastic-banded branches, measured in situ	Shinn (1966)
	transplant to coral patch Key Largo (3.5 m)	43	17.2-32.8	2/61-2/62	Plastic-banded branches, measured in situ	Shinn (1966)
	transplant to nearer shore Key Largo (1 m)	34	13.3-33.8	2/61-2/62	Plastic-banded branches, measured in situ	Shinn (1966)
	Dry Tortugas	40			Removed and measured, then returned	Vaughan (1915)
	Buck Island, Virgin Islands	71	26	2/10/77-4/5/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
	Barbados (10 m)	146	--	full year	Direct	Lewis, et al. (1968)
	Jamaica	266	--	full year	Direct	Lewis, et al. (1968)
	Bahamas	45	--	--	Direct	Vaughan (1915)
	Eastern Sambo Reef, Florida	115	--	--	Direct	Bright, et al. (1981)
Acropora palmata	Backreef, Buck Island, Virgin Islands (0.5 m)	58.5	29.5	8/5/77-9/30/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
		55.4	26.0	2/10/77-4/5/77		
	Shallow forereef, Buck Island, Virgin Islands (0.5 m)	82.7	29.5	8/3/77-9/30/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
		47.3	26.0	1/20/77-4/5/77		
	Deep forereef, Buck Island Virgin Islands (9 m)	99.3	29.5	8/3/77-9/30/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
		65.4	26.0	1/20/77-4/5/77		
	Curacao	88.0	--	--	Direct	Bak (1976)
		76.0	--	--	Direct	Bak (1976)
	Eastern Sambo Reef, Florida	105	--	--	Direct	Bright, et al. (1981)
Acropora prolifera	Backreef, Buck Island, Virgin Islands (2 m)	81.8	29.5	9/15/77-11/16/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
		59.2	26.0	1/11/77-4/5/77		
Oculina varicosa	Fort Pierce, (6 m) Florida	11.3	13.7-31	6/78 - 6/79	Tie wrap banded branches, Alizarin stain	J. Reed (1981)
	(80 m)	16.0	7.4-26.7			

Table 5-12. Growth rates for unbranched scleractinians. References are listed. Growth measured as linea extension, i.e., growth outward from base (stain, spike, etc.) in diameter.

SPECIES	LOCATION (DEPTH)	GROWTH RATE (mm/yr)	TEMPERATURE (0°C)	STUDY DURATION	MEASUREMENT TECHNIQUE	REFERENCE
Montastraea annularis	Backreef, Buck Island, Virgin Islands (2 m)	8.3	29.5	8/12/77-11/10/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
	Same (2 m)	6.6	--	1/13/77-5/6/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
	Deep forereef. Buck Island V. I. (10 m)	7.0	29.5	8/12/77-11/5/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
	Same (10 m)	8.9	26.0	1/18/77-5/5/77	Alizarin Red S stain procedure	Gladfelter, et al. (1978)
	Carysfort Reef Key Largo, Fla.	8.4	--	12/11/60-8/6/71 (10 yrs. 8 mos.)	Imbedded spike in skeleton	Shinn (1976)
	Carysfort Reef Florida (3 m)	10.7	--	3 years	Direct	Hoffmeister and Multer (1974)
	Florida	5.0-6.8	--	--	Direct	Vaughan (1916)
	Curacao	8.0	--	--	Direct on intact colonies	Bak (1976)
	Jamaica (10 m)	6.7			Alizarin Red S	Dustan (1975)
	Barbados (10 m) (transplanted)	19.2	--	--	Direct	Lewis, et al. (1968)
	Jamaica (transplanted)	25.0	--	--	Direct	Lewis, et al. (1968)
	Buck Island, Virgin Islands	7.3-8.8	--	18 years of corings	X-radiography	Hudson and Shinn (unpublished) in Gladfelter, et al. (1978)
	Forereef, back-reef, patch reef Key Largo, Fla. (2-10 m)	8.0-9.7	16-32	75 years of data	X-radiography	Hudson (1981)
	East Flower Garden Bank	6.5-9.0	18-26	50 years of data	X-radiography	Hudson and Robbin (1980)
	St. Croix, Virgin Islands (3-7 m)	9.2-10.4	--	--	X-radiography	Baker and Weber (1975)
	Jamaica (0-15 m)	6.2-8.8	--	--	X-radiography	Aller and Dodge (1974)

Table 5-12 (continued)

SPECIES	LOCATION (DEPTH)	GROWTH RATE (mm/yr)	TEMPERATURE (0°C)	STUDY DURATION	MEASUREMENT TECHNIQUE	REFERENCE
Montastraea annularis (continued)	British Hondorus and Florida	6.6-8.7	--	--	X-radiography	Macintyre and Smith (1974)
	East Sambo Reef, Florida	7.0	--	--	--	Bright, et al. (1981)
	Near Key West, Florida	9.0	--	--	--	Agassiz (1890) Bright, et al. (1981)
	Fort Jefferson, Dry Tortugas, Florida	7.0	--	--	--	Vaughan (1914)
	Bermuda	8.0	--	--	--	Iams (1969) Bright, et al. (1981)
	Bahamas, Goulding Cay	6.0	--	--	--	Vaughan (1914)
	Jamaica	8.8	--	--	--	Dodge, et al Bright, et a (1981)
	Jamaica	16.0	--	--	--	Lewis, et al. (196 Bright, et al. (1981)
Porites astreoides	Backreef, Buck Island,	3.53	29.5	9/9/77-11/15/77	Alizarin Red S	Gladfelter, et al. (1978)
	Virgin Islands (2 m)	3.36	26.0	1/13/77-5/6/77		
		3.36	26-29.5	9/76-5/77		
	Deep forereef Buck Island, Virgin Islands (10 m)	3.00	26.0	1/26/77-5/5/77	Alizarin Red S	Gladfelter, et al. (1978)
	Caribbean	3.0-3.4	--	--	--	Lewis, et al. (1968
Porites porites	Caribbean	36	--	--	--	Lewis, et al. (1968
Porites spp.	Caribbean	20-40	--	--	--	Lewis, et al. (1968
Diploria strigosa	Carysfort Reef Florida	5.0	--	12/11/60-8/6/71 (10 yrs 8 mos)	Imbedded spike in skeleton	Shinn (1976)

TABLE 5-13. Deeper-water scleractinian growth rates based on colonies attached to undersea cables near Norfolk Island, Australia (29°20'00"S, 168°07'35"E; 800 nmi or 1480 km east of Brisbane). Legend: A = based on data from a 17-year old cable; B = from a 30-year old cable. Weights based on dry weight of cleaned corallum (i.e. skeleton). (From Squires, 1960).

SPECIES	A HEIGHT (mm/yr)	A WEIGHT (gms/yr)	B HEIGHT (mm/yr)	B WEIGHT (gms/yr)
<u>Caryophyllia profunda</u>				
Specimen A	2.02	0.57	1.15	0.32
B	1.55	0.42	0.88	0.24
C	1.96	0.39	1.11	0.22
Average	1.84	0.46	1.05	0.26
<u>Goniocorella dumosa</u>	2.94	0.77	1.67	0.44
<u>Culicia australiensis</u>	0.46	---	0.26	---
<u>Tubastrea aurea</u>				
Specimen A	1.82	1.16	1.03	0.66
B	3.16	4.50	1.79	2.52
Average	2.49	2.83	1.41	1.59

TABLE 5-14. Summary of growth data from deepwater scleractinians on undersea cables. References as noted. (Adapted from Squires, 1960).

SPECIES	CABLE DEPTH (m)	CABLE LOCATION	CABLE AGE (yrs)	NO. OF SPECIMENS	GROWTH RATE (mm/yr)	REFERENCE
Caryophyllia electrica	2000-2800	Mediterranean	2*	10	2.5*	Milne-Edwards (1861)
Caryophyllia arcuata	2000-2800	Mediterranean	2	1	---	Milne-Edwards (1861)
Lophosmilia telegraphicus	2000-2800	Mediterranean	2*	1	5.0*	Milne-Edwards (1861)
Lophelia prolifera	---	Off Spain	6	--	7.5	Pratje (1924)
Lophelia prolifera	1139-1200	North Atlantic	6	--	6.8	Duncan (1877)
Desmophyllum cristagalli	1139-1200	North Atlantic	6	1	7.1	Duncan (1877)
Solenosmilia variabilis	1139-1200	North Atlantic	6	--	---	Duncan (1877)

*These data are based on a cable age of 2 years. However, the cable age was actually 3 years. Therefore, the growth rates reported by Milne-Edwards are probably too high. Assuming the rates are a average of two years of growth, the values may be reclaculated for 3 years: Caryophyllia electrica - 1.67 mm/yr and Lophosmilia telegraphicus - 3.33 mm/yr.

corals, Acropora cervicornis, at Dry Tortugas," Davis, 1979, personal communication). Such conversational data represents the best available information. General aspects of coral mortality are discussed in the work of Antonius (1975, 1976, 1977, and in press).

One quantitative study was that of Antonius, et al. (1978) at Looe Key, Florida. Dive transects and inspections of the reef-building corals were transformed in to a "percent dead" number: patch reefs (ten percent); reef flat (25 percent); fore reef (ten percent); and deep reef (22 percent). The total at the Looe Key study area was 13 percent dead. These data are presented by species in the report.

Grigg (1976) calculated the annual instantaneous natural mortality rate of pink coral (Corallium secundum) in the Makapuu Bed off Hawaii to be 0.066 or 6.6 percent.

Natural massive mortalities of staghorn coral (Acropora cervicornis) at Dry Tortugas have been observed on two occasions: 1878 when nearly 100 percent of the colonies died because of unidentified "black water" (Vaughan, 1911) and in 1976 to 1977, when a winter cold front killed about 90 percent of the staghorn corals (Davis, 1979, personal communication).

The work of Jaap (1979, personal communication) at Biscayne National Park also provides some insight into coral mortalities. By measuring recruitment, Jaap has quantified net changes in 4 m^2 quadrants. Negative net changes (see Table 5-16) show mortality.

Other discussions of mortalities are reflected in the description of the present health of corals (Section 6.2).

5.4.3 Abundance and Density

Insufficient data exist on which to base calculations of the total amount or percent coverage of corals in the management area. At best, estimates may be made by extrapolating from small scattered studies, such as the work of Walter Jaap and Jennifer Wheaton Lowry at Biscayne National Park, however, their data are not representative of the entire management area. Qualitative statements on the distribution and abundance of corals may be made under similar confidence limits. Coral reefs are very limited in distribution, perhaps to less than one percent of the total management area; patch reefs cover slightly more area than outer bank reefs. Deepwater banks again account for less than one percent, probably less than the coral reefs. Most of the corals in the management area occur in hard bottom areas or as solitary specimens.

5.4.3.1 Octocorals

Wheaton Lowry (in preparation), Opresko (1973), and Goldberg (1973a), have detailed abundance and diversity for octocorals in the southeastern Florida and Florida reef tract areas. Very limited information exists for the remainder of the management area.

At Biscayne National Park (Schooner, Elkhorn, Star, and Dome reefs), Jaap and Wheaton Lowry (in press), surveyed octocoral abundance and density by transect, species count, and photographic analysis. Octocoral colonies usually comprised more than half of the total coral colonies (Table 5-15), i.e., octocorals were more abundant than stony corals in a 1977 survey. In 1978, a similar pattern of octocoral predominance was found but the total number of species was slightly lower. The five most abundant species (53.9 percent of total octocorals) were Plexaura flexuosa, P. homomalla, Gorgonia ventalina, Eunicea succinea, and Pseudopterogorgia americana.

Mean numbers of octocoral colonies counted along a 20 m (66 ft) transect of the eight reefs listed in Table 5-15 in 1977 and 1978, respectively, were 102.81 and 155.17 (Wheaton Lowry, in preparation).

Octocoral densities were surveyed by Wheaton Lowry (in preparation) by dive counts and photographic analysis at Biscayne National Park. The 1977 results, as dive counts per quadrant, were 27.41 colonies/m^2 (range 16.00 to 46.50); in 1978, photo plot counts were 26.28 colonies/m^2 (range 9.75 to 50.00). By both methods, Schooner Reef and its control exhibited highest densities compared to the other three reef pairs.

Opresko (1973), based on field study at Soldier Key, Boca Chita Pass, and Red Reef, calculated mean densities of gorgonians of 11.3, 6.9, and 27.1/m^2 respectively. Most common genera at the three areas were Eunicea, Pterogorgia, Pseudopterogorgia, Briareum, and Plexaura; densities of those species are listed in Table 5-17.

The only other density information for octocorals is from off Palm Beach County, Florida. Goldberg (1973) reported an average density of 25.1 colonies/m^2. No data were given on abundance in that area. Several researchers noted the high numbers of sea pansies (Renilla) taken in trawls in the northeastern Gulf of Mexico but no quantitative data exists. Holland, et al. (1977) reported the species to be abundant in patches at 30 m (100 ft) off the Texas coast.

5.4.3.2 Stony Corals

Data on abundance and density of stony corals in the management area are presented in Bright and Pequegnat (1974), Bright and Abbott (in Bright and Rezak, 1978), Jaap (1979), and Jaap (in preparation). As listed in Table 5-15, stony corals comprise only about 21 to 22 percent of the coral biota at eight reefs in Biscayne National Park. The most common five species are Porites astreoides, Millepora alcicornis, Porites porites, Montastraea annularis, and Siderastrea siderea.

Based on 25 m (80 ft) diver transects, stony coral abundance at the Biscayne reefs in 1977 and 1978 averaged 25.06 and 26.95 colonies, respectively (Jaap, in preparation).

Stony coral densities recorded at Biscayne National Park at eight locations were 7.53 colonies/m^2 in 1977 (quadrant sampling; range 0 to 23) and 6.16 colonies/m^2 in 1978 (photographic analysis; range 2 to 16) (Jaap, in preparation). At the Dry Tortugas, Wells (unpublished) gave densities of shallow-water stony corals ranging from 2.79 to 9.15 colonies/m^2.

In the northwest Gulf of Mexico, Bright and Pequegnat (1974) reported 30 to 40 percent live stony coral cover at the peak of West Flower Garden Bank. Bright and Abbott (in Bright and Abbott, 1978) observed 60 to 65 percent live stony corals at East Flower Garden Banks.

5.4.4 Diversity

5.4.4.1 Octocorals

Once again, most of the data on diversity has been done by Wheaton Lowry (in preparation) in Biscayne National Park. Highest octocoral diversities along a single 20-m (66-ft) transect were 3.2 at Schooner Reef Control in 1977 and 3.98 at the same reef in 1978. Calculations using the H'n Shannon-Weaver species diversity index were relatively high, mostly above 3.00.

5.4.4.2 Stony Corals

Species diversity for stony corals at Biscayne National Park (Table 5-16) was comparably lower than that for octocorals (Jaap, in preparation; Jaap, 1979). Whereas many transects revealed octocoral diversities of over 3.00, the highest stony coral diversities (Shannon-Weaver H'n) were 2.80 at Star Reef in 1977, 3.33 at Dome Reef in 1978, and 3.06 at Schooner Reef in 1979; diversity values remained

TABLE 5-15. Octocoral and stony coral abundance and percent composition per $1m^2$ quadrat at four experimental reefs and adjacent control reefs in 1977 and 1978 at Biscayne National Park. Variability between years attributed to inconsistency in sampling techniques (after Jaap and Smith, in preparation).

Reef Name	Octocoral Colonies		Stony Coral Colonies		Total of all Corals		Percent Octocorals		Percent Stony Corals	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
Elkhorn	66	39	28	20	94	59	70.2	66.1	29.8	33.4
Elkhorn control	186	86	42	33	228	119	81.6	72.3	18.4	27.7
Schooner	149	61	38	21	187	82	79.7	74.4	20.3	25.6
Schooner control	182	100	36	14	218	114	83.5	87.7	16.5	12.3
Star	70	77	54	15	124	92	56.4	83.7	43.6	16.3
Star control	67	110	9	16	76	126	88.2	87.3	11.8	12.7
Dome	64	N/A	16	23	80	N/A	80.0	----	20.0	----
Dome control	93	N/A	18	16	111	N/A	83.8	----	16.2	----
TOTALS	877	473	241	119	1118	592	----	----	----	----
AVERAGES	--	--	--	--	--	--	77.9	78.6	22.1	21.4

under 3.00 in all but four cases for the three years combined. Compared to other regions (see Loya, 1972; Porter, 1972; Ott, 1975), these diversities are lower for stony corals. At the 96 m^2 surveyed in Biscayne National Park, H'n ranged from 0.47 to 3.06, H'max from 1.58 to 3.46, evenness J' from 0.30 to 0.94 (Table 5-16).

5.4.5 Age

Age data on corals include scattered reports on the age of living corals and relic reefs. In the relic reefs underlying the Florida reef tract, Shinn, et al. (1977), calculated accumulation rates and ages (± standard deviation) by Carbon-14 dating of drill cores from six reef sites (see Figure 5-6 for map):

Site	Accumulation Rate (m/1,000 yrs)	Age (yrs)
1. Bal Harbor	0.38	6,300 ± 120
2. Sewer Trench	0.74	4,930 ± 70
3. Long Reef	0.65	5,630 ± 120
4. Carysfort Reef		
- 4.0 m depth	0.86	4,570 ± 85
- 7.3 m depth	1.39	5,250 ± 95
5. Marker G Reefs		
- 3.1 m depth	0.49	6,170 ± 80
- 4.6 m depth	0.56	7,160 ± 85
- 8.2 m depth	-	37,480 ± 1,300
6. Ft. Jefferson National Monument (Dry Tortugas)		
- 9.1 m depth	1.91	4,762 ± 85
-13.7 m depth	2.28	6,017 ± 90

These data confirm the thickness and ages of coral rock in relic reefs. The corals present varied between sites but included Siderastrea, Monstastraea annularis, M. cavernosa, Colpophyllia, and Diploria. Acropora palmata, long considered a major reef-builder in Florida, was absent in most reefs drilled.

Shinn (1979), in a coring survey at the Grecian Rocks off Key Largo, stated that the growth rates of Montastraea sp. indicate 1 m (3.3 ft) of upward growth in less than 150 years.

In Makapuu Bed, Hawaii, the Western Pacific Fishery Management Council (1979) calculated the "critical age" at which coral growth gains are overtaken by natural mortality losses. For the pink coral (Corallium secundum), that age was 31.4 years, which corresponds to an average colony weight of 237 g (8.2 oz).

5.4.6 Reproduction and Recruitment

Reproductive and recruitment capabilities of corals in the management area have been studied at Biscayne National Park and the Flower Garden Banks. Ongoing research on eight reefs in the Park has quantified changes in marked plots between the summers of 1978 and 1979 (Jaap, 1979, personal communication). Data compiled for Pacific corals are also presented.

Table 5-16. Preliminary data on recruitment (1978 to 1979) for eight reefs in Biscayne National Park, including four reefs at mooring buoys (see Figure 6-6) and four control reefs near the buoys. Data based on changes in colonies and species in $4m^2$ (four $1m^2$ adjacent plots) as determined by diver examination. Range, mean, standard deviation, and diversity data are calculated from the four individual $1m^2$ and expressed for the entire $4m^2$ plot. H'n = Shannon-Weaver Index; H'max = number of species x log base^2; J' = evenness; NC = no change. (From unpublished data of Jaap, 1979, personal communication.)

Reef Sampled and Plot Number	TOTAL Colonies	TOTAL Species	CHANGE Colonies	CHANGE Species	RANGE Colonies	RANGE Species	MEAN Colonies	MEAN Species	STAND. DEVIATION Colonies	STAND. DEVIATION Species	H'n	H' max	J'
Elkhorn Plot 1-1	26	6	-3	-2	3-10	3-5	6.50	4.00	2.89	0.82	2.23	2.58	0.87
Elkhorn Plot 1-2	45	7	+10	+1	8-17	1-6	11.25	3.25	4.03	2.2[illegible]	1.61	2.81	0.57
Elkhorn Plot 1-3	34	3	+14	NC	6-13	1-3	8.50	2.00	3.11	0.82	1.04	1.58	0.66
Elkhorn Plot 1-4	26	3	-1	-4	4-11	2-3	6.50	2.50	3.32	0.50	1.20	1.58	0.76
Elkhorn Control Plot 1-6	69	7	+20	NC	8-37	3-7	17.25	5.00	13.52	1.63	2.28	2.81	0.81
Elkhorn Control Plot 1-7	67	6	+34	-2	7-24	3-5	16.75	4.00	7.50	0.82	1.78	2.58	0.69
Elkhorn Control Plot 1-8	49	6	+33	NC	7-17	3-5	12.25	3.50	4.27	1.00	1.79	2.58	0.69
Elkhorn Control Plot 1-9	40	9	+24	+5	5-16	3-7	10.00	4.50	4.55	1.91	2.03	3.17	0.64
Schooner Plot 2-1	29	5	-7	-2	2-12	2-4	7.25	3.00	4.27	0.82	2.06	2.32	0.89
Schooner Plot 2-2	27	7	+7	+2	5-9	3-5	6.80	3.80	1.71	0.96	2.36	2.81	0.84
Schooner Control Plot 2-6	27	10	+4	+1	4-10	4-6	6.75	5.00	3.20	1.15	3.06	3.32	0.92
Schooner Control Plot 2-7	26	3	+6	-1	5-11	1-2	6.50	1.50	2.00	0.58	0.47	1.58	0.30
Star Plot 3-1	29	8	+7	NC	5-10	2-6	7.25	4.25	2.06	1.71	2.57	3.00	0.86
Star Plot 3-2	30	9	+4	NC	6-9	3-6	7.50	4.50	1.29	1.29	2.77	3.17	0.87
Star Plot 3-3	35	8	+12	+1	6-11	3-5	8.75	4.25	2.06	0.96	2.31	3.00	0.77
Star Control Plot 3-6	25	5	+2	NC	2-12	1-5	6.25	2.25	4.35	1.89	1.32	2.32	0.57
Star Control Plot 3-7	25	7	-10	-3	4-8	2-5	6.25	3.50	2.06	1.29	2.18	2.81	0.77
Star Control Plot 3-8	26	6	+11	NC	5-10	1-4	6.50	2.63	2.38	1.19	1.66	2.58	0.64
Dome Plot 4-1	22	9	+8	+1	2-9	2-6	5.50	4.00	2.89	1.83	2.99	3.17	0.94
Dome Plot 4-2	26	7	NC	NC	4-8	2-5	6.50	3.75	1.73	1.26	2.26	2.81	0.80
Dome Plot 4-3	20	6	-1	-3	2-10	2-3	5.00	2.50	3.46	0.58	1.91	2.58	0.74
Dome Control Plot 4-6	22	5	+7	NC	4-7	2-5	5.50	3.25	1.29	1.26	1.86	2.32	0.80
Dome Control Plot 4-7	32	11	+4	+2	4-12	3-6	8.00	5.00	3.27	1.41	2.92	3.46	0.85
Dome Control Plot 4-8	35	8	+19	+3	3-15	2-7	8.75	4.25	4.92	2.06	2.39	3.00	0.80

Preliminary results of the research of Walter Jaap at Biscayne National Park are presented in Table 5-16. Recruitment can be calculated from the "change" column, which quantified differences in the numbers of colonies and species between the summers of 1978 and 1979. The results are variable, ranging from an addition of 34 colonies at Elkhorn Plot 1-7 or five species at Elkhorn Plot 1-9 to a loss of ten colonies at Star Plot 3-7 or four species at Elkhorn Plot 1-4. Generally, recruitment did not appear to differ between control and experimental reefs. However, some plots (e.g., Elkhorn Controls 1-6 to 1-9) did have exceptionally high changes.

Spawning in rose coral, Manicina aerolata, apparently occurs in late spring to early summer in Florida waters (Boschma, 1929; Yonge, 1935).

Pink corals in Hawaiian waters apparently reach sexual maturity at a height of about 12 cm (4.7 in) or an age of 13 years ((Grigg, 1976). The reproductive cycle is annual with spawning taking place in June and July.

Based on the assumption of steady state recruitment of the Makapuu Beds off Hawaii (Western Pacific Fishery Management Council, 1979), an estimate of recruitment was obtained by calculating the quantity of coral lost via mortality. In a system in equilibrium, the rates should be equal. The estimate of annual recruitment to Makapuu for pink coral was 5,227 colonies (Western Pacific Fishery Management Council, 1979). Fluctuations between year classes are probable. There is some indication that the assumption of an equilibrium state may not be valid in coral reefs.

5.4.7 Distribution

Data on the areal distributions of corals in the management area are lacking. Isolated collection records pinpoint locations of certain species but convey little information on the area of a stony coral bed. This fact in combination with the paucity of abundance data in many regions prevents a realistic calculation of standing stock and biomass.

5.4.8 Biomass

Biomass calculations are possible where data for a particular area are available for: 1) total area (A) of the coral bed; 2) density (D) as colonies per m^2; and 3) average weight (W) per colony. This information may be used to estimate living biomass (B_o) of an unfished stock,

$$B_o = A \times D \times W$$

Several assumptions are inherent in calculating B_o. First, weights per colony vary greatly depending on the species and its age. In recognition of this problem, typical weights have been deduced from the literature (Table 5-17). Second, since weights include both living and dead tissues, an estimate of percent living tissue in a colony must be made. This again is dependent upon species and size but is herein restricted to a colony of typical weight. Hence, it has been assumed that three percent of the weight of typical stony corals and four percent of typical gorgonians are alive. Using the estimated typical weights and the data of Jaap and Smith (in preparation) and Opresko (1973), total and living biomass calculations have been made for several communities in the Florida reef tract (Table 5-18).

By comparison, the Western Pacific Fishery Management Council (1979) determined the total biomass of pink coral (Corallium secundum) to be 43,500 kg for the Makapuu Bed (3.6 km^2 in area, or about 20 times the area of Elkhorn Reef) or 0.01 kg/m^2 total biomass. The lower biomass in the Hawaiian bed reflects the great differences in colony weight between the stony corals and gorgonians.

Table 5-17. Summary of dry weight data used to determine typical weights per coral colony.

SPECIES	OBSERVED WEIGHT RANGE (kg)	AVERAGE WEIGHT (kg)	TYPICAL WEIGHT (kg)	SOURCE
Diploria clivosa	<1 to 100 or higher	--	4.0	Jaap (1979, pers. comm.)
Porites proites	0.001 to 1.0	0.10	0.10	Jaap (1979, pers. comm.)
Porites astreoides	0.001 to 0.797	0.10	0.10	Jaap (1979, pers. comm.)
Eunicea succinea succinea	max. 0.23	0.06		Opresko (1973)
E. s. plantaginea	max. 0.02	0.01		Opresko (1973)
E. tourneforti tourneforti	max. 0.36	0.17	0.22	Opresko (1973)
E. t. atra	max. 1.45	0.73		Opresko (1973)
E. calyculata subsp. with lip	max. 0.39	0.13		Opresko (1973)
E. calyculata without lip	max. 0.67	0.46		Opresko (1973)
Pterogorgia citrina	max. 0.12	0.03	0.07	Opresko (1973)
P. anceps	max. 0.23	0.08		Opresko (1973)
Pseudopterogorgia acerosa	max. 1.27	0.32	0.28	Opresko (1973)
P. americana	max. 0.80	0.10		Opresko (1973)
Briareum asbestinum	max. 0.28	0.05	0.05	Opresko (1973)
Plexaura homomalla	max. 2.38	0.15	0.16	Opresko (1973)
P. flexuosa	max. 0.94	0.18		Opresko (1973)
Pseudopterogorgia bipinnata	max. 0.08	0.01		Opresko (1973)
P. rigida	max. 1.99	0.67	0.13	Opresko (1973)
P. acerosa	max. 0.24	0.06		Opresko (1973)
P. americana	max. 0.86	0.09		Opresko (1973)

TABLE 5-18. Calculations of tissue (skeletal and living) and biomass (total and per m^2) for gorgonians at three reef locations and stony corals at Elkhorn Reef. See text for discussion of calculations and assumptions.

LOCATION	SPECIES	AREA SURVEYED (m^2)	DENSITY (colonies/m^2)	TYPICAL DRY WEIGHT (kg)	TOTAL BIOMASS (kg)	TOTAL LIVING BIOMASS (kg)	LIVING BIOMASS per m^2 (kg)	TOTAL BIOMASS per m^2 (kg)	SOURCE
Elkhorn Reef	*Diploria clivosa*	16	0.50	4.0	32.0	9.6	0.6	2.0	Jaap (in prep.)
	Porites porites	16	1.00	0.10	1.6	0.5	0.1[7]	0.1	Jaap (in prep.)
	Porites astreoides	16	1.25	0.10	2.0	0.6	0.1[7]	0.1	Jaap (in prep.)
Soldier Key	*Eunicea* spp.[1]	64	5.70	0.22	80.3	32.1	0.5	1.3	Opresko (1973)
	Pterogorgia spp.[2]	64	4.18	0.08	21.4	8.6	0.1	0.3	Opresko (1973)
Boca Chita Pass	*Pseudopterogorgia* spp.[3]	16	4.00	0.28	17.9	7.2	0.4	1.1	Opresko (1973)
Red Reef	*Briareum* spp.[4]	64	5.82	0.05	18.6	7.4	0.1	0.3	Opresko (1973)
	Plexaura spp.[5]	64	6.02	0.16	61.6	24.7	0.4	1.0	Opresko (1973)
	Pseudopterogorgia spp.[6]	64	4.40	0.13	36.6	14.6	0.2	0.6	Opresko (1973)

Footnotes:

1 Includes *E. succinea*, *E. tournefortI*, and *E. calyculata*

2 Includes *P. citrina* and *P. anceps*

3 Includes *P. acerosa* and *P. americana*

4 Includes only *B. asbestinum*

5 Includes *P. homomalla* and *P. flexuosa*

6 Includes *P. bipinnata*, *P. rigida*, *P. acerosa*, and *P. americana*

7 Quantity actually less than 0.1 kg

5.4.9 Maximum Sustainable Yield (MSY)

The lack of sufficient data on biomass and mortality, and the absence of a fishery from which catch and effort data may be obtained, prevents any calculation of MSY for the entire management area. An estimated MSY (MSY*) has been determined for several species at specific reefs in the Florida reef tract, but cannot be expanded to other corals due to great differences in species, density, growth rates, and other factors. Using the data presented in Table 5-18, an approximation of MSY may be calculated for several communities. The calculation uses the method developed by Gulland (1970), and applied by the Western Pacific Fishery Management Council to its coral resources:

$$MSY^* = 0.4\, M \times B_o$$

0.4 = a constant with no units attached

M = mortality

B_o = living biomass = A x D x W

Applicability of MSY* for Gulf and south Atlantic corals generated from this equation is remote. The probability of error in the estimates of MSY are enhanced by using mortality data from Hawaiian precious coral, biomass data for Floridian stony and gorgonian corals, and a constant derived for fisheries quite different than corals. This constant may range in value from 0.17 to 0.95; 0.4 was selected to be consistent with the Western Pacific Council's plan. To show how alternate mortality and biomass values could affect MSY*, sensitivity analyses were run on the corals for which MSY* was calculated (Table 5-19). The sensitivity test examines the changes in MSY* when mortality or biomass are reduced by one quarter (-.25y), one half (-.5y), or three quarters (-.75y), or increased by one half, 100 percent (1y), or 200 percent (2y).

As shown in Table 5-19, MSY* per m^2 for corals varies dependent upon the different M and B_o values. No one set of values may be selected as more realistic than others with the existing data. Hence, a range is the most appropriate way to state MSY* per m^2. The range may be derived from the first and last columns in Table 5-19.

Table 5-19. MSY* calculations standardized as kg/m^2/yr dry weight and sensitivity analyses for alternate mortalities (M) and biomasses of living tissue (B_o). Symbols x and y refer to B_o and M for each species from Table 5-18. Due to the equation, values of MSY* are identical within one sensitivity level for one species regardless of which variable, B_o or M, is altered, i.e., .25x(y) equals .25y(x).

SPECIES	B_o: M:	x -.75y	x -.50y	x -.25y	x y	x +.50y	x +1y	x +2y
Diploria clivosa (brain coral)		0.0040	0.0079	0.0119	0.0158	0.0237	0.0316	0.0474
Porites astreoides (finger coral)		0.0007	0.0013	0.0020	0.0026	0.0039	0.0052	0.0078
Porites porites (finger coral)		0.0007	0.0013	0.0020	0.0026	0.0039	0.0052	0.0078
Eunicea spp. (octocoral)		0.0033	0.0066	0.0099	0.0132	0.0198	0.0264	0.0396
Pterogorgia spp. (octocoral)		0.0007	0.0013	0.0020	0.0026	0.0039	0.0052	0.0078
Pseudopterogorgia spp. (octocoral) (Boca Chita Pass, Florida)		0.0027	0.0053	0.0080	0.0106	0.0159	0.0212	0.0318
Pseudopterogorgia ssp. (octocoral) (Red Reef, Florida)		0.0007	0.0013	0.0020	0.0026	0.0039	0.0052	0.0078
Briareum spp. (corky sea finger)		0.0027	0.0053	0.0080	0.0106	0.0159	0.0212	0.0318
Plexaura spp. (black sea rod)		0.0013	0.0027	0.0040	0.0053	0.0080	0.0106	0.0159

Source: From data of Jaap (in preparation) and Opresko (1973).

Very few data exist on MSY* for corals outside the management area. Generally, other areas suffer from the same lack of information encountered in this FMP. MSY* has been calculated by the Western Pacific Fishery Management Council (1979) for three corals in Makapuu Bed, Hawaii (Table 5-20).

Table 5-20. Estimates of MSY* (landed dry weight) via the Gulland method for three corals in the Makápuu Bed of Hawaii (area of 4,500,000 m^2).

SPECIES	Total MSY* (kg/yr)	MSY* ($kg/m^2/yr$)
<u>Corallium secundum</u> (pink coral)	1,148	0.000255
<u>Gerardia</u> sp. (gold coral)	313	0.000070
<u>Lepidisis</u> sp. (bamboo coral)	285	0.000063

Source: Western Pacific Fishery Management Council, 1979.

5.5 Probable Future Conditions

The information available on productivity and health (see Sections 5.4 and 6.1) enable several curso statements to be made:

1) Coral growth rates are so slow in most species that recovery rates following large-magnitude harvest, human impact, or natural stresses are far slower than observed in most other living resources. In most respects many corals may be considered as a nonrenewable resource.

2) Human impacts that have been identified as possible limiting factors in coral health, do not appear to be subsiding. Many chronic problems such as shipping bilge discharges, industrial and recreational pollution, and sewage could become larger problems in the future even with implementation of this plan.

3) Natural stresses continue to act on portions of the management area where species occur at or near their geographical limits.

Despite the data gaps already mentioned, several recent efforts have generated preliminary data for use in indicating any future trends. Coring studies at Key Largo National Marine Sanctuary indicate that coral growth rates have increased in the past decade (Hudson, 1981). Whether or not that improvement is attributable to management practices is masked by the discovery by Hudson in the same study that cyclical coral growth may be normal. Studies at Biscayne National Park have shown concentrated damage to coral immediately adjacent to several mooring buoys (Tilmant, 1979, personal communication).

Perhaps the approach of directing users to particular areas may be detrimental to objectives of preserving corals. Conversely, limited damage in high use areas may decrease damage to other areas and enhance overall coral management efforts. Quantifying these impacts is difficult. The variability in apparent impact is summarized in Table 5-16; total counts of corals and diversities between buoyed and control plots reveal no pattern in all 24 plots.

One future determinant of coral health in the management area is the status of stocks in nations that export corals to the United States, i.e., the Philippines and a few others. The possibility that coral exports from the Philippines may be curtailed or even stopped could redirect resource pressures to domestic stocks. A Philippine law may have severely restricted the exportation of corals since 1977 (see Section 7.1.1 of this plan). Thus far, the law appears not to have been enforced.

To allow a realistic assessment of future conditions, it appears mandatory that a multiyear survey of coral growth, stress factors, and management practices be initiated on a species- and area-specific basis. These data are a minimal base from which estimates of future conditions could be made and supported. This subject is discussed below in Section 14.4.

Because corals in the FCZ have until recently been protected and managed by the Bureau of Land Management and the fact that they are now unprotected is not generally understood; the stocks are presently in a good but precarious position. Massive harvest of stony corals and destruction of coral reefs could occur at any time.

A recent expansion of the effort for snapper and grouper has introduced various types of bottom fishing gear directed at those fishes closely associated with hard bottoms and reefs. Roller trawls, bottom longlines, and fish traps are used in this fishery frequently in proximity to coral and coral reefs where the fish congregate. Although gear may be lost when it becomes entangled in coral, the competition among fishermen for a finite resource has increased fishing effort in all areas thus increasing the incidental damage to corals and coral reefs. Similarly the high recreational fishing level increasingly subjects coral bottoms to injury from anchoring by small boats and vessels.

Octocorals other than sea fans are being harvested for aquarium use in a small fishery off Florida without apparent damage to the stocks. Because they are a rich source of hormone material, the possibility exists for harvest of substantial amounts for experimental or even commercial purposes. One American pharmaceutical company estimated its annual need to be ten tons per year of Plexaura homomalla for use in extraction of prostaglandin for medical research. This material was harvested in the Cayman Islands. On Bache Shoal in Biscayne National Park about four acres would be needed to yield ten tons of this coral, but if selectively pruned to allow (rapid) regrowth, the amount of reef area required might be increased by tenfold or more (Bayer and Weinheimer, 1974). The stocks can most likely provide adequate material for experimental research purposes, but may not be able to sustain an extended commercial market should one develop. In either case, local depletion could occur as the result of localized harvest of large numbers of colonies.

6.0 DESCRIPTION OF HABITAT

6.1 Geographical Range of Habitat Types

Coral reef communities or solitary specimens exist throughout the geographical areas of authority of both Councils. This wide distribution places corals in oceanic habitats of corresponding variability, from nearshore environments to continental slopes and canyons, including the intermediate shelf zones. Habitats supporting corals and coral-associated species are discussed below in groupings based on their physical and ecological characteristics.

Dependent upon many variables (see Sections 5.3 and 6.2.2), corals may dominate a habitat (e.g., coral reefs), be a significant component (e.g., hard bottoms), or be individuals within a community characterized by other fauna (e.g., solitary corals). Geologically and ecologically, the range of coral assemblages and habitat types is equally diverse (see, e.g., James, 1977). The coral reefs of shallow warm waters are typically, though not always, built upon coralline rock and support a wide array of hermatypic and ahermatypic corals, finfish, invertebrates, plants, and microorganisms. Hard bottoms and hard banks, found on a wider bathymetric and geographic scale, often possess high species diversity but may lack hermatypic corals, the supporting coralline structure, or some of the associated biota. In deeper waters, large elongate mounds called deepwater banks, hundreds of meters in length, often support a rich fauna compared to adjacent areas. Lastly are communities including solitary corals. This category often lacks a topographic relief as its substrate, but instead may use a sandy bottom, for example.

This discussion divides coral habitats (i.e., habitats to which coral is a significant contributor) into five categories - solitary corals, hard bottoms, deepwater banks, patch reefs, and outer bank reefs (defined in Table 5-1). The order of presentation approximates the ranking of habitat complexity based upon species diversity (e.g., zonation, topographic relief, and other factors). Although attempts have been made to generalize the discussion into definable types, it must be noted that the continuum of habitats includes many more than the five distinct varieties discussed below. However, in compliance with existing knowledge, the following categories will suffice.

6.1.1 Solitary Corals

Throughout much, if not all, of the management area, research has located bottom communities which include corals as a minor component of biotic diversity (for example, Giammona (1978) in the Gulf of Mexico and Cairns (1979) in the Atlantic). Although these solitary corals (see definition in Table 5-1) contribute benthic relief and habitat to communities throughout the fishery conservation zone, they apparently comprise a minor percentage of the total coral stocks in the management area.

6.1.2 Hard Bottoms

Hard bottoms (see definition in Table 5-1) constitute a group of communities characterized by a thin veneer of live corals and other biota overlying assorted sediment types. Hard bottoms on banks are topograhic highs or salt domes created by geologic uplifting; they have vertical relief measured in tens of meters (Bright and Rezak, 1978). Hard bottoms are usually of low relief and on the continental shelf (Bright, et al., 1981); many are associated with relic reefs where the coral veneer is supported by dead corals.

This grouping of coral habitats is one of the most widely distributed of the five categories identified above, being common throughout the management area. Hard bottoms or banks have been described by Hopkins, et al. (1977), and Giammona (1978), in the Gulf of Mexico; Goldberg (1973a) and Bright, et al. (1981), off southeastern Florida; off the coasts of southeastern states (Johnston, 1976); off Georgia and South Carolina (Stetson, et al., 1962; Porter, 1978, personal communication; Thomas, 1978, personal communication); and North Carolina (Huntsman, in press; MacIntyre and Pilkey, 1969).

Ecologically and geologically, hard bottoms and hard banks are two diverse categories. Both habitats include corals but typically not the carbonate structure of a patch or outer bank coral reef nor the lithified rock of lithoherms, a type of deepwater bank (see discussions below). Diverse biotic zonation patterns have evolved in many of these communities because of their geologic structure and geographic location. Hard bottoms are common on rocky ledges, overlying relic reefs, or on a variety of sediment types. In each case, species compositions may vary dependent upon water depth and associated parameters (light, temperature, etc.). Hard banks nearly always exhibit zonation patterns, as depicted in the Figures 5-8 to 5-17, and a much larger vertical relief than hard bottoms (Bright and Rezak, 1976 and 1978).

Shelf-edge banks occur off central eastern Florida at depths of 70 to 100 m, with relief up to 25 m and covered with massive, contiguous colonies of O. varicosa (1 to 2 m in height). Some of the pinnacles are covered entirely with dead Oculina debris. At 3 to 50 m depths solitary colonies (<30 cm diameter) of O. varicosa grow on limestone ledge systems (1 to 3 m relief) that parallel the coast of Florida (Reed, 1980b).

Hard bottoms and banks in different geographical areas support different coral assemblages. In the Gulf of Mexico, where water temperatures and other factors affect hermatypic coral growth, ahermatypic corals prevail. Agaricia (lettuce coral) and Madracis bearing zooxanthellae are abundant in the algal-sponge zones of "group three" banks identified in the northwestern Gulf of Mexico (see Table 5-8 and accompanying discussion). Some hermatypic species have been collected in hard bottoms in the Florida Middle Grounds; Hopkins, et al. (1977) categorized those assemblages as "hermatypic coral communities." Grimm and Hopkins (1977), described the scleractinian and octocorallian diversity of that region while Bright and Rezak (1978) described the hard banks in the northwestern Gulf. The only hard banks reported in the northeastern Gulf were the "deepwater coral structures" located by Moore and Bullis (1960) east of the Mississippi River Delta in 390 to 505 m (1,280 to 1,650 ft). Near the Florida Keys, hard bottoms co-exist as underdeveloped reefs nearshore and seaward of the outer bank reef tract. North of Fowey Rocks off southeastern Florida, hard bottoms include all types of corals, though hermatypic species are near their northern limit (see, for example, Goldberg, 1973a). Coral communities from Florida north to North Carolina, are dominated by ahermatypic species (gorgonians, Oculina), although some hermatypic species do occur off North Carolina (MacIntyre and Pilkey, 1969), and Georgia (Hunt, 1974). The corals on the hard banks off North Carolina near the 720 and 990 m (2,230 to 2,970 ft) isobaths consist primarily of Lophelia prolifera and Enallopsammia profunda, but also Bathypsammia spp., Caryophyllia clavus, and Balanophyllia spp. (Stetson, et al., 1962).

6.1.3 Deepwater Banks

The existence of deepwater banks called lithoherms in the Straits of Florida off Little Bahama Bank has been reported in the literature by Moore and Bullis (1960), Neumann, Keller, and Kofoed (1972) and Neumann, Kofoed and Keller (1977). As defined by Neumann, et al. (1977), lithoherms are deepwater structures composed of surface hardened layers of lithified sandy carbonate sediments supporting a regionally diverse array of benthic fauna. Other types of deepwater banks may not be hardened but do support varying amounts of corals.

True lithoherms are located predominantly beyond the outer edge of the continental shelf on the continental slope. Although their distribution is still being delineated, these structures have been identified only in the western south Atlantic region, especially within Bahamian national waters (Figure 6-1). Some lithoherms do, however, occur near the outer edge of the FCZ. Neumann, et al. (1972, 1977), encountered lithoherms at 600 to 700 m (1,988 to 2,310 ft) in the northeastern Straits of Florida, along the base of the Little Bahama Banks; Wilber (1976), analyzed the petrology and environmental setting of some banks on the flank of the Little Bahama Bank.

Neumann, et al. (1977), in describing a lithoherm in the Straits of Florida, listed the ahermatypic

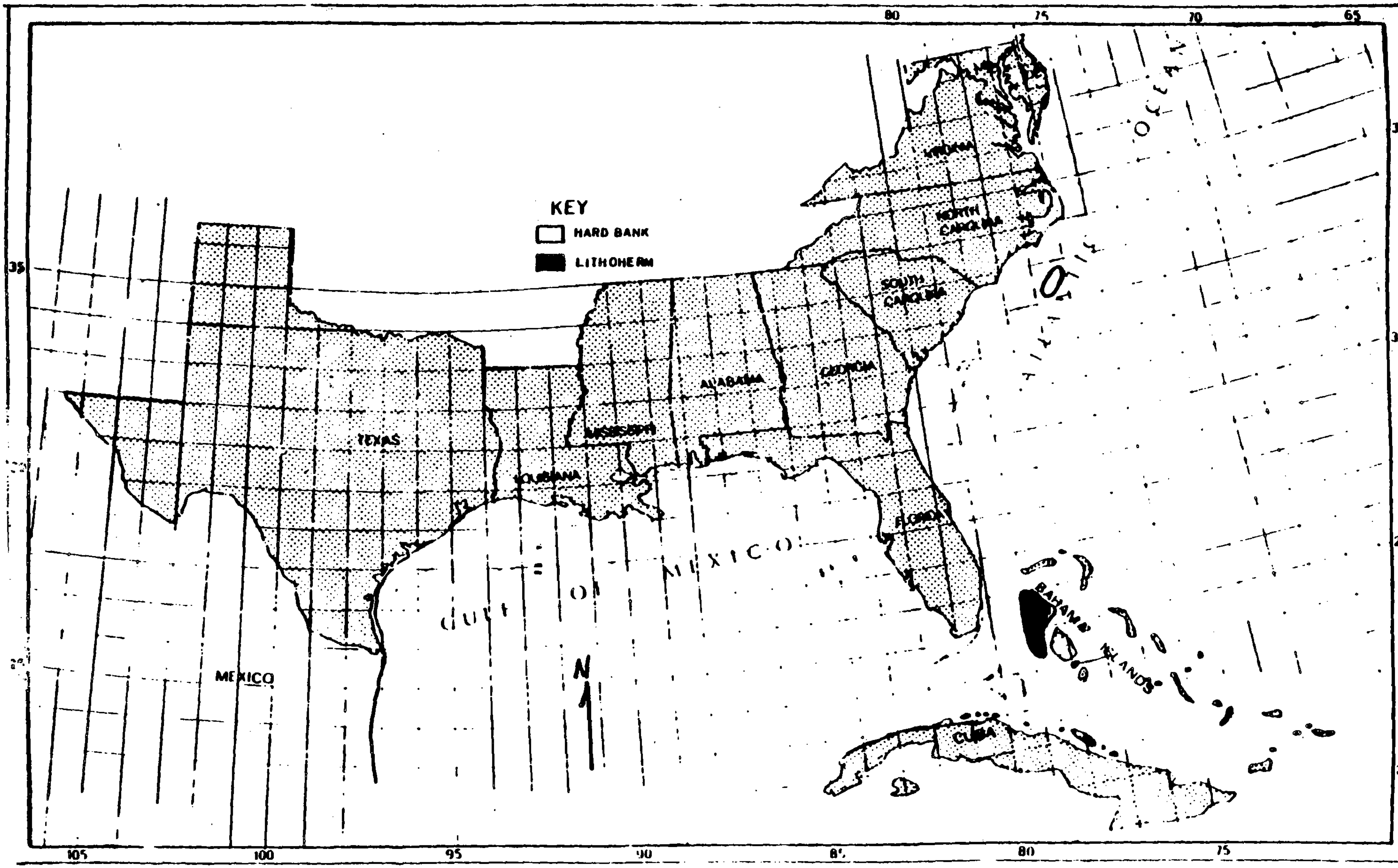


FIGURE 6-1. Known distribution of deep water hard banks and lithoherms in the south Atlantic (after Macintyre and Pilkey, 1969; Neumann et al., 1977).

branching corals, Lophelia prolifera and Enallopsammia profunda, as the chief contributors to structure and habitats. As noted by James (1977) and others, sponges and other invertebrates also add to bottom relief, species diversity, and total available habitat. Wilber (1976), emphasized the roles of corals, alcyonarians, sponges, and crinoids in baffling, binding, and trapping sediments to the lithoherm.

Deepwater banks may occur in a variety of shapes. Among the formations observed are rocky mounds 30 to 40 m (100 to 133 ft) high and hundreds of meters long (Neumann et al., 1977); or individual mounds or "haystacks" (Hurley, Siegler and Fink, 1962). Because of accumulated sediments, seismic profiles are often necessary to unmask the true lithified interior of some lithoherms (Wilber, 1976).

Banks have been found to vary greatly in vertical and horizontal dimension. Depending upon age, rates of sedimentation and lithification, currents, and species composition, banks may show a topographical expression ranging from a few meters to as much as 144 m (475 ft), as quoted by Stetson, et al. (1962). These differences alter water flow over the structure and hence biotic zonation (Lang, 1979, personal communication). Within this category of coral assemblages, the word lithoherm is often confused with other terminologies. The precise definition of lithoherm identifies banks accumulated by sustained chemical precipitation, i.e., lithification, that is thought to be facilitated by upward-moving, deep, cold water, as on the eastern side of the Straits of Florida. In contrast, most hard banks in the Gulf of Mexico are actually salt domes with a different origin. Bioherms, another term applied to rock structures resembling lithoherms, may appear similar to lithified structures, but are actually quite different.

6.1.4 Patch Reefs

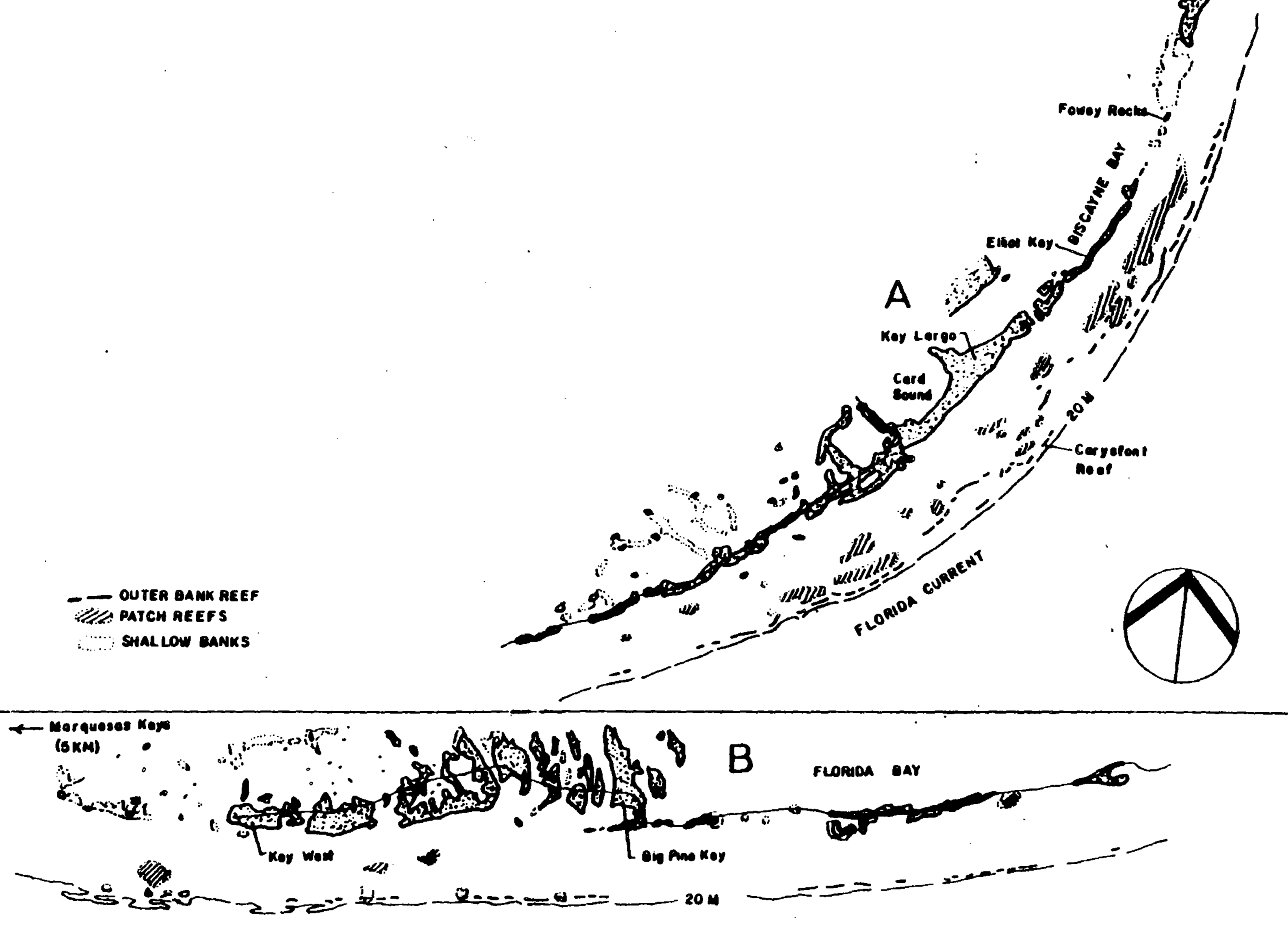
As defined in this FMP (see Table 5-1), patch reefs are diverse coral communities typified by the presence of hermatypic (reef-building) and ahermatypic species. Patch reefs differ from consolidated outer bank reefs by their smaller size and lower scale of vertical relief.

These are usually distributed irregularly in clusters nearshore in warm waters like the Florida Keys, (Marszalek, et al., 1977). However, as defined in Table 5-1, many coral assemblages occurring at the Dry Tortugas, in the Keys, or north of Miami, are more appropriately called hard bottom communities.

In south Florida, patch reefs as defined herein, have been the subject of studies by Marszalek, et al. (1977) and Jones (1977), among others. More than 6,000 patch reefs occur in the Florida reef tract between Miami and the Marquesas Keys, (Marszalek, et al., 1977); most of those patches occur between Hawk Channel and the outer bank reefs, i.e., in a general strip 3 to 7 km (1.6 to 3.8 nm) offshore (Figure 6-2). Typically, patch reefs form on coralline rock or another suitable substrate such as coral rubble (Marszalek, et al., 1977).

Geologically, patch reefs tend to form in two patterns - dome and linear - although transitional shapes occur, (Marszalek, et al., 1977). Dome-type reefs are roughly circular to elliptical as viewed from above. Most reefs of this type exhibit well-developed sandy bottom halos around their fringes. [Randall (1965), Ogden, Brown and Salesky (1973), Jones (1977), identified sea grass grazing around coral assemblages by sea urchins (for example, Diadema antillarium), parrot fish (family Scaridae) and other biota, plus current scouring as possible causes of halo formation]. From above, a trend toward clustering with limited territoriality is easily perceived, i.e., although the domes are grouped, some distance is maintained between individual patch reefs. Most dome patch reefs have less than 5 m (17 ft) of topographic relief, but some as high as 9 m (30 ft) do occur. Linear-type reefs are usually situated seaward of dome-type patch reefs parallel to the outer bank reefs. In top view, linear patch reefs appear acuate to linear, much like the true outer coral reefs of the Florida reef tract. Hence, instead of forming clusters, these patch reefs often occur end-to-end.

FIGURE 6-2. Distributions of coral reefs in the Florida Reef Tract, (A) Fowey Rocks south to Tavernier Creek and (B) Tavernier Creek south to the Marquesas Keys (after Marszalek et al., 1977).



The distribution of patch reefs, dome- and linear-type, is not uniform in southern Florida waters. Due to the clustering of dome-type reefs, the relationship of the linear-type reefs to coral reefs, and numerous stresses (water temperature and sewage effluents, for example; see Section 6.2.2), patch reefs are most abundant in the upper Keys (Table 6-1; Figure 6-2).

Table 6-1. Patch reef distribution in the Florida reef tract.

Area		Approx. no. patch reefs
Fowey Rocks to Broad Creek (Key Largo)		3,975
Broad Creek to Tavernier Creek		1,590
Tavernier Creek to Big Pine Key		50
Big Pine Key to Marquesas Keys		420
	Total	6,035

Source: Marszalek, et al., 1977.

Patch reefs also exhibit ecological variability. Dome-type assemblages support a diverse array of scleractinians and octocorals, plus numerous benthic invertebrates, algae, and fish (Marszalek, et al., 1977). Except for the noticeable absence of elkhorn coral, Acropora palmata, the biota of dome patches resembles that of consolidated outer bank reefs, but usually lacks coral zonation. At Biscayne National Park, however, dome patch reefs display biotic zonation believed related to relief and sedimentation, (Jaap, 1979, personal communication). Octocorals dominate the top interior zones whereas M. annularis, Diploria spp., and Colpophyllia natans dominate western margin. The dominant coral in this type of patch reef is the small star coral, Montastraea annularis, which is often present in single enormous colonies, (see also Shinn, 1963). Linear-type patch reefs support corals and other marine life much like dome-types with the frequent addition of A. palmata. When found on a linear patch reef, A. palmata colonies are usually smaller, more widely spaced, and oriented differently than when found on an outer bank coral reef (Marszalek, et al., 1977). Of the two types of patch reefs, the linear-type is probably the ecologic transition form between dome patch reefs and outer bank reefs (Marszalek, et al., 1977).

One hypothesis classified patch reefs of both types according to their presumed developmental stages of youth, maturity, and senescence (Jones, 1977):

Youth (early development) -- Young patches consist primarily of pioneering scleractinian and alcyonarian species capable of attachment to the sediments. The young patches grow in size by outward expansion and by upward growth on living and dead pioneering corals. Corals in young assemblages on solid substrates are dominated by the star corals Montastraea annularis and M. cavernosa, and the starlet corals Siderastrea siderea and S. radians. On less stable bottoms, the brain coral Diploria (especially D. labyrinthiformis) and the moon coral Colpophyllia natans, are major patch forming species. Smaller colonies of Porites (P. astreoides and P. porites), Favia fragum, Agaricia agaricites, Dichocoenia stokesii, and Mussidae corals, may grow between coral heads. Millepora (M. alcicornis and M. complanata) aid in cementing the components into a patch reef.

Maturity -- Mature patch reefs are characterized by vertical relief of several meters and a diameter of 10 to 20 m (33 to 66 ft). Generally, these patches extend upward to the level of lowest low water. Mature patches usually have a horizontal zonation pattern. Montastraea annularis, whose large boulders (3 m or 10 ft and more) are the chief contributors to patch structure, usually occurs on the eastern and southeastern (windward and seaward) margins (M. cavernosa may also occur there); Diploria (brain coral) and Colpophyllia (moon coral) heads more than one meter in diameter occur on the leeward sides or in eddies; and Siderastrea (starlet coral) colonies less than one meter in diameter occupy the center and remaining margins (Jones, 1977). At Biscayne National Park, however, the largest buttresses occur on westward fringes (Jaap, 1979, personal communication).

Senescence -- When coral growth rates are exceeded by mortality in the massive reef-building species, senescence begins (Jones, 1977). This occasion is accentuated by simultaneous increases in growth of alcyonarians. During senescence, the scleractinians such as *Montastraea* and *Siderastrea* may survive due to size and silt resistance. Most of the patch, however, evolves into accretion piles of coral fragments overlain by a thin layer of loose sediment. At least during early senescence, other corals may survive by expanding mucous production (*Porites*, *Dichocoenia*, some Mussidae), vertical orientation or rapid growth (*Agaricia* and *Millepora*), or branching and vertical growth (*Porites porites*). Unless rejuvenated by new stocks, senescent reefs probably die.

6.1.5 Outer Bank Reefs

Outer bank reefs are restricted geographically to the Florida Keys; special class occurs at the Flower Garden Banks in the northwestern Gulf of Mexico. Geologically and ecologically, outer bank reefs represent perhaps the oldest, most structurally complex, and diverse type of coral assemblage. Although lithoherms, salt dome hard banks, and other environments that support coral may be older, these reefs are the height of ecological complexity for systems actually formed by corals and their associated organisms.

Outer bank reef distribution is worthy of further discussion. In the Gulf of Mexico, Bright and Rezak (1976, 1978), following initial research by Stetson (1958) and others, have studied the topographic highs at East and West Flower Garden, Stetson, Sonnier (formerly Three Hickey Rocks), and about 20 other features on the Texas-Louisiana shelf. Of those banks, only the two Flower Garden sites suppo true coral reef communities. Except for the Flower Gardens, the areas described above are here beli more appropriately classified as hard banks and hard bottoms (see Section 6.2.1.2). Southeast of the Florida Keys, on the upper shelf, lie all of the remaining coral reefs in the management area, occurring as a discontinuous arc between Fowey Rocks and the Dry Tortugas (Figure 6-2).

Outer bank reefs located in the Keys and at East and West Flower Garden Banks are different in many ways (Table 6-2). Hence, generalities on mean depth, scales of relief, total area, species composition, etc., must be presented for each area separately.

Northwestern Gulf of Mexico -- The coral reefs recognized by this FMP in the northwestern Gulf are East and West Flower Garden Banks, located near the shelf break about 200 km (110 nm) offshore (Figures 5-11 and 5-12). Both reefs rest atop topographic highs that rise to within 20 m (66 ft) or less of the sea surface, (Bright and Rezak, 1976, 1978; Rezak, 1977). With increasing depth, zones of corals, algae-sponge, antipatharians, deepwater corals, and finally soft bottom, are encountered. These coral reefs are discussed in greater detail in Sections 5.2.1.7 and 6.3.

Florida Reef Tract -- In contrast, the Florida reef tract is within easy access of the coastal population centers of Miami-Homestead and the entire Keys (Marszalek, et al., 1977). The Florida reefs also differ in their structural composition, in their location on the shelf, and their ecology. Instead of a dome-like base of geologically-uplifted salt, the outer bank reefs are a discontinuous arc of skeletons and sediments accumulating in situ. Although reefs have their origin on sand or other suitable substrate (shells, rocks, fossil reefs, coral debris), their composition is predominantly coral, i.e., limestone or coral rock. Shinn, et al. (1977) and Shinn (1979), concluded that the linearity of these reefs approximately parallel to the Keys is due to underlying bedrock topography, rather than to biological or water quality causes.

The Florida reef tract includes approximately 96 km (52 nm) of outer bank reefs located between Fowey Rocks and the Dry Tortugas, a distance of about 270 km (146 nm) along the 20 m (66 ft) isobath. A large portion of the reef tract is in the FCZ just beyond Florida's three-mile terrotirial sea. As

TABLE 6-2. Comparative zonation of biological communities in coral reefs within the management area. Note depth differences.

FLORIDA OUTER BANK REEFS (modified after Shinn, 1963)

Zone	Depth (m)	Community dominant or indicator organisms
Back Reef	1.5-3.0	Head corals, M. annularis, octocorals grading into sea grass shoreward
Reef Flat	0.6-1	algae, octocorals, Favia fragum, Siderastrea radians
Spur Groove Tract I	0.6-4.5	Acropora palmata, Millepora complanata, Palythoa sp., Gorgonia ventilina (heavy wave energy)
Forereef Slope	4.5-12.1	M. annularis, octocorals with diminished spurs grading into silt sand
Second-Third Platform	12-15	Relief features rising from 24-30m to 12-15m Mycetophyllia spp., Agaricia lamarckii, Helioseris cucullata terminating in silt sand shoreward and seaward

FLOWER GARDEN BANKS (Bright & Pequegnat, 1974)

Zone	Depth (m)	Community dominant or indicator organisms
Diploria-Montastraea Porites	24-45	M. annularis, D. strigosa P. astreoides
Algae Sponge	45-73	Gypsina, Lithothamnium
Crinoid	73-85	comatulid crinoids
Soft Bottom	85-100	some octocorals attached to hard out crops

shown by Table 6-3 and Figure 6-2, these coral reefs are distributed unevenly along that range; most of the reefs are found off the Key Largo area. Marszalek, et al. (1977), best described the reefs as "... typically elongate features of variable vertical relief which occur at the shallow shelf edge between the 5 m and 10 m (16 to 33 ft) depth contours. Their long axes form a discontinuous line of reefs oriented parallel to the shelf edge. The northernmost reefs trend N-S and the reefs near Key West E-W reflecting the change in orientation of the arcuate shelf edge." Most of the outer bank reefs have well-developed spur and groove formations on their seaward faces. Spurs are extensions of coral reef growth seaward up to 30 m (100 ft) or more; grooves occur between adjacent spurs. Spurs and grooves are best developed in the upper and lower Keys. The middle Keys area exhibits some spur and groove formation but the orientation and development is variable (Marszalek, et al., 1977). Shinn (1963), found that spur and groove development in Key Largo Dry Rocks, Florida, is a constructional rather than erosional feature. Shinn, et al. (1981) found that spurs at Looe Key were constructed of Acropora palmata and had formed over five meters of carbonate sand. Spurs at Looe Key are no longer accreting due to the extensive die-off of A. palmata a few thousand years ago. Robbin (1981) also documented the Keys wide die-off of A. palmata at Alligator Reef.

The deep reef at Looe Key is being smothered by migrating carbonate sand. Examination of air photos revealed that carbonate sand that originated to the east and northeast of Looe Key is moving in a westerly direction (Shinn, et al., 1981).

Table 6-3. Outer bank reef distribution in the Florida reef tract.

Area		Outer Bank Reef (km)
Fowey Rocks to Broad Creek		22.2
Broad Creek to Tavernier Creek		34.3
Tavernier Creek to Big Pine Key		16.6
Big Pine Key to Marquesas Key		22.6
	Total	95.8

Source: Marszalek, et al., 1977.

Generally, Florida reefs are smaller in area, less biologically diverse, and lack the vertical relief of most coral reefs of the Bahamas or Caribbean Sea (Marszalek, et al., 1977). However, coral species diversity is still comparable to or greater than reefs bordering nearby countries. Like the patch reefs described above (Section 6.2.1.4), outer bank reefs may be grouped according to their extent of development, i.e., underdeveloped and well-developed (Marszalek, et al., 1977).

Underdeveloped -- Very common throughout the tract, occurring as coral reefs with sparse coral growth and no Acropora palmata zone. These reefs may represent relict limestone ridges in the spur and groove arrangement or relatively young reefs with immature biological zonation patterns. Long Reef in the upper Keys is an example of the relic reef case. (See, for example, Shinn, et al., 1977). Small stands of immature coral reef biota often bridge the gaps between more well-developed reefs.

Well-developed -- Marszalek, et al. (1977), characterized these coral reefs by their "reef-flat forms of in situ dead encrusted elkhorn coral, Acropora palmata, skeletons and rubble." Colonies of Acropora, finger coral Porites, and starlet coral Siderastrea plus encrusting fire coral Millepora, and dozens of benthic species form most of the live reef structure. The typical zonation pattern shows

A. palmata colonies on the seaward face of the reef to a depth of about 4 m (13 ft), with M. complanata and the colonial zooanthid Palythoa in the turbulent shallow zone and a diverse coral assemblage dominated by small star coral, Montastraea annularis, heads in the deeper sections (Shinn, 1963). Within the Florida reef tract, Carysfort Reef and Key Largo Dry Rocks (Grecian Rocks) are examples of well-developed coral reefs.

As discussed in Section 6.3, several of these well-developed reefs are being considered for recommendation as habitat areas of particular concern. Those areas, e.g., Looe Key and Dry Tortugas, are discussed in greater detail in that section.

6.2 Condition and Trends

Several important impacts on coral health, are categorized and discussed below. Present knowledge is not sufficient to establish a definite scale of impact severity.

Many of the man-induced and natural stresses described below possess the capability of temporarily or permanently depressing coral health and stability. Some of the more common responses to stress include polyp retraction, altered physiological or behavioral patterns, and modified energy cycles; the latter may be difficult to observe or quantify but it is a significant component of overall coral health. Another phenomenon, the "shut-down reaction" (SDR), has been studied in the laboratory and observed on rare occasions in the field in stony corals (Antonius, 1977). The SDR appears to be elicited by exposure of sick or diseased corals to a naturally sublethal stress, e.g., predation by the polychaete Hermodice carunculata, and proceeds as a rapid disintegration of body tissues resulting in death. Some doubt exists whether the SDR is a real physiological process or a continuation of tissue lysis in the sick coral. Lastly, damaged corals (abraded from anchor chains, storm damaged, etc.) may provide a starting point for infection with the blue-green algae, Oscillatoria submembranacea, that can potentially kill entire specimens (Antonius, 1975, 1976, and in press).

Generally, these data imply that certain specific areas may be in poorer health than others. Furthermore, the data provide insight for detecting areas with the potential for declining health assuming present stresses continue. Potential problem areas include the upper Florida reef tract where sewage pollution and recreational stresses are escalating, Looe Key, where recent promotion in dive magazines may impact the reef community, and the Florida Middle Grounds, where low temperatures and dissolved oxygen have been known to stress and even kill corals and benthic algae.

6.2.1 Man-made Impacts

Anchor damage -- Anchors and anchor chains from commercial and recreational vessels (especially private recreational boats) have often been cited for physical damage in coral systems. However, the nature of anchoring (underwater, often at night, widespread areal occurrence, difficulty to police, often an emergency), and the variety of ships involved (private recreation boats, tankers, commercial fishing boats, supply boats, party boats, dive boats, etc.), has limited existing knowledge of the activity.

Despite the paucity of data, it is known that the amount of damage is proportional to the level of use in an area, the method of anchoring, the size of anchor used, and the composition of the biotic community. Unpublished accounts from several areas have emphasized the relationship of user levels to anchor damage. Heavy use areas, such as Key Largo Coral Reef Marine Sanctuary off Key Largo, Florida, exhibit more anchor damage (see, e.g., Dustan, 1977), than an area like Biscayne National Park in the upper Keys, with fewer visitors to the reefs (Tilmant, 1979, personal communication). Indeed, heavily used, marked coral areas of the Sanctuary at Key Largo are in distinctly poorer condition than more remote regions of the park; anchoring and concentrated dive pressure have been attributed to a significant portion of that stress (Jameson, 1979, personal communication). Despite the evidence indicting anchors for damage to corals, it should be clarified that in many coral reef areas the species damaged (e.g., Acropora), are also the corals with the greatest growth rates and regeneration capabilities (see Section 5.4.1.2). Even at the Flower Gardens and 28 Fathom Banks on the Texas and Louisiana outer continental shelf where few boats anchor, anchor damage still occurs and is considered to be a major source of mechanical damage to corals (Bright and Jaap, in press; Bright and Rezak, 1976; National Oceanic and Atmospheric Administration, 1977; Zingula, 1978). As detailed below, damage need not arise from anchors in use. Bright and Jaap (in press) noted apparent scarring in Florida reefs from 14 anchors unintentionally snagged and imbedded in the corals near Pulaski Shoal at Dry Tortugas. Furthermore, at East Flower Garden Bank, one damaged area below the coral zone in the algal-sponge zone at 45 m (150 ft) circumscribes an abandoned Coast Guard mooring buoy and block (Bright and Rezak, 1976).

In addition to the frequency of anchoring, another determinant of the amount of damage is the method of anchoring. Anchor fluke span, length of chain played-out relative to water depth (i.e., chain slack), and placement of the anchor on the bottom, are each important factors. Many vessels, perhaps especially the larger commercial fishing boats (Davis, 1977a) and private boaters, attempt to snag anchor flukes on corals or coral rock to attain a firm position. Any anchoring technique also has an associated problem of chain abrasion on corals. The extent of denudation is comparable to the amount of slack in the anchor chain or cable. Bright and Rezak (1976) and Davis (1977a) reported cases where swinging anchor lines and ground tackle had cleared the bottom of all benthos, including corals, over areas 10 to 30 m (30 to 100 ft) in diameter. Bright (1980, personal communication) has observed several large oil tankers anchored on the Flower Garden Banks. The anchoring of tankers directly over the coral reef area of Eas- Flower Garden must have resulted in substantial damage to the living coral (Bureau of Land Management, 1981).

Lastly, anchor damage is related to the localized type of biota in the anchor drop zone. The least amount of damage occurs where the anchor can be placed in a sand flat amongst the corals, provided chain or cable damage does not ensue. Staghorn and elkhorn corals, plus other branched species, may be more susceptible to physical damage than nonbranched, or encrusting species. Davis (1977a) documented that 20 percent of an extensive staghorn coral (Acropora cervicornis) stand west of Loggerhead Key in Fort Jefferson National Monument, Dry Tortugas, was damaged in one winter season of anchoring, mostly by commercial fishing vessels. Sudden storms may have necessitated such concentrated anchoring on the leeward side of the reef (Davis, 1979, personal communication).

Pollution -- Water pollution can arise from any number of sources or activities and involve many types of pollutants. Responsibility for pollution control and regulation of man-made discharges lies with other agencies; hence, this discussion will be restricted to a review of a few of the more pertinent pollution impacts.

Oil pollution, especially from vessel spills and bilge cleaning, has been studied frequently as a potential stress on coral polyps. Oil slicks floating over submerged corals apparently inflict minimal damage (Johannes, 1975). A Shell Oil report (Shinn, 1972) concluded that "Montastraea annularis (small star coral) can survive two hours total immersion in Louisiana crude whereas Acropora cervicornis (staghorn coral) exposed for two hours to a mixture of seawater containing one part crude to six to 12 parts seawater caused immediate retraction of the polyps but complete recovery in 24 hours." A study by Bak and Elgershuizen (1976) of the reaction of 19 Caribbean hermatypic corals to ingestion of oil-sediment particles revealed that rejection was identical to that of clean sediments. Furthermore, physical contact appeared to be less harmful than toxic biochemical effects. No evidence was found of oil absorption into coral tissues.

Conversely, other research has shown apparent damage to corals from petroleum fractions. The effects of oil pollution on corals have been studied in the northern Gulf of Eilat, Red Sea, by Loya (1975, 1976; and Rinkevich and Loya, 1977). Although these studies are outside the management area and in a rather unique area combining industry with extreme tidal fluctuations, they do constitute well-documented cause and effect relationships between oil pollution and coral health. At the study area, a chronically polluted and a control reef (free of pollution) both exhibited approximately 90 percent mortality due to an extremely low tide. Three years later, the control reef had recovered to a highly diverse coral community; the polluted reef had not been recolonized. Loya (1975, 1976) suggested that the combination of phosphate eutrophication and chronic oil pollution prevented recovery of the polluted reef flat. Specifically, chronic oil exposure caused: 1) damage to the reproductive system of corals; 2) decreased viability of coral larvae; and 3) changes in some physical characteristics of the surface upon which larvae normally settle.

Of primary concern among oil pollution incidents are discharges of diesel fuel or other petrochemicals resulting from groundings or bilge cleaning. Many of these pollutants are readily dissolved into the water column and hence may spread locally on the reefs. Detergents, dispersants, etc., used to immobilize oils may also be detrimental to corals and associated reef biota.

Oil and gas exploration and development on the Gulf of Mexico continental shelf and the Blake Plateau, necessitates consideration of drilling platform discharges of cuttings and muds. Whereas cuttings are predominantly rock and sediments, drill muds are complex chemical mixtures of coolants, lubricants, biocides, and stabilizers (American Petroleum Institute, 1978). Lease agreements for oil and gas exploration and development issued by BLM stipulate measures and practices for the protection of corals.

Third is the general grouping of pollutants termed heavy metals, which can accumulate in coral tissues above the naturally-occurring levels. Taylor and Bright (1973) found high levels of mercury, cadmium, lead, copper, and zinc in groupers from Gulf of Mexico coral reefs. Certain fish (e.g., swordfish) naturally accumulate some heavy metals, including mercury. However, elevated body burdens of some metals in some biota may result from man-made sources of pollution such as antifouling paints, construction materials, power plants, air pollution, or sewage and desalination plants (Johannes, 1975). For instance, a heavy metal plume was discovered extending off Virginia Key near Miami (Manker, 1975). Manker also found that mercury, zinc, lead, cobalt, and chromium are present in sediments of the bays and coastal regions off southeastern Florida. These metals, thought to have origins specifically from urban sewage, industrial wastes, power plants, and automobile emissions, are also concentrated off the coasts of other major population/urban centers. Corals there exhibited higher chromium levels than seen at the Florida Middle Grounds (Manker, 1975; Bright, et al., 1981). Lead and mercury may also be accumulating in sediments at Tavernier Key and the John Pennekamp Coral Reef State Park marina. Heavy metals in sediments are easily resuspended by disturbance of the sediment-water interface.

Excess sewage qualifies as a fourth category of pollution. Although little work has been done on this subject in the management area, extrapolations from Hawaiian, western Pacific, and Caribbean coral communities, indicate that sewage alters nutrient cycles, disrupts ecological balances, depresses oxygen levels, and may totally alter the composition of a community (Johannes, 1975). Recent history at Kaneohe Bay, Hawaii, shows that 99 percent of the shallow reef corals are now dead due to sewage pollution, onshore development, sedimentation, and freshwater run-off (Maragos, 1972; Smith, et al., 1973; Smith, 1977). In the six east coast Florida counties between St. Lucie and Monroe Counties, sewage treatment facilities are so over-burdened that many hotels and other buildings pump their sewage into coastal waters untreated (Bright, et al., 1981). While most Key Largo houses have septic tanks, many homes in Key West and Dade County, Florida, also pump sewage directly into the ocean. Even septic tanks offer no guarantee of safety since storms and porous Keys' soils often permit run-off directly into coastal waters.

Eutrophication, as a result of nutrient loading, may also limit coral growth and health. Loya (1975) hypothesizes that phosphate eutrophication is one of the major man-made disturbances of corals in the Gulf of Eilat, Israel. In Kaneohe Bay, Hawaii (Maragos, 1972) and elsewhere around the world

Gulf of Eilat, Israel. In Kaneohe Bay, Hawaii (Maragos, 1972) and elsewhere around the world (Johannes, 1975), corals stressed by eutrophication or other forces are often dominated by thick beds of the encrusting alga Dictyosphaeria cavernosa or other opportunistic algae.

Recreation activity -- Increased, concentrated use of coral resources and adjacent waters in parks and preserves for boating, diving, specimen collecting, photography, and other bottom-contact activities has had a noticeable adverse affect on coral health. Diving for specimens (i.e., souvenirs or curios) appears to be the major recreational stress. Since reef assemblages are often near shore and biologically diverse, patch reefs and outer bank reefs, especially those marked with buoys and on maps, receive an inordinate percentage of the total recreational pressure. For example, Davidson (1979, personal communcation) observed about 50 recreational boats in less than 3.4 km^2 (1 nm^2) atop Looe Key at noon on Memorial Day, 1979. Florida's resources and, to a much lesser extent, the offshore banks of the northwestern Gulf of Mexico, are two areas of stress. These impacts are most severe on small populations, those with slow growth rates, or members of an interwoven ecological cycle (predator-prey, symbiosis, etc.).

Dustan (1977) identified activities such as diving, snorkeling, and boating that are localized around reefs, as the chief contributors to reef damage. Swimmers may grasp corals for leverage or scrape against them, which, along with other contact activities, may kill corals or alter energy cycling to repair wounds.

Coral collecting is a difficult activity to assess. As described in Sections 7.3 and 7.4, it is illegal unless a special permit is received; some scientific specimen collecting by colleges and supply houses occurs in Florida state waters. It is possible that much more pressure is exerted by illegal collections of many corals and associated animals for curios or live sale.

Vessel groundings -- Groundings (either temporary strandings or as shipwrecks), by a wide range of vessels engaged in many activities constitute a significant source of coral destruction (Davidson, 1979, personal communication). The amount of damage appears most dependent upon the species of coral struck, ship variables (speed, hull design, construction materials, etc.), and meteorological factors (wave surge, tides, winds, etc.). Often, spilled cargo or vessel fuel can have a greater impact on the reef biota than the grounding itself. Vessel salvage may also cause harm to the reef.

Although physical damage to the corals may be severe following a grounding, in some cases the coral community can recover within a few years. Groundings at Grecian Rocks near Key Largo, Florida, in 1964 and 1975, cut swaths in Acropora stands but are largely regenerated today (Shinn, 1979, personal communication).

Recent studies at Biscayne National Park near Elliot Key, have identified groundings as a major human impact (Tilmant, 1979, personal communication). Park staff have initiated a study of eight patch and coral reef areas (four study and four control locations), to assess the frequency and impacts of groundings and other events. Surveys in September and October 1977, and in January and February 1978, encountered one case of grounding on a head of small star coral, Montastraea annularis, at Dome Control Reef in the January transect. An impacted coral head measuring several meters in maximum dimension was split and toppled (Biscayne National Park, 1978a). Other surveys in 1978 (Biscayne National Park, 1978b) revealed disturbed colonies of M. annularis at Star Control Reef, bottom paint on portions of a ballast pile at Schooner Reef, and a yacht grounded at Elkhorn Reef. Acropora palmata (elkhorn coral), Montastraea annularis, and Siderastrea siderea (starlet coral) colonies showed damage. In summary, four boat grounds and numerous "scrapings" were observed during the first 18 months of study on the eight reefs at Biscayne National Park (Tilmant, 1979, personal communication). Many more probably go unreported.

The amount of damage inflicted by a grounding depends greatly upon the speed of the vessel, shape of hull (i.e., area of contact with the corals), hull construction (strength of the material versus corals), wave surge, tides, and winds (which contribute to whether a grounding is permanent or temporary).

Over a two year period (1974 to 1976) in John Pennekamp State Park and at Looe Key, Bright, et al. (1981) recorded several other groundings and shipwrecks. While these vessels were breaking up, sewage, garbage, engine oils, cargoes (molasses), ship parts, and onboard supplies, were strewn over the reefs. Corals observed to be damaged included elkhorn (Acropora palmata) at Key Largo Dry Rocks, and brain coral (Diploria strigosa) and small star coral (Montastraea annularis) colonies at Looe Key. During a 16-month period of 1974 to 1975, Dustan (1977) observed six groundings or wrecks in the State Park. Numerous other unquantified observations of propellor hits were also recorded by Dustan. Davidson (1979, personal communication) described a wreck on Looe Key on May 18, 1977, where seeping fuel oil from the 'Robby Dale' made diving physically nauseating for several days. The effects of a later salvage mission on the corals were documented by Bureau of Land Management (BLM); the salvors were prosecuted in court by BLM.

The grounding problem has a different perspective at the Flower Garden Banks and other offshore coral communities. Whereas most reefs in Florida are near shore where recreational boats abound, offshore corals are also endangered by commercial vessels. The West Flower Garden Bank, for instance, is located only 11 km (6 nm) from the Gulf Safety Fairway, a major east-west corridor for tankers and cargo vessels into and out of Texas ports. With the advent of deep draft designs, many tankers have drafts too deep to pass over some of the northwestern Gulf hard banks or the reefs along the Florida Keys.

With a grounding, the primary worry is that a large ship could decimate a significant portion of the coral assemblage, especially those atop coralline or carbonate bases. Many groundings of commercial vessels could lead to a spill of hazardous cargo to impose another stress on the corals. The effects of spills and pollutants on corals are discussed earlier in this subsection.

Fishing -- Commercial and recreational fishing can potentially stress the health of the coral or coral reefs. These fishing operations are directed at a multitude of finfish and shellfish that live near or in coral habitats. Among the most important such species near outer bank reefs are snappers (Lutjanus spp. and Rhomboplites spp.), grouper (Mycteroperca spp.), and tilefish (Lopholatilus spp.) (Bright and Pequegnat, 1974; Antonius, et al., 1978). Patch reefs and hard bottoms supply habitat to comparably diverse fisheries stocks, including the fish listed above, plus stone crabs (Menippe mercenaria), spiny lobsters (Panulirus argus), shrimp (Penaeus spp.), and many others (Smith, 1976; Hopkins, et al., 1977; Davis, 1979, personal communication). Nearly all areas in which corals live support some type of fishing venture. Tropical specimen collectors harvest fish from areas with or without corals. Extensive tropical fish collecting may alter ecological relationships. Fish collectors harvest mostly juveniles from waters less than 15 m (50 ft) deep (Feddern, 1979, personal communication). Fish populations in deeper waters and in difficult collecting areas (e.g. coral reefs) may remain as recruitment reserves.

In addition to specific fishing-related stresses, fish gear impacts may also be an important source of coral destruction both inside and outside state waters. Based on observations of the industry and conversations with scientists in the field, these potential gear damages could include shrimp trawling in hard bottom areas, calico scallop dredging, snapper-grouper trawling, shrimpers trawling for lobsters, lobster pot fishing, and reef fish traps. In each case, the gear is equipped with weights or chains that may physically damage corals and associated biota. Geographically, these activities occur in the northeastern and eastern Gulf of Mexico (shrimp trawling, scallop dredging), the shelf off western Florida between St. Marks and Tarpon Springs (trawling), Florida Middle Grounds near parts of Tarpon Springs and Madeira Beach (snapper and grouper), the Florida Keys (lobster potting, lobster trawling, fish traps), off northeastern Florida and Georgia (rock shrimp, brown shrimp), and off Georgia and South Carolina (shrimp trawling, snapper-grouper trawling). The potential impacts include disruption of the hard bottom communities inhabited by the silt-tolerant corals (Solenastrea, Oculina, and Siderastrea), sponges, shellfish, and finfish in the Gulf and off the southeastern states; physical harm to coral reefs that have fish or shellfish traps dropped on, dragged through, or swept into them; and possible biological harm to the reef associated biota (e.g., lobster pot removal of adult tropical fish and fish trap removal of resident reef species). The opinion that lobster traps are harmful to hard bottom areas when they are fished with excessively long buoy lines has been expressed. These practices in shallow waters entail dragging the traps across the bottom during retrieval.

Bottom longline fishing for snapper and grouper has recently expanded in the management area as a result of economic stress in other fisheries. Lines are frequently set adjacent to coral reefs where reef fishes congregate. They are not normally set across the reefs because of potential loss of the gear. An increased use of stronger wire cable for longline allows use of the gear over hard bottom with less risk of gear loss, but with more potential for habitat damage. Jaap (1981, personal communication) has identified two species of corals brought in by bottom longline fishermen.

Significant user conflict has developed between traditional reef fish fishermen and roller trawl fishing vessels off Daytona Beach and in the eastern Gulf of Mexico. The former claim that roller trawls are destroying the habitat, including Oculina varicosa coral banks.

Tunnicliffe (1980) reported coral damage in Jamaica where large fish traps thrown on the reefs caused much breakage and death of corals. Similarly, a Florida fish trap study (Taylor and McMichaels, 1981. personal communication) reported coral pieces, some identified as staghorn in traps, indicating that wire traps will break some fragile corals.

The impact of fishing activities on coral via incidental catch has been studied by the St. Petersburg laboratory of the Florida Department of Natural Resources. The study, sponsored by the National Marine Fisheries Service during 1978, consisted of onboard sampling of collections from 196 shrimp trawls on the shelf off western Florida, between Apalachicola and Dry Tortugas. Results showed soft corals (Renilla) in 25 of the 196 trawls, with most of those trawls in the northern Gulf region near Apalachicola. The quantity of corals per trawl ranged from only a few pieces to about 25.

A 1965 film entitled "Gulf of Mexico Shrimp Trawls", produced by the National Marine Fisheries Service's Gear Research Unit, showed the effects of various trawl designs and fishing methodologies. The film also showed destruction by a net towed over a stump coral and suggested gear adjustment to avoid contact.

Impacts from fishing may be categorized as physical or chemical. Physical impacts may result from gear damage or simply gear use. Nets and pots may be lost on reef outcropings as seen near Dry Tortugas and at the Sambo Reefs in the Keys (Bright and Jaap, in press). Hand fishing by spear or lobster loop may result in overturned coral heads or damaged corals from diver contact. Hook and line fishing may affect corals to a limited extent, but not nearly so much as towed or emplaced gear. Lobstering with traps directly on corals is a rare, accidental occurrence that can damage fragile species (Acropora cervicornis or staghorn coral) or large brain corals like Diploria (Bright and Jaap, in press). Lobsters and other reef residents may also be collected by stunning with poisons or explosions. Jaap and Wheaton (1975) conducted field studies on acetone, quinaldine in an acetone solution, and Chem-Fish-Collector (a commercial rotenone preparation) and also reviewed the literature on anaesthetics and poisons. Their field studies on gorgonians and scleractinians at Eastern and Western Sambo Reefs off Boca Chita Key, Florida, revealed that rotenone and quinaldine often induced coral polyp retraction and occasionally caused tissue discoloration. The scleractinians Acropora cervicornis, A. palmata, Siderastrea siderea, Diploria strigosa, and Dichocoenia stokesi, were damaged by the rotenone (Jaap and Wheaton-Smith, 1974). Several gorgonians and other test corals were not affected by the chemicals at the test levels. Associated reef species such as the urchin, Diadema antillarum and some crabs and shrimps, vacated the treatment area or died. Quinaldine and bleach are used to stun or drive out mobile animals to ease live capture; rotenone is a toxicant when used in sufficient doses (Jaap, 1979, personal communication). In the Bahamas, chlorine bleach fishing among corals was a common practice of fishermen. Often, a characteristic pattern of infection ensues whereby zones of the blue-green algae, Oscillatoria submembranacea, the bacteria, Desulfovibrio and Beggiatoa invade the stressed tissues (Campbell, 1977). Explosives may be used in some areas to collect fish (Ronquillo, 1950; Christian, 1973) or move coral rock, but its damage to living corals has never been adequately quantified (Johannes, 1975). Explosives do not appear to be in use at this time, but were used at Carysfort Reef near Key Largo from about 1900 to the early 1950s (Shinn, 1979, personal communication). Damage throughout that period was severe but recovery since the 1950s has resulted in no visible effects of the blasting.

Lastly are the possible impacts of artificial fishing reefs. Throughout the management area, fishing associations, state resource agencies, and private groups have built artificial reefs on the inner continental shelf. In many instances tires have been the primary reef building blocks. Problems arise, however, when the bundles of tires weighted with concrete break loose from their mooring and roll about unanchored. In Monroe County, Florida, near Coffins Patch Reef off Marathon, the damage to coral has been so severe that the tires were removed (Richard Helbling, personal communication). A similar problem occurred off Fort Myers, Florida (Casey, 1979, personal communication). The problem appears to be proper placement of the reef and not the construction. Although the untethered tires are doing much damage, artificial reefs firmly attached do provide valuable habitat for many fishes.

Dredging and sedimentation -- Dredging has an effect on the natural turbidity regimes of coastal environments. This impact is critical because of the dependence of corals upon clear waters and the fact that resuspended particulates often increase availability of pollutants to marine biota. In coastal Florida waters, sediments tend to be fine-grained and suspended naturally in winter months. Aerial photographs on file at the Planning Department of Monroe County, Florida, in Key West, emphasize the amount of sediments involved and their persistence. In other areas, especially in deeper waters, turbidity problems occur but not with such obvious repercussions. In all cases, storms, normal wave surges, and boating, resuspend the particulates. Storms also contribute naturally to this man-made impact. Fine-grained sediments have occurred naturally for thousands of years in the reef tract (Enos, 1977).

Sedimentation resulting from dredging causes damages proportional to particle size, total load, and settling rates, which in turn influence a multitude of ecological variables (growth, respiration, reproduction, energy cycling, etc.). Hubbard and Pocock (1972), studying 26 Caribbean corals, have suggested that corals are "size-specific sediment rejectors" and that this ability varies between species. In general, only silt, the smallest particle size considered, was effectively removed by all species tested. Strong currents may assist corals in removing more coarse-grained sediments (see summary in Johannes, 1975) but mucus transport, ciliary beating, or other biological means, account for most polyp cleansing.

The impacts of dredging operations are also dependent upon the techniques involved. Griffin (1974) noted that use of a diaper or silt curtain around the operation may decrease plume size although not affecting the total sediment load. "Hard-rock" dredging as practiced at Key Largo and studied by Griffin, has less impact, i.e., lower particle concentration in the plume, than hydraulic dredging.

Sediment trap studies at Key Largo determined that Siderastrea siderea (starlet coral), cleared at least 125 mg/cm^2/day during a period when no dredging was occurring (Griffin, 1974a). During dredging, fallout may exceed 300 mg/cm^2/day; the capabilities of corals to clear that amount are not known. At high load levels, waters may become anoxic (Griffin, 1974a). A detailed summary of one Florida Keys dredge and fill project is presented in Griffin (1974b).

Beach nourishment projects, barging, and pipeline excavations may threaten corals, too Bright, et al. (1981). Shinn, 1979, personal communication). Courtenay, et al. (1974) observed that sand being transported to shore to replenish an eroding beach smothered a small coral assemblage off Hallandale, Florida, north of Miami. Aerial photographs of the Hawk Channel and Key Largo areas, have revealed persistent trails of sediments from barges and glass bottom boats (Griffin 1974a,b; Shinn, 1979, personal communication).

A second impact of dredging is direct removal of corals. Coral rock has been used as construction materials (buildings, roads, etc.), extensively in various parts of the Florida Keys. This material is relict reef limestone, usually occurring onshore or nearshore. However, as cited in Schlapak and Herbich (1978), corals are still dredged in the Pacific for use in construction and navigational channel development.

Research -- Research activities may impose a mixture of stresses resembling those described above. Hence, the impacts of research operations to collect corals, trawl on hard grounds, search for petroleum, etc., parallel the impacts of the respective activities. It is thought that, in general, these impacts are minor since the research institutions are aware of the potential damages and often supervised by their contracting agency.

Summary

The physical/chemical impacts associated with human activities (anchor damage, pollution, recreation, fishing, trapping, vessel groundings, dredging, and research), impart economic impacts which may be observed in two forms from two perspectives. First, in the short-term, these impacts increase the immediate income or enjoyment of the individuals causing the impacts. This occurs because the individuals are reaping some personal benefit (e.g., recreation, sewage disposal, fishery harvest), while paying less than full price for the resource. For example, a diver can increase his enjoyment by anchoring directly over a coral formation and decreasing his time and air consumption to reach the coral; shrimp trawlers can increase both harvest and income by engaging in "bottom preparation" activities. Second, over the longer term, impacts of these human activities can impose costs on the U.S. economy through fishery habitat destruction. Even partial degradation of habitat areas could decrease biomass potentials for shrimp, snapper, grouper, calico scallop, lobster, and less visible forage for recreational species. Habitat destruction also reduces the aesthetic appeal of the area to recreational users. Thus, the potential harvest of associated species and the recreational benefits could be reduced resulting in corresponding reductions in income generated.

6.2.2 Natural Impacts

The impacts summarized here are detailed in Appendix I.

Hurricanes -- The most destructive short-term impact on corals is a hurricane. Wave surge and intensity coupled with sand and debris being carried by the water can wreak havoc on shallow-water coral communities. Because of the usual storm tracks, the Florida Keys and the Gulf are especially vulnerable to this stress.

Light, depth, and wave energy -- These three factors are interrelated. Hermatypic coral distributions are limited by the wave length (spectral quality) and intensity of penetrating light, functions of water depth. Ahermatypes do not require light but can be excluded from areas of high turbulence, such as some reef caps or surf zones.

Temperature -- The distribution of corals relative to water temperature is correlated with the presence or absence of zooxanthellae. Generally, hermatypic corals possessing symbionts are found in warm waters within the range of 15° to 35°C or 60° to 95°F (Mayer, 1916). Ahermatypic species are not limited by temperature and therefore are more widely distributed.

Researchers in the Florida Keys (Vaughn, 1918; Davis, 1979, personal communication; Roberts, et al., 1979; Hudson, 1981; Tilmant, 1979, personal communication), have developed extensive data sets on temperatures in Keys waters. Roberts and Rouse (in preparation) have summarized many of these natural temperature effects.

Salinity -- The salinity preference of corals are species-specific, with some categories euryhaline and others stenohaline. Generally, many nearshore species such as gorgonians are more euryhaline than the reef inhabitants or deepwater species. Local oceanographic conditions in the management area influence salinity and hence coral distribution and health - Mississippi River outflow, Everglades discharge and salty lagoons along the Texas coasts among others.

Ecological relationships -- Coral health can be altered by a variety of inter- and intraspecific relationships - competition, predation, natural toxicants, infection, and others (see also Appendix H, in addition to Appendix I). Each of these relationships involves biological and behavioral elements that affect coral health.

Sedimentation -- In various portions of the management area, particularly in the Florida reef tract and off the Mississippi River Delta, natural turbidity and sediment may limit light penetration, feeding efficiency, and other determinants of coral health.

Gas seeps -- Seep of biogenic and petrogenic gases are known to occur on several hard banks in the northwestern Gulf of Mexico.

6.3 Habitat Areas of Particular Concern

For purposes of this section, habitat areas of particular concern (HAPCs) are discussed solely as areas of special biological significance. As required in the guidelines for developing Fishery Management Plans (50 CFR Part 602.3b.6.ii), these geographic areas include those " ... which are of particular concern because of a requirement in the life cycle of the stock(s), e.g., spawning grounds, nurseries, migratory routes, etc. .... (and) ... those areas which are currently or potentially threatened with destruction or degradation." Whereas the following discussion focuses on delineating these areas for coral stocks, it should be noted that this plan also used the term HAPC to connote a management concept designed to focus regulatory and enforcement abilities on particular localized areas of significance. Although the two meanings are obviously closely related, the conceptual distinction between HAPCs as significant biological areas and HAPCs as a classification category conferring special management provisions, should be recognized by the readers of this plan.

As a vital first step in understanding and managing the coral resource, it is necessary to recognize that corals are not spread evenly over the management area. Rather, dense clusters of certain species concentrate at specific geographic locations to form reefs, hard bottoms, lithoherms, etc. Precise understanding of the geographic distribution of major coral habitats has, until recent mapping efforts (see Table 6-4), been largely ignored. As these and other mapping projects are completed, expanded, and refined, they will become an important source of coral HAPC information.

For delimiting specific coral areas, HAPCs are taken only to include localities where large concentrations of adult (sedentary) corals are found. (The open water planktonic life style of larval forms precludes the isolation of specific geographic localities of larval concentration.) On a regional basis, these coral habitats comprise only a very small percentage of the geographical area of authority of the Gulf of Mexico and South Atlantic Fishery Management Councils. Since the focus here is only on coral habitats of particular concern, the area percentage is even smaller.

In order to focus only on habitats of particular concern, a set of HAPC criteria has been developed for use in this plan (see Table 6-5). These criteria are general guideline statements intended to narrow the full complement of coral habitats down to a select few representing the most important coral concentrations in the management area.

Table 6-4. Major sources of coral mapping and species distribution information for U.S. Gulf of Mexico and south Atlantic waters.

WHO	WHERE	SCALE	SPONSOR	STATUS	COMMENTS
C. Giamonna (Texas A&M)	Gulf of Mexico	n/a	--	Completed Ph.D Dissertation (1978)	Summarized available information on ecology and distribution of Gulf octocorals.
T. Bright & R. Rezak (Texas A&M College Station, Texas)	Topographic highs located in western Gulf of Mexico	n/a	U.S. Bureau of Land Management (OCS Office, New Orleans, Louisiana)	Separate reports for first three years completed	Provides a descriptive account of biotic communities observed on Gulf banks.
W. Jaap-Scleractinia J. Wheaton-Octocorallia (FL. Dept. of Nat. Res.)	"Hourglass" area off midwestern Florida	n/a	Florida Department of Natural Resources	Completed field sampling	A major oceanographic collection providing a grid of stations from which coral distributions could be plotted.
D. Marszalek (RSMAS, Miami)	South Florida	1:24,000	State of Florida Department of Natural Resources, Bureau of Land Management	Completed, being readied for press	Reef and bottom types.
W. Adey (Smithsonian)	Northern Little Bahama Bank	1:6,000	U.S. Bureau of Land Management	Nearly completed	Major bottom types.
J. Porter (University of Georgia, Athens, Georgia)	Tortugas, Florida	>1:10	National Park Service	Continuing	Underwater photographs of staked quadrants: squares allow mapping of coral species; repeated views can assess changes.

Table 6-4. (continued)

WHO	WHERE	SCALE	SPONSOR	STATUS	COMMENTS
G. E. Davis (U.S. National Park Service-Everglades National Park)	Fort Jefferson National Monument	about 1:30,000	U.S. Bureau of Land Management (OCS Office, New Orleans, Louisiana)	Published 1979 by BLM (see Fig. 6-8 herein).	Provides a resource map of coral distribution to the Monument boundary; grass, fleshy algae, staghorn reefs, patch reefs, and hard bottoms are mapped. See Fig. 6-6.
S. D. Cairns (Smithsonian)	Gulf of Mexico Caribbean, SE coast of U.S.	n/a	University of Miami	Completed Ph.D Dissertation (1976), published 1979.	Series of 60 maps of deep water Scleractinia distributions; descriptions and illustrations of 88 species; zoogeography.
Woodward-Clyde Consultants	Eastern and north-eastern Gulf of Mexico	1:48,000	U.S. Bureau of Land Management (Washington, D.C.)	Report published January 1979.	Study maps and described benthic habitats at ten locations to determine their suitability for OCS oil and gas leasing.
T. Hopkins and R. Rezak (Univ. of South Alabama)	Florida Middle Grounds	1:12,000 and 1:40,000	U.S. Bureau of Land Management	Ongoing	Submersible observations of biotic communities and bottom contours.
Continental Shelf Association	Pfleger and Sweet Banks, northern Gulf of Mexico	n/a	U.S. Bureau of Land Management (Washington, D.C.)	Published 1980	Maps topographic highs and "live bottoms".

Table 6-5. Criteria for Identifying coral Habitat Areas of Particular Concern.

1. Ecological

   a. An area that contains an outstanding example of a coral community type found over a broad ocean area. (For example, a deepwater Lophelia-Enallopsammia bank, a shallow-water Acropora coral reef, patch reefs, etc.).

   b. Areas known to possess rare species of coral.

   c. Areas whose coral diversity contributes to a highly unusual or unique biologic relationship or ecologic condition.

2. Research

   a. Areas with a substantial history of coral research and study. Such areas offer an opportunity to develop a long-term history of corals in their natural setting which should enhance the indentification of trends in growth or response to stress - both vital information for coral managers.

   b. Areas which display in an especially clear cut fashion, coral habitat features of particular research interest such as spur and groove formations or particular biotic zonation patterns.

3. Exploitation

   a. Areas where high concentrations of economically valuable corals subject to harvesting can be found. This might include prime banks of black or pink precious corals, or areas where Plexaura homomalla can be abundantly found. These resource areas can then be managed as development areas under optimum yield objectives.

   b. Areas where specific man-made development plans, use, or pollution impacts have inflicted, or threaten to inflict, environmental damage including reduced coral species diversity, abundance or health.

4. Recreation

   a. Areas which are documented as locations frequented on a regular basis by recreational divers, sports fishermen, or glass bottom boat sightseers.

   b. Areas that offer a high but underutilized recreational resource because of their outstanding aesthetic qualities and proximity to population centers or boat access points.

At a minimum, any coral area chosen as an HAPC must meet one or more of the specific criteria presented in Table 6-5. In addition to these criteria, an effort should be made to ensure inclusion of areas that represent all coral community types found in the management area. Consideration of a geographic factor will provide for a regional system of HAPCs in which the full diversity of important coral habitat sites is included. Particular attention should be given major coral habitat areas. Foremost of these broad areas is the extensive Florida reef tract which stretches along the Florida Keys. Other such habitat areas include the topographic highs or banks in the northwestern Gulf of Mexico; the reef and hard bottom coral habitats scattered throughout the northeastern Gulf of Mexico (including the Florida Middle Grounds areas); and the hard bottom communities scattered off North Carolina and South Carolina (see Figure 5-4).

All habitat areas should be mapped on a scale suitable to show the particular resources and associated habitats. A set of geographic coordinates and boundaries should accompany the map to clarify the precise area.

The coral habitat areas described below have been determined to satisfy the criteria and include the important element of geographic distribution. The Councils will address, with review by their Scientific and Statistical Committees, nominations for HAPCs periodically and take action as they deem necessary, including public hearings and any other fishery management plan amendment processes.

Coral habitat areas of particular concern (HAPC) and the criteria by which they qualify.

Coral HAPC	Criteria (see Table 6-5)
East and West Flower Garden Banks (nominated national marine sanctuary)	1.c, 2.a, 2.b, 3.b, and 4.a.
Dry Tortugas (Fort Jefferson National Monument)	1.a, 2.a, and 3.b.
Looe Key (designated national marine sanctuary)	1.a, 1.b, 2.b, 3.b, and 4.b.
Key Largo Coral Reef (designated national marine sanctuary)	1.a, 2.a, 2.b, 3.b, and 4.a.
Biscayne National Park	1.a, 2.a, 3.b, and 4.a.
Gray's Reef (designated national marine sanctuary)	1.c, 2.b, 4.a, and 4.b.
Florida Middle Grounds (nominated marine sanctuary)	1.a, 1.b, 1.c, 2.a, 2.b, 3.b, and 4.a.
Oculina Bank	1.a, 1.b, 1.c, 2.a, 2.b, 3.a, 3.b, 4.a, and 4.b.

Gulf of Mexico Topographic Highs

As described briefly in Section 5.2.1.7 and shown in Figures 5-4 and 5-7, the northwestern Gulf of Mexico includes almost 30 identified banks rising from the otherwise flat continental shelf. Many of these banks possess corals. Although other banks may eventually be determined to be of sufficient significance to be termed as an HAPC, only the East and West Flower Garden Banks are here considered as such.

East and West Flower Garden Banks

The two separate banks at the Flower Gardens (see Figures 5-11, 5-12, and 6-3) are distinct geologic

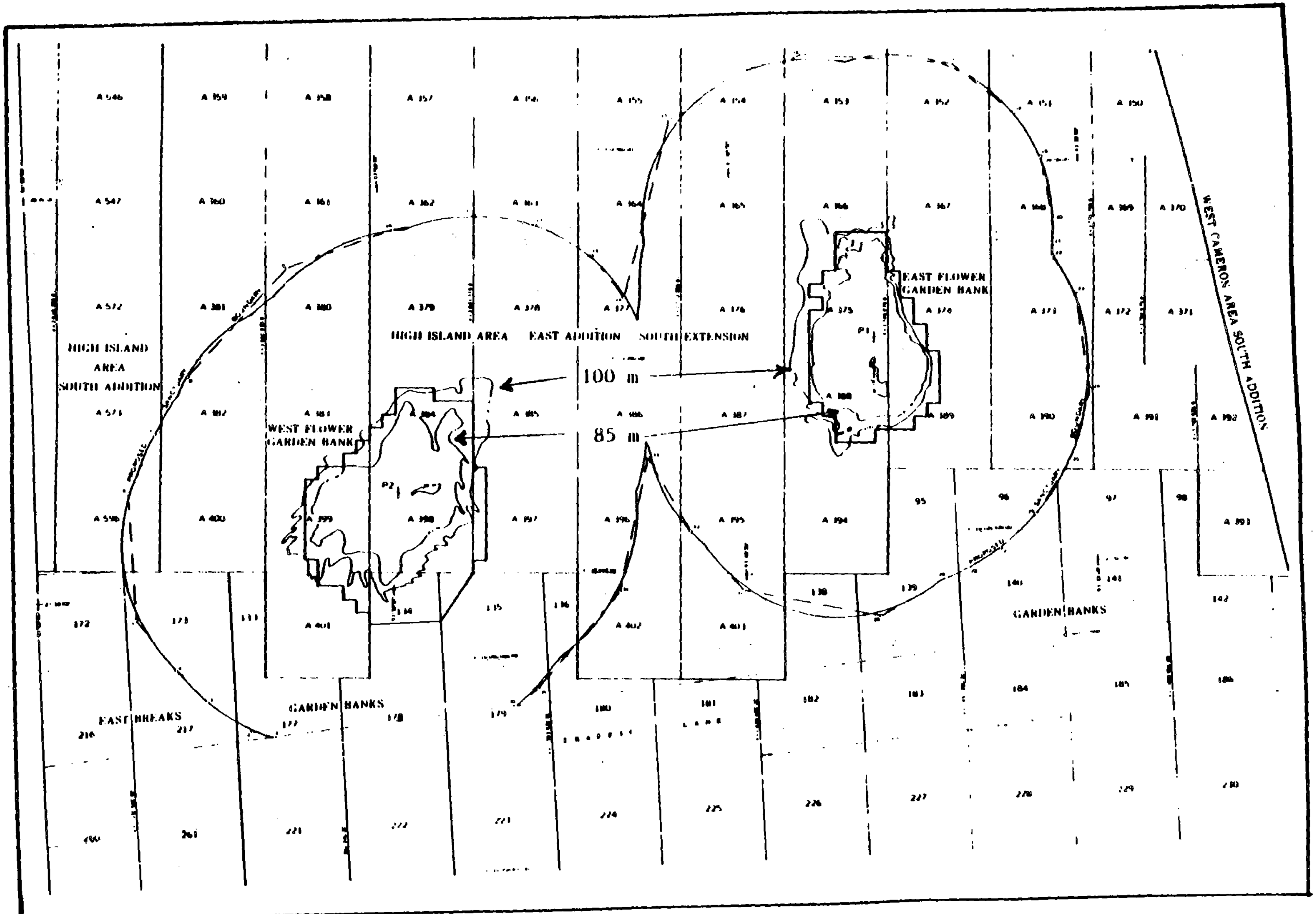


FIGURE 6-3. Location of Flower Garden Banks HAPC (with 100m shown). Also shows the proposed marine sanctuary, BLM oil and gas tract numbers, and the traff[illegible]ne (Office of Coastal Zone Management, 1979a). Tracts are three miles (statute) square.

structures located about 25 km (13.5 nm) apart and over 200 km (108 nm) from the coasts of Texas and Louisiana. Located on the edge of the continental shelf, the East Bank's midpoint is located at about 27° 55' 07.44" N and 93° 36' 08.49" W. The West Bank centerpoint is at 27° 52' 14.21" N and 93° 48' 54.79" W. The salt dome infrastructure of the Banks projects up through the overlying rock strata and forms two distinct hills rising several hundred meters above the sea floor to less than 50 m (165 ft) of the sea surface. The HAPC is limited to the portions of each bank above the 50-fathom isobath (Figure 6-3).

East Flower Garden Bank is a tear-shaped dome roughly 5 km (2.7 nm) in diameter rising to within 20 m (66 ft) of the sea surface (Bright and Rezak, 1976, 1978). The total area of coral reef atop the bank is 75 acres (0.3 km^2) (Office of Coastal Zone Management, 1979a). The corals and associated species occur in seven distinct zones (see Figure 5-12) from the cap at 16 m (52 ft) to the base of the bank (i.e., onset of soft bottom community) at 110 to 120 m (360 to 393 ft): 1) leafy algae; 2) Madracis; 3) Diploria, Montastraea, and Porites; 4) algae-sponge; 5) deepwater corals; 6) antipatharians and drowned reefs; and 7) soft bottom (Bright, 1977). The Madracis zone is occupied almost entirely by populations of the small branching coral M. mirabilis. Principal species, including corals, within each of the zones have been elucidated by submersible transects and listed by Bright and Rezak (1976, 1978).

West Flower Garden Bank is oblong shaped roughly 11 km by 8 km (6 by 4.3 nm), trending northeast to southwest. The live reef atop the dome occupies 100 acres (0.4 km^2) (Office of Coastal Zone Management, 1979a), including a peak rising to within 20 m (66 ft) of the surface (Rezak, 1977). Biotic zonation at West Flower Garden is characterized by assemblages similar to those observed at the East Flower Garden Bank. From its peak at about 20 m (66 ft) depth to the dome base at 136 m (450 ft), four zones exist (see Figure 5-11): 1) Diploria, Montastraea, Porites; 2) algae-sponge; 3) deepwater corals; and 4) soft bottom (Bright, et al., 1974). No leafy algae or Madracis zones were described (Bright, 1977). Antipatharians have been observed amidst the soft bottom zone. Corals at West Bank have been classified and published by Tresslar (1974); Bright and Pequegnat (1974) describe a substantial number of the associated species.

Coral assemblages and habitat at East and West Flower Garden Banks comprise a unique resource. The coral reefs on those banks are the northwestern most reefs in the Gulf of Mexico. Hence the biota they support are stressed climatologically, at least partially isolated from the gene pool, and susceptible to collapse should existing populations be destroyed. As the northwestern most coral reefs, they are of particular research interest. The biotic zonation at the Flower Gardens has been described as one of the most extensive of all Gulf of Mexico banks (Bright, 1977). The banks have also been subject to an environmental impact statement as a nominated marine sanctuary (Office of Coastal Zone Management, 1979a). Potential threats to the reefs exist in the form of increased oil and gas drilling in the area, expanding deep draft vessel traffic, increasing recreational use, and anchoring by any vessel.

The following two management measures are proposed to protect the corals from incidental damage by the use of fishing gear or anchors.

- Traditional, historical fishing methods are allowed but bottom longlines, traps and pots, and bottom trawls are prohibited within the 50-fathom isobath. The taking of all corals is prohibited except as authorized by permit.

- Anchoring shall be prohibited on the East and West Flower Garden Banks, 20 and 24 square mile areas above 50 fathoms in depth except for vessels less than 100 feet in registered length. (Note: this measure has been disallowed by NOAA as being beyond authority of MFCMA.)

Florida Reef Tract

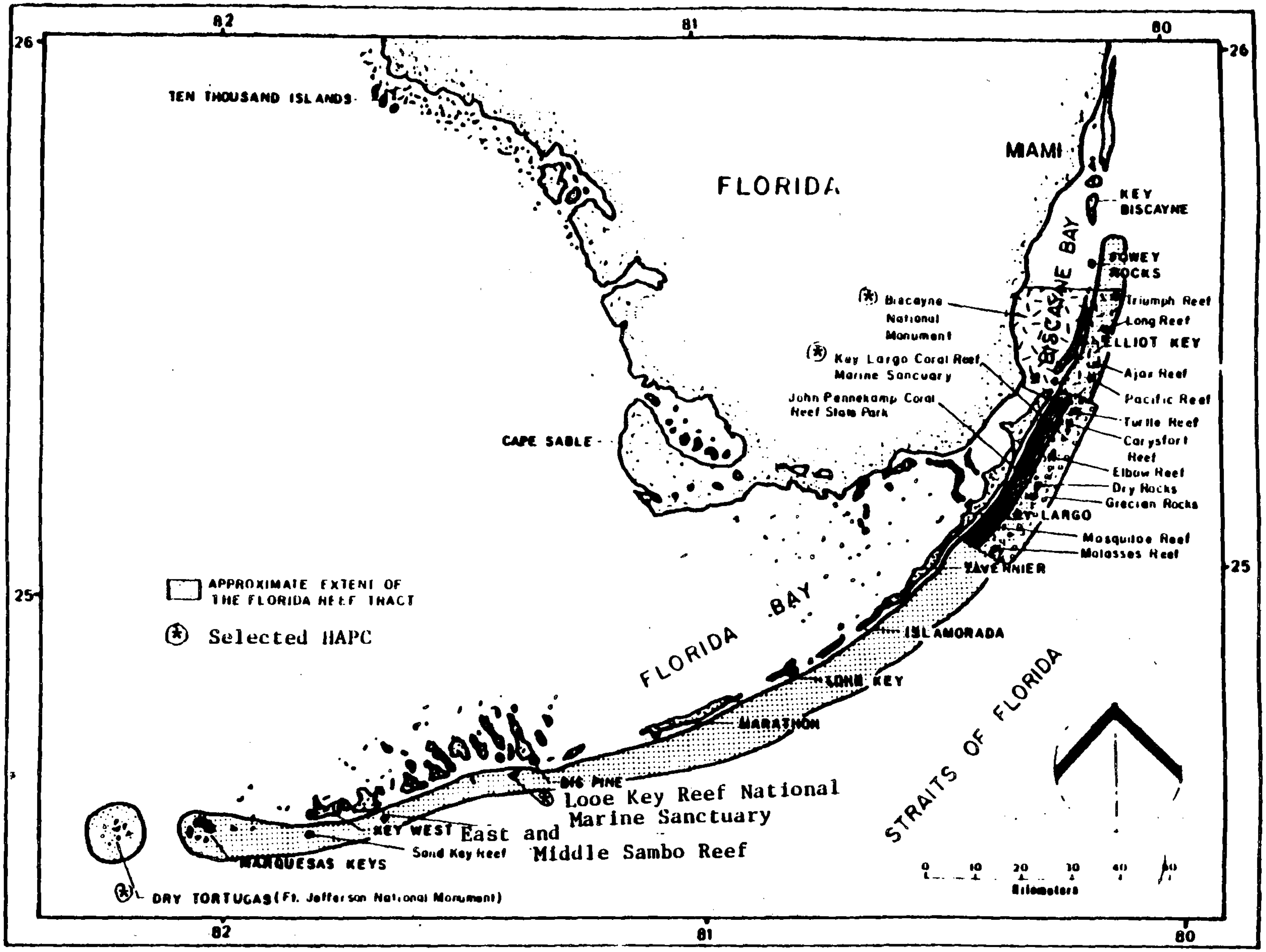


FIGURE 6-4. Florida Reef Tract reefs selected as Habitat Areas of Particular Concern.

The Florida reef tract (see Figure 6-4 and Section 5.2.1.4) contains the continental United States' most extensive coral habitat. Composed of a chain of individual reefs, the tract stretches in a curve of some 370 km (200 nm) from Miami to the Dry Tortugas (DiSalvo and Odum, 1974). The tract is bounded on the shoreward side by the Florida Keys and on the seaward side by the Florida Straits (see Figure 6-3). Its width is about 6.5 km (4 nm) with the seaward edge following the 18 m (60 ft) bathymetric contour. Although Shinn (1963) reports that the tract's flourishing reefs are largely limited to the northern half of the tract particularly off Key Largo, other prospering reefs also exist further south.

For purposes of identifying coral habitats of particular concern along the Florida reef tract, a total of four areas have been selected. Two areas including many separate reefs near Key Largo have been selected in the northern reef portion; Looe Key off Big Pine Key is identified from the middle portion; and the Dry Tortugas represents the southern end of the tract. Each is discussed in greater detail below. Other tract reefs which were considered, but were not included at this time, are Sand Key off Key West and the Sambo reefs off Boca Chica Key.

The Florida reef tract is exposed to a variety of both natural and man-made threats. Land based pollutants such as sediment, sewage, and various chemicals may be damaging certain reefs. However, the significance and even cause-effect relationships have yet to be clearly established. Perhaps the most significant threat is from recreational use which exposes the reefs to direct damage by souvenir and specimen collectors and anchor damage.

Key Largo Coral Reef National Marine Sanctuary

This HAPC has already been recognized by the Department of Commerce (OCZM) as an outstanding example of the patch and outer bank coral reefs found in the Florida reef tract. The national recognition as a national marine sanctuary has intensified public use of the area; resource collection pressures are low but user impacts, such as diver contact injury and recreational boat anchoring, continue. Many of the more prominent reefs are mapped on Figures 6-4 and 6-5. Sanctuary regulations allow hook and line fishing but prohibit spearfishing and the taking of tropical reef fishes.

The coral reefs within this area comprise the approximate northern limit of reef growth along the mainland coast of the Western Hemisphere. The zonation pattern of the reef structures for the northern Florida reef tract as described by Shinn (1963 and 1979) includes five zones; a back reef, a reef flat, an Acropora zone, a Millepora zone, and a rubble zone. The coral species composition of reefs in the marine sanctuary is described by the Office of Coastal Zone Management (1979b). Several of the reefs within the area exhibit the spur and groove formation described by Shinn (1963) at the Dry Rocks Reef.

The northern tract reefs have a long history of scientific research. Much of the relevant research has been reviewed by the Office of Coastal Zone Management (1979b). A continuation of this research history is evident in the coral reef resource survey being coordinated by the Office of Coastal Zone Management (1979c) for the National Marine Sanctuary and an environmental assessment and biological inventory being organized jointly by OCZM and the Florida Department of Natural Resources.

Biscayne National Park

Biscayne National Park is another HAPC that has been protected at least in part because of the coral resources found on its numerous patch and outer bank reefs. Since these coral communities are located closer to the Dade County urban areas than the Key Largo Coral Reef National Marine Sanctuary, the Park is exposed to considerable recreational activity. Divers tend to concentrate at four buoyed reefs (Figure 6-6). This HAPC would include only that portion of the Park located outside state waters, as shown on Figure 6-6.

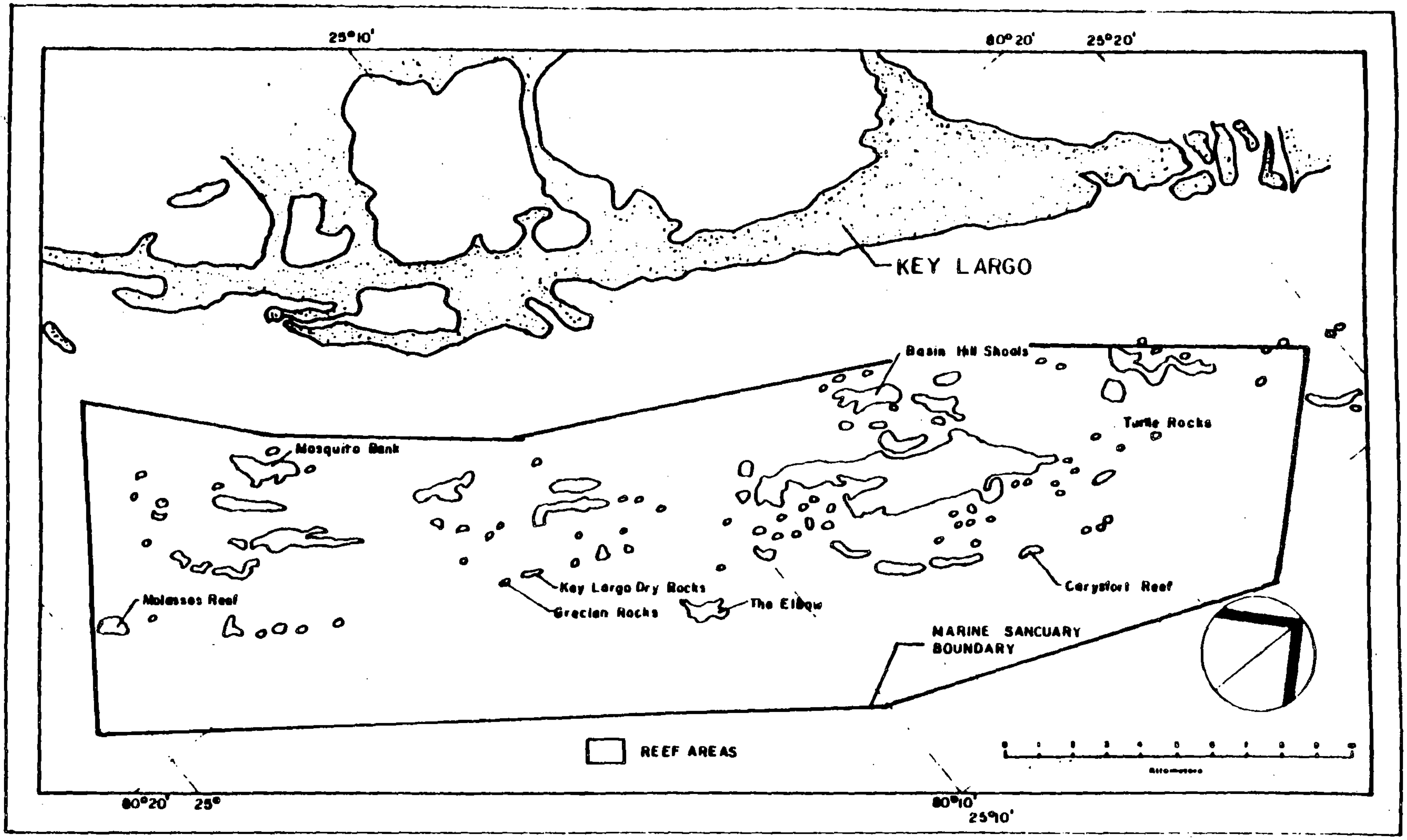


FIGURE 6-5. Reefs and approximate boundaries of the Key Largo Coral Reef Marine Sanctuary (Jameson, no date).

Coral reef assemblages in this HAPC closely resemble those described above for the Key Largo sanctuary; typical zonation patterns exist. Species composition has been studied by Jaap (1979), and Jaap (in preparation). On-going research efforts are described in Biscayne National Park (1978a, b). Most importantly, the Park represents the only sector of the management area and perhaps the world, where all of the data necessary for calculating MSY have been collected.

There are currently no special regulations for the Park. General regulations in Title 36 of the Code of Federal Regulations apply to all units of the national park system. Title 36 includes Part 2 on public use and recreation, Part 3 concerning boating and vessel permits, Part 5 on commercial and private operations, and Part 7 on special regulations.

Looe Key National Marine Sanctuary

Looe Key HAPC has been recognized by the Department of Commerce (OCZM) as an outstanding example of a submerged coral reef in the lower Florida reef tract. The 5nm^2 sanctuary area is located 12.4 km (6.7 nm) southwest of Big Pine Key, Florida (see Figures 6-4 and 6-7). From an ecological and topographic point of view, five major zones have been described by Antonius, et al. (1978): 1) a patch reef area; 2) a reef flat; 3) a forereef; 4) a deep reef seaward of the forereef; and 5) a deep ridge still further seaward. Each of these zones contains a representative coral species assemblage. Of particular significance, the forereef zone contains a spectacular spur and groove system that is among the best examples in the entire Florida reef tract (Antonius, et al., 1978). In order to protect the reef's resources the following activities are prohibited: taking or damage to sanctuary resources, including tropical fish and corals; spearfishing; using wire fish traps, poisons, or electric charges; littering; and lobster trapping within the forereef area of the Sanctuary.

The reef is a diving attraction rapidly growing in popularity with both local residents and tourists (Barada, 1979). Concurrently, it is subject to growing pressure from souvenir hunters and anchor damage (Antonius, et al., 1978). The reef is also used regularly for teaching and recreational purposes by the Newfound Harbor Marine Institute facility on Big Pine Key. The reef was nominated for consideration as a marine sanctuary (see Section 6.4) in November 1976 by the Florida Keys Citizens Coalition and was subsequently designated as such in 1981.

Dry Tortugas (Fort Jefferson National Monument)

Located at the southwestern tip of the Florida reef tract, this HAPC includes the Fort Jefferson National Monument, with approximately 26,166 ha (64,657 acres) of water area (Figures 6-4 and 6-8). Although it may be an ideal destination for recreational divers and tourists, because of the area's remoteness (116 km or 63 nm west of the nearest port at Key West), the reef resources make up one of the most spectacular and least disturbed reef areas in south Florida.

Between 1904 and 1937, the Carnegie Institute maintained a marine research laboratory on Loggerhead Key, thereby pioneering coral reef studies. Many of the studies conducted on the neighboring reefs have become classics contributing greatly to our present understanding of coral reef ecology. Recently, the benthic marine habitats of the Monument have been mapped (see Figure 6-6). Some of the more common reef corals at specific reefs within the Monument have been described by Davis (1977a, b). A field guide to the reefs was written by Davis (1977b).

Fort Jefferson National Monument is administered under a set of special regulations plus the general National Park Service regulations listed above for the Biscayne National Monument HAPC. Relevant special regulations for the Monument, as described in 36 CFR Chapter 1, Part 7.27, are:

(a) fishing - "no species of coral, shells, shellfish, seafan, sponges, sea anemones or other forms of marine life ... shall be taken or disturbed ... except in accordance with paragraphs (a) (2) to (7) ..." The paragraphs cited are being redrafted and/or eliminated such that the only permissible consumptive use of Monument resources will be recreational hook and line

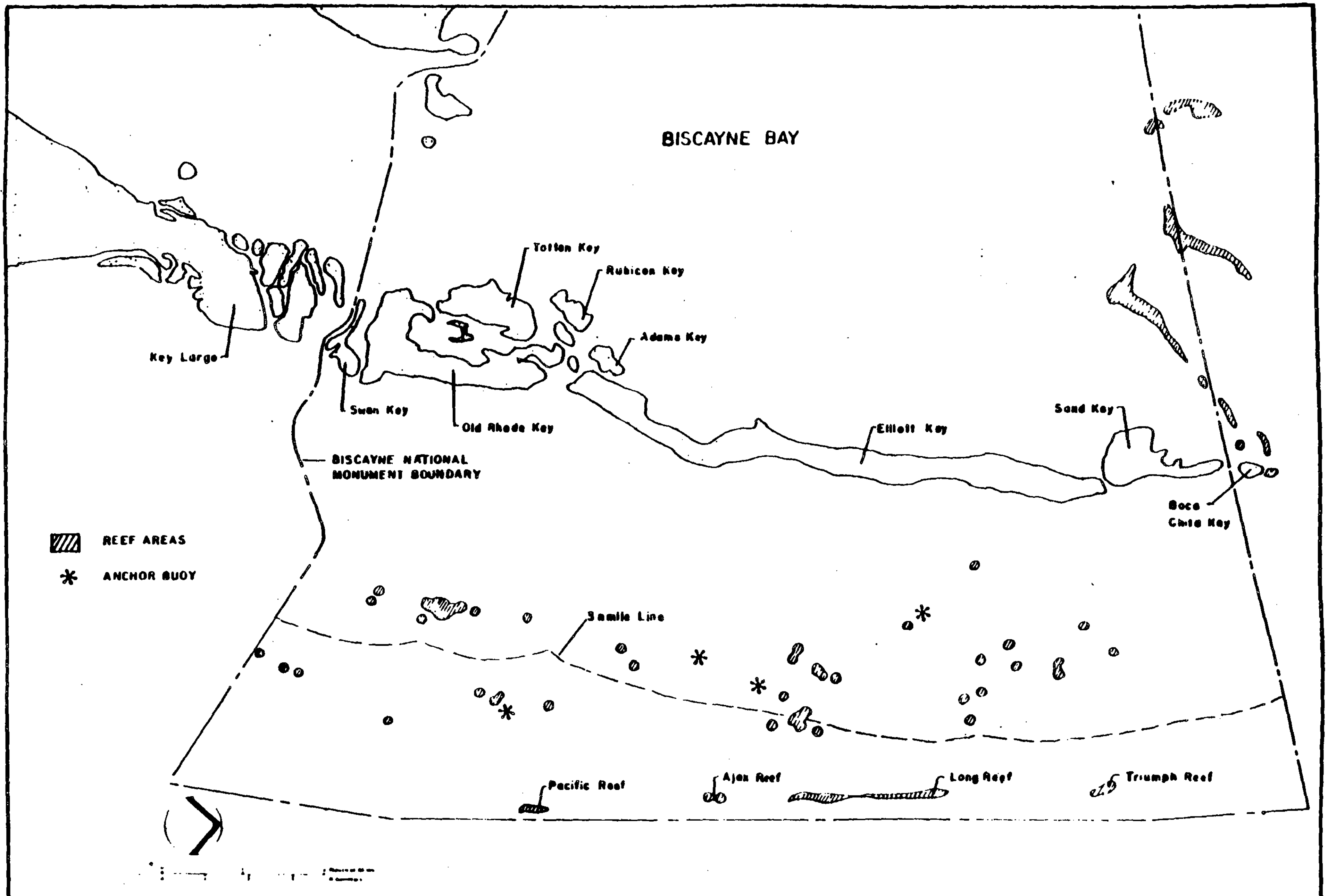


FIGURE 6-6. Reefs in the Biscayne National Park boundary.

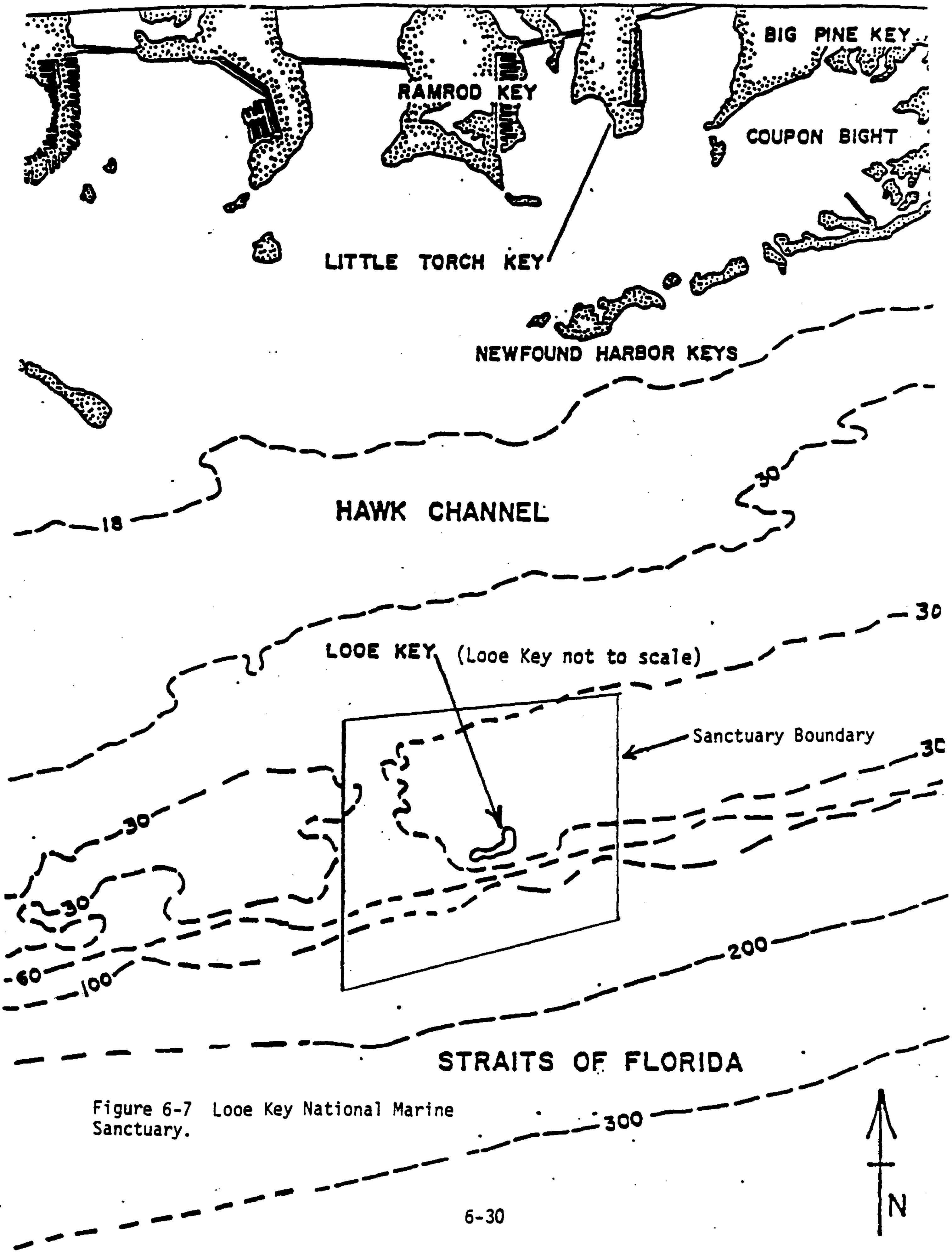


Figure 6-7 Looe Key National Marine Sanctuary.

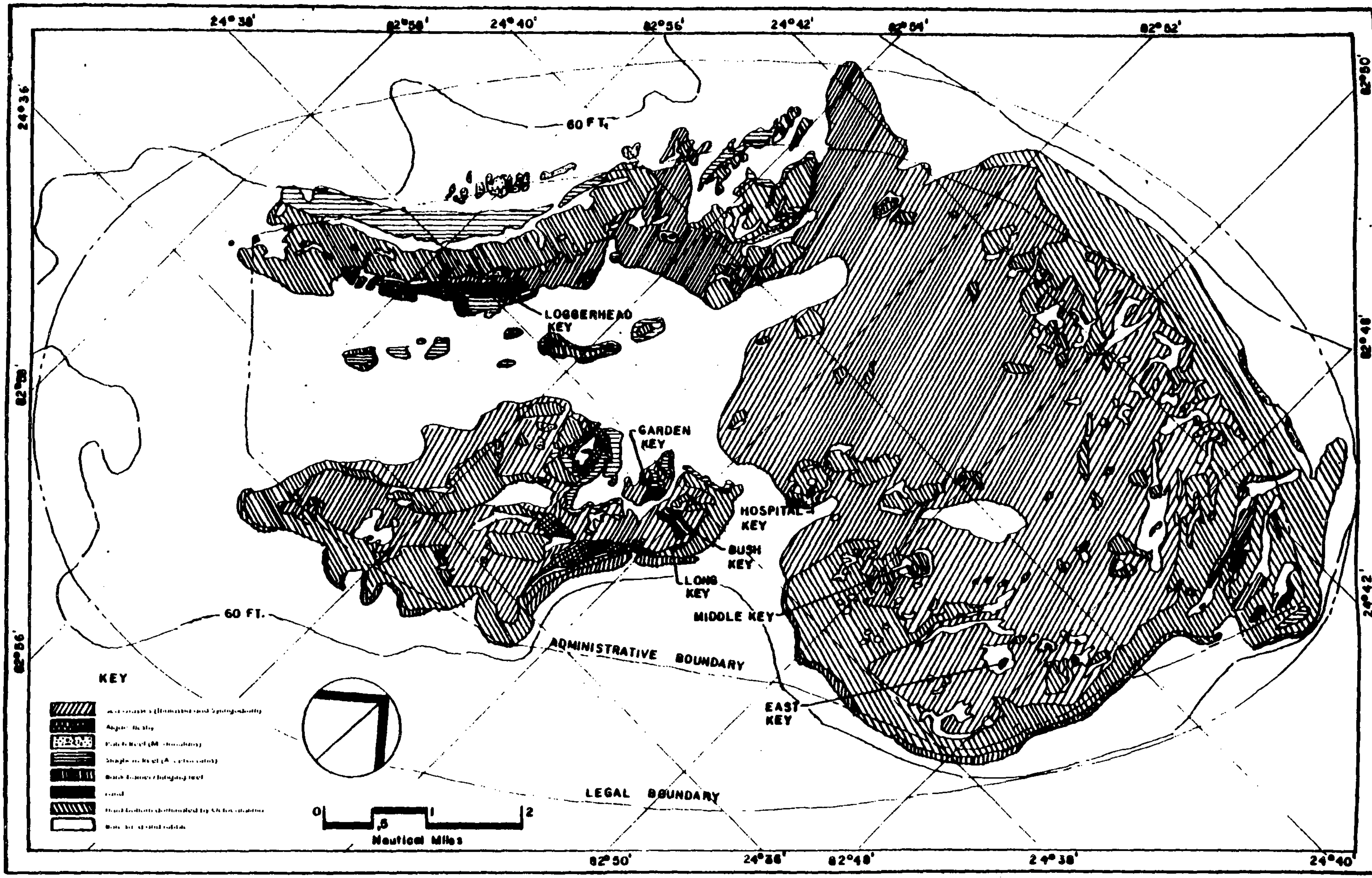


FIGURE 6-8. Outer continental shelf resource management map, coral distribution, Fort Jefferson National Monument, The Dry Tortugas (after map published by BLM, OCS Office, New Orleans, 1979).

(b) designated anchorage - "all vessels entering Tortugas Harbor in the vicinity of Garden Key shall anchor only in the designated anchorage area of Bird Key Harbor southwest of Garden Key ... Anchoring by recreational vessels is limited to not more than eight hours between sunrise and sunset by permission from the Monument Superintendent or his/her representative."

Northern Live Bottom Coral Habitats

North of Miami, Florida, coral diversity and abundance fall abruptly. Live bottom communities with hermatypic corals and gorgonians can be found as far north as Cape Lookout, North Carolina, although coral abundance does not approach the dominance displayed in the Florida reef tract (see Figure 6-9). The stony corals which may extend north include species of Oculina, Phyllangia, Solenastrea, Cladocora, Astrangia, and Siderastrea. Between Miami and Cape Lookout, three sites have been considered as HAPCs; Oculina banks off central eastern Florida, Gray's Reef off Georgia and an unnamed live bottom off Bogue Bank in Onslow Bay off North Carolina. However, Onslow Bay has not been listed as a HAPC at this time due to a lack of site-specific information. The area may be reconsidered as more data are collected.

Oculina Bank

A 90-mile shelf-edge strip of coral reefs is located off central eastern Florida and is composed of banks, thickets, and rubble zones of the scleractnian Oculina varicosa (ivory tree coral). This fragile, branching stony coral forms massive contiguous colonies in deeper water (70 to 100 m) where in shallow water it forms only small, discrete colonies (Reed, 1980b).

The shelf-edge Oculina reefs are a unique ecosystem. They are monospecific, comprised of a single species of colonial coral, and form delicately branched bushes 1.5 m in height, hundreds of feet long, and covering hills and pinnacles with 25 m relief. These are the only known banks composed of monospecific colonial coral that occur on the continental shelf (200 m depth) anywhere in the United States (Reed, 1982).

This bank or reef system has only recently been discovered. Dense and diverse populations of fishes and invertebrates (Reed, et al., in press) are associated with the Oculina. The area supports a substantial but unquantified recreational and commercial fishery for grouper, sea bass snapper, and other fishes (Reed, 1982).

The HAPC is a 23 by 4 nm strip located approximately 15 nm off shore at its nearest point (see Figure 6-10). Its depth ranges from approximately 30 fathoms to 75 fathoms. This 92 nm^2 area is bounded by latitude 27° 53' N to latitude 27° 30' N and longitude 79° 56' W to longitude 80° 00' W and contains representative shelf-edge Oculina banks, major Oculina thickets, and coral rubble pinnacles.

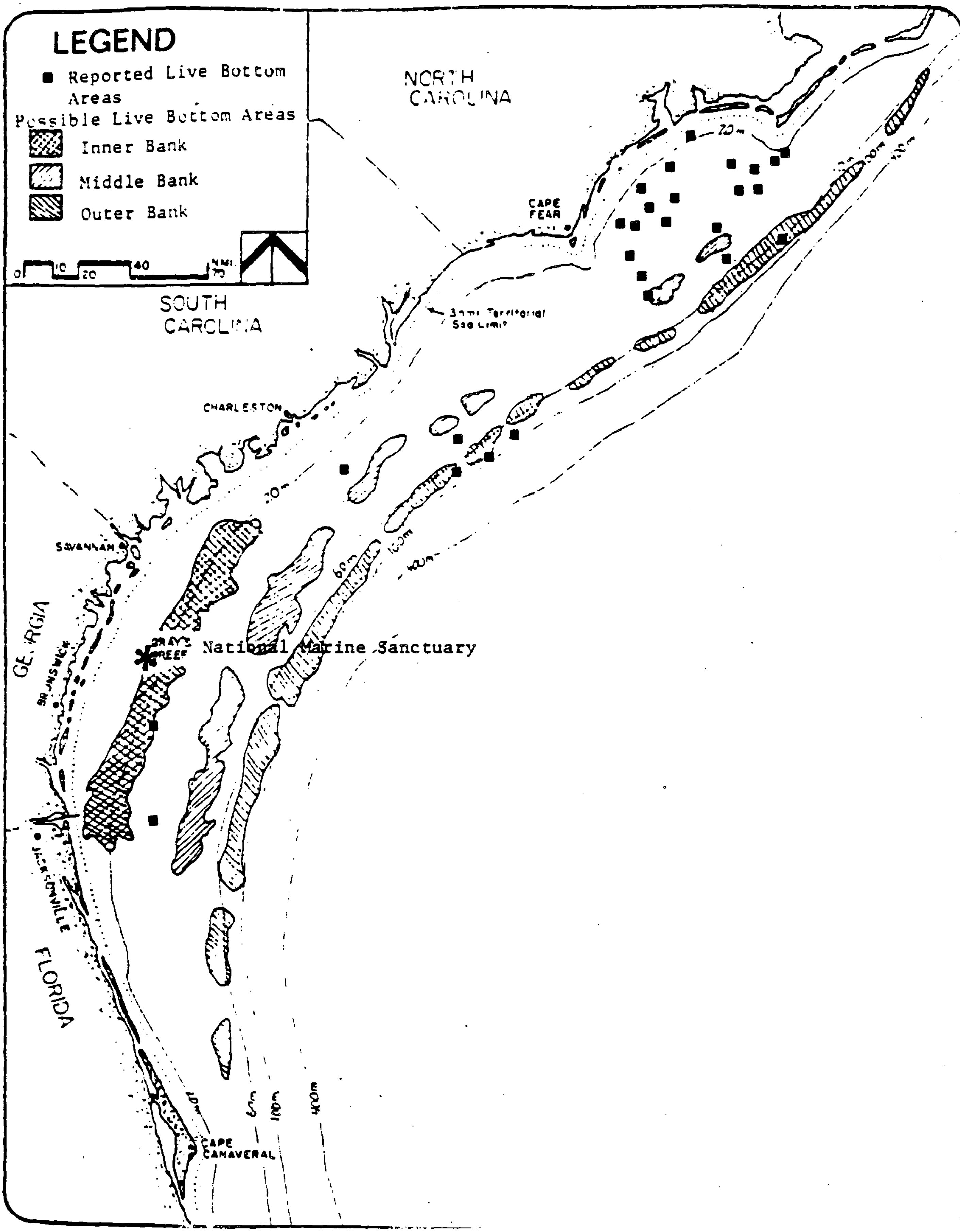
In a relatively new fishery for bottom reef fish, trawlers are utilizing roller trawls to take fish off rough bottoms. Although such trawls are subject to damage and loss if used in high relelf areas, they are apparently being used in close proximity to the banks and can damage the habitat and corals in hard bottoms.

In order to protect the corals the use of all bottom trawls, bottom longlines, dredges and fish traps and pots is prohibited within the HAPC.

Gray's Reef National Marine Sanctuary

Gray's Reef, located about 33 km (18 nm) off Sapelo Island on the Georgia coast (see Figures 5-4 and 6-9) has been recognized by the Department of Commerce (OCZM) as an outstanding example of northern live bottom habitat by its designation as a National Marine Sanctuary. Although referred to as a

FIGURE 6-9. Hard-bottom areas which may support live-bottom communities and reported live-bottom areas. Source: Bureau of Land Management, 1978.



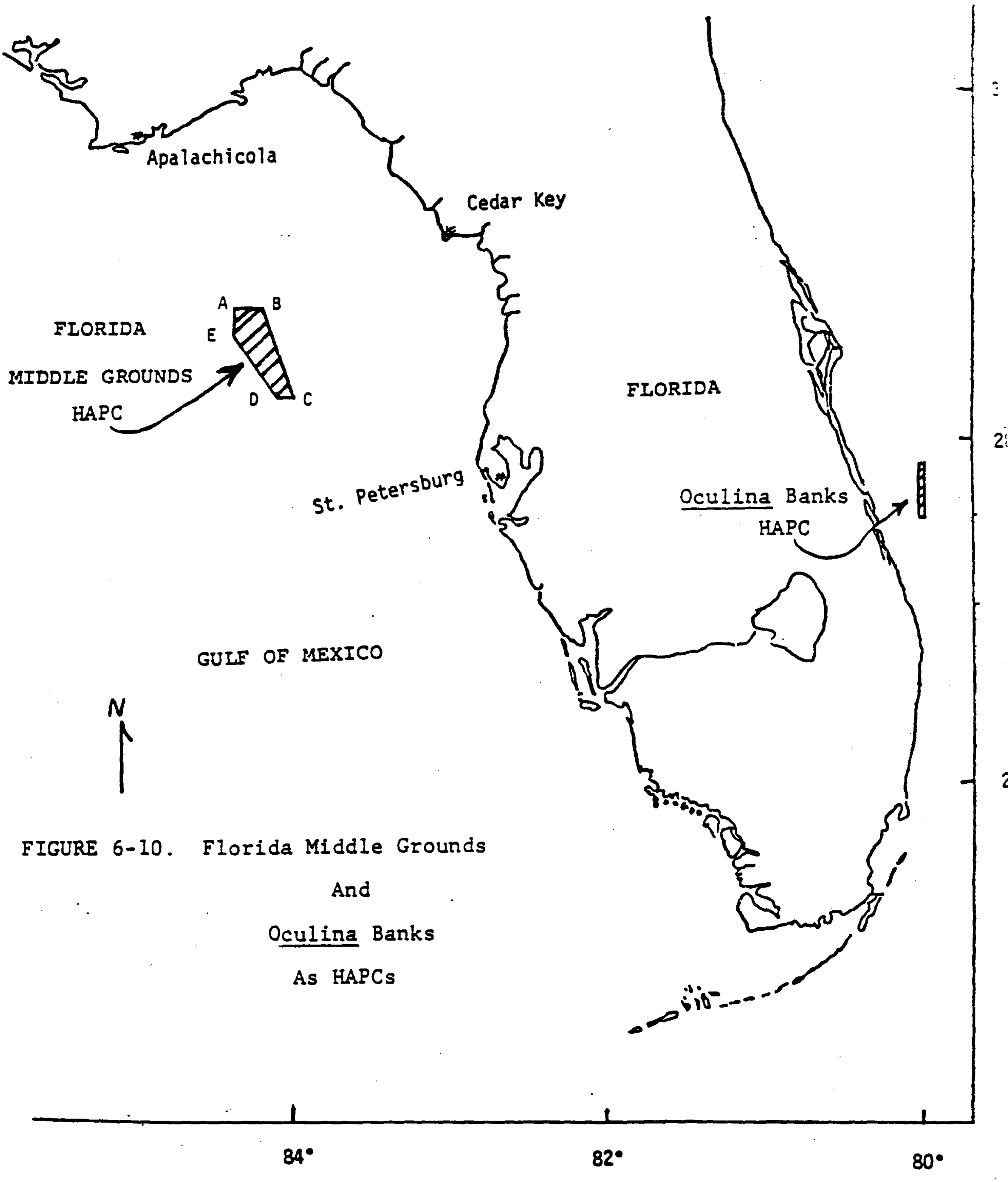


FIGURE 6-10. Florida Middle Grounds And *Oculina* Banks As HAPCs

"reef," the 20 m (65 ft) deep area is actually a live bottom composed of a series of rocky ridges running in a southwest-northeast direction and covering an area of about 57 km^2 (16.68 nm^2). Among the benthos at the site are scattered heads of stony corals and a variety of soft corals. The site is visited only occasionally by scientists, SCUBA divers and commercial and sport fishermen, and is relatively poorly known (Porter, 1979, personal communication). The most authoritative description of the live bottom was prepared by Hunt (1974) on the geology and origin of the area. The Georgia Department of Natural Resources, largely based on information presented by Hunt, nominated the area as a national marine sanctuary (Neuhauser, 1979), and it was designated as such in 1981.

In the 57 km^2 (16.68 nm^2) area bottom alteration activities, trawling and dredging, fish traps, and collection of marine plants, invertebrates, tropical fish, and historic or cultural resources are to be controlled by permits. The status quo activities of anchoring and spearfishing are to be monitored for future consideration. Other fishing activities are to be regulated under plans developed by the South Atlantic Fishery Management Council.

Florida Middle Grounds

The Florida Middle Grounds is a live hard bottom area located on the outer edge of the continental shelf in the eastern Gulf of Mexico. It is approximately 160 km (87 nm) west-northwest of Tampa and 140 km (76 nm) south-southeast of Cape San Blas, Florida (see Figure 6-10).

The Florida Middle Grounds is the best known and most important area in terms of coral in the northeastern Gulf of Mexico. The dominant stony corals include Madracis decactis, Porites divaricata, Dichocoenia stellaris, Dichocoenia stokesii. Octocorals, a relatively minor component of other Gulf reefs, are prominent on the Middle Grounds; dominant forms include Muricea elongata (orange Muricea), Muricea laxa (delicate Muricea), Eunicea calyculata (warty Eunicea) and Plexaura flexuosa (sea rod), Hopkins, et al. (1977).

Recreational activities are limited by the distance from shore. Although requiring at least a two-day trip to reach the Florida Middle Grounds and return, enthusiastic sport fisherman and recreational divers have been reported to frequent the area.

This area is frequented by commercial fishing boats. Primary fish species involved include the red snapper and grouper which dominate the landings and value of landings of Gulf of Mexico reef fish.

The boundary of the area identified as a habitat area of particular concern is defined in Section 12.4, measure 5b and contains the major area of high relief bottom (see Figure 6-10). The Florida Middle Grounds were nominated as a marine sanctuary but no further action has yet been taken. The BLM has identified as "no activity areas" for oil and gas exploration and development areas in the northern portion of this HAPC.

One management measure is recommended:

- Within the HAPC, the use of bottom longlines, traps and pots, and bottom trawls is prohibited. The taking of all corals is prohibited except as authorized by permit.

6.4 Habitat Protection Programs

This section describes existing habitat protection programs that are actively utilizing their authorities to provide some form of protection for corals within their respective management units (e.g., parks, preserves, sanctuaries, etc.). The programs which are considered in detail include: 1) the federal Office of Coastal Zone Management's Marine Sanctuaries Program; 2) the National Park Service's

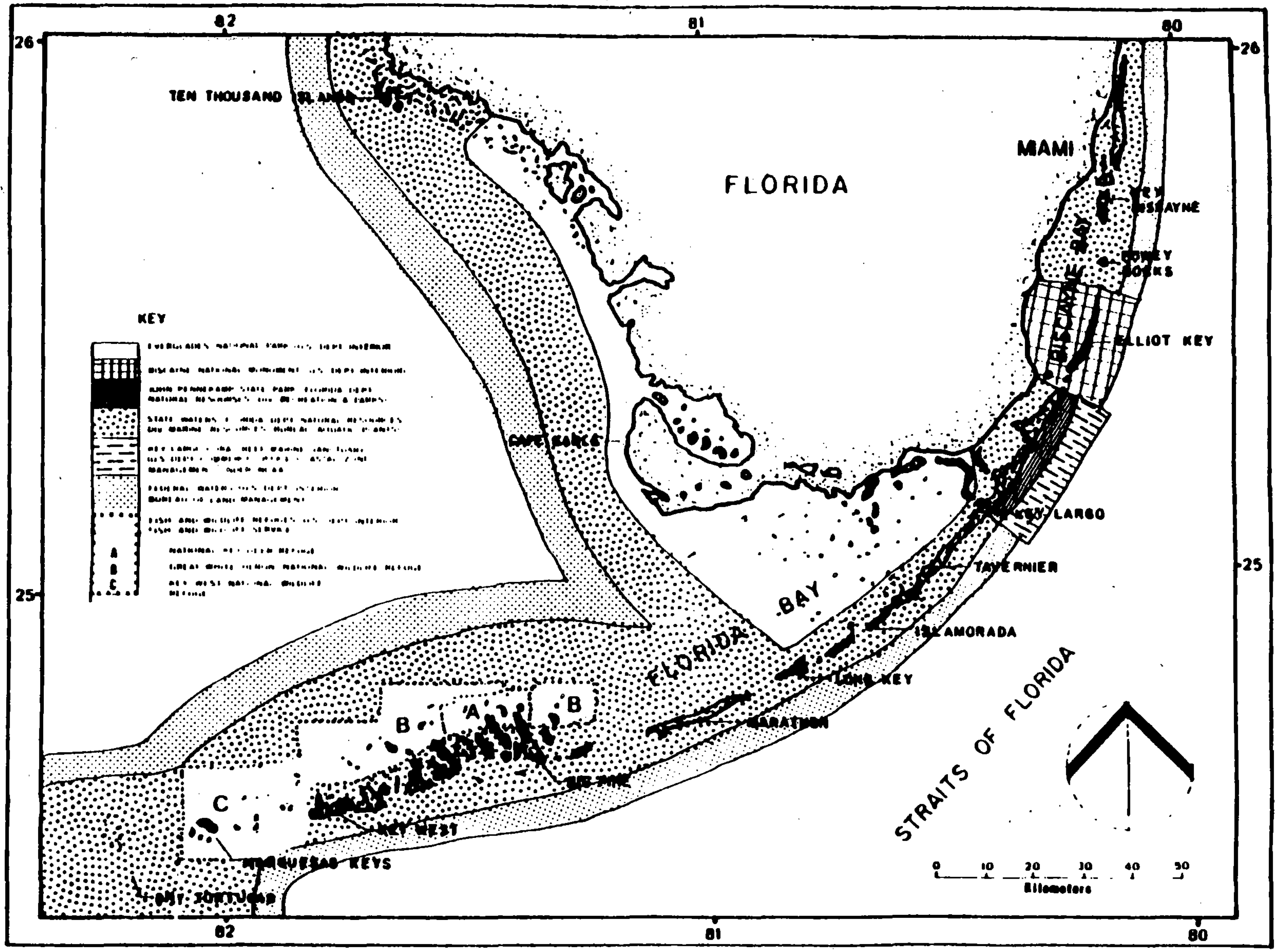


FIGURE 6-11. Habitat management authorities and associated programs associated with the Florida Reef Tract (after Shinn, 1979b).

National Parks and National Monuments; 3) the Bureau of Land Management's Outer Continental Shelf Leasing Program; 4) the Florida Aquatic Preserve System; and 5) the Florida State Park System. The discussion presented below for each of these programs emphasizes the specific efforts they are taking on behalf of coral habitat protection interests within the current fishery management area jurisdiction.

In the Florida Keys area, many of these individual program management efforts, as well as general coral protection provisions administered by the State of Florida (see Section 7.4) and the U.S. Bureau of Land Management (see Section 7.3), interface to form a complex patchwork of geographically-variable management restrictions for coral. The geographic distribution of the various management authorities has been reviewed by Shinn (1979) and is illustrated in Figure 6-11.

In addition to the area-specific management programs, a variety of other federal, state and international authorities have a significant though less focused coral habitat protection role and are discussed in Sections 7.1, 7.2, 7.3, and 7.4.

Federal Programs: National Marine Sanctuaries Program

In terms of complementing the protection objectives of the coral fishery management plan from a site-specific perspective, one of the most important federal programs is undoubtedly the Office of Coastal Zone Management's (OCZM) National Marine Sanctuaries Program. This program was authorized under Title III of the Marine Protection Research and Sanctuaries Act (MPRSA) of 1972. Its purpose is to preserve or restore the conservation, recreational, ecological, or aesthetic values of localized areas "... as far seaward as the outer edge of the continental shelf, ... [and in] other coastal waters whether the tide ebbs and flows ..." (MPRSA, Section 302a). In effect, the National Marine Sanctuaries Program is a coastal water counterpart to the more familiar national park, forest wildlife refuge, and wilderness systems.

The National Oceanic and Atmospheric Administration (OCZM's parent organization) has made a firm commitment based on expressed Presidential support (see text of President Carter's May 23, 1977, Environmental message) to expand program efforts to designate and manage new sanctuaries. At the time of this writing, six sanctuaries have been designated, four of which are in the Coral FMP management area. Of particular interest to the Coral FMP, consideration of new sanctuaries begins with a nomination that may originate from a variety of sources, including Regional Fishery Management Councils and National Marine Fisheries Service.

Following prescribed evaluation steps including public hearings, a sanctuary environmental impact statement, consultation with interested parties, governmental and Presidential approval, an individual sanctuary management plan is finalized and implemented. Significantly, management aspects can vary widely among different marine sanctuaries with each designation receiving individual treatment. Title III of the MPRSA provides clear authority to manage and control uses within sanctuary boundaries that are incompatible with the sanctuary's recognized values. As part of the individual attention accorded each designation, a separate set of sanctuary-specific regulations are tailored to the protection needs of each designated area. Regulations are placed only on those activities within the sanctuary boundaries judged to be incompatible with the sanctuary's purpose.

Actual site management and administrative responsibility for a particular sanctuary may either be retained by OCZM or delegated with necessary funding support to other appropriate management units that could include the Regional Fishery Management Councils.

The National Marine Sanctuary Program is particularly interested in protecting outstanding coral reef areas. One of the six existing sanctuaries - the Key Largo Coral Reef National Marine Sanctuary off Key Largo, Florida, - complements state efforts at John Pennekamp State Park by protecting a 343

km^2 (100 nm^2) section of the upper Florida reef tract. A management plan for the Key Largo sanctuary has been designed to provide the protection necessary to insure long-term viability of the ecosystem. The management plan also addresses public education, environmental monitoring and regulatory enforcemental monitoring and regulatory enforcement needs at the site. Enforcement is conducted cooperatively by the Florida Department of Natural Resources (Marine Patrol and Park Rangers) and the U.S. Coast Guard. A deepwater resource survey at Key Largo Coral Reef National Marine Sanctuary conducted in March and June, 1979, accurately mapped the extent of deepwater coral and qualitatively inventoried the resource (OCZM, 1979c).

The Gray's Reef National Marine Sanctuary, covering 16.68 nm^2 of live bottom reef located 18 nm off Sapelo Island, Georgia, was designated in January, 1981, to maintain and protect the live bottom ecosystem in its natural state; to promote scientific understanding of the ecological nature and the role of the ecosystem and the functional relationships of live bottom areas throughout the south Atlantic, to one another and the marine and coastal ecosystems of the region; and to promote public appreciation and wise use of regionally significant live bottom resources (OCZM, 1980a). A management plan will soon be developed to guide efforts in resource protection through management, research, education and regulatory enforcement, and to ensure maximum public benefit from this national marine sanctuary.

The Looe Key National Marine Sanctuary, covering a 5 nm^2 coral reef area located 6.7 nm east of Big Pine Key, Florida, was designated in January, 1981, to maintain, protect and enhance the quality of the natural, biological, aesthetic and cultural resources of the Looe Key system, to promote and stimulate marine research efforts directed toward improved management decisionmaking and identification and analysis of marine ecological interrelationships, and to enhance public awareness of the functioning of the Looe Key coral reef system (OCZM, 1980b). A management plan for the sanctuary will soon be developed to provide direction toward fulfilling these sanctuary purposes.

Other management areas containing coral reefs under consideration as active candidates for sanctuary designation by the National Marine Sanctuary Program include Flower Garden Banks in the northwestern Gulf of Mexico; waters southeast of St. Thomas, Virgin Islands; water around Mona and Monita Islands, Puerto Rico; the area off southwest Puerto Rico known as La Parguera; and the waters around Culebra and Culebrita Islands and the Cordillera reef chain off northwest Puerto Rico.

The purpose of the proposed Flower Garden Banks sanctuary is "... to protect and preserve the banks' ecosystems in their natural state and to regulate uses within the sanctuary to insure the health and well-being of the coral and associated flora and fauna and the continued availability of the area as a recreational and research resource ..." (OCZM, 1979a). The activities proposed for regulation address, among others, deliberate harm of coral, dredging, trawling and oil and gas operations.

The purpose of the proposed St. Thomas sanctuary is to conserve sanctuary resources in a manner compatible with the National Marine Sanctuary Program goals and objectives in order to maintain, protect and enhance the quality of the area's biological, aesthetic, and cultural resources; to encourage scientific research within the sanctuary focused on management-related questions and enhancement of knowledge of the area's natural systems; to enhance national and local awareness of the significance of the marine resources within the proposed sanctuary; to encourage wise use of these resources; and to promote understanding of the role of the National Marine Sanctuary Program in marine conservation. The proposed area is extremely important to recreational, commercial, and education users, offering a unique area for a variety of water-related interests. The three Puerto Rican sites are proposed for sanctuary status for the purpose of protecting the resources within the context of a comprehensive management framework. Management objectives have yet to be developed for these sites.

National Parks and Monuments

Another site-specific management program with applicability to coral protection is the system of national parks and monuments operated by the National Park Service (NPS) within the Department of Interior. In the broadest terms, the purpose of the NPS units are to "... preserve for all times scenic beauty, wilderness, native wildlife, indigenous plant life and areas of scientific significance and antiquity ..." (16 U.S.C §1). Although the National Park System includes several marine areas, their distinctly land-based orientation makes them somewhat less likely to include new marine areas within their system. Nevertheless, two areas operated by the NPS within the present study area include and manage significant coral resources - the Biscayne National Park north of Key Largo, Florida, and the Fort Jefferson National Monument in the Dry Tortugas, Florida.

Both the statement for management for the Fort Jefferson National Monument (U.S. National Park Service, 1977), and the general management plan for Biscayne National Park (U.S. National Park Service, 1978), include as major management objectives the protection of natural resources (including corals) within their boundaries. At the Fort Jefferson Monument, all areas within the Monument's administrative boundaries (with the exception of Garden Key), are classified as an outstanding natural area under the National Park Service's land classification system. Prohibited activities include commercial fishing and the taking of lobsters while allowed uses include sport fishing and non-consumptive recreational activities. Under NPS management, the coral resources at the Fort Jefferson National Monument appear to be well protected (Jaap, 1979, personal communication).

According to the general management plan, Biscayne Park is "... designed to facilitate the existing recreation activities in a compatible manner with the physical and biotic environment, and [to] provide mechanisms for detecting areas of existing or potential environmental degradation" (U.S. National Park Service, 1978). Recognizing that recreational use often creates a certain level of coral damage, some of the management provisions at this Monument include: 1) monitoring to detect destruction of a area at early stages (to allow initiation of corrective measures); 2) improvement of monument boundary, channel, and depth warning markers at critical locations; 3) establishment of activity areas, 4 enforcement of regulations prohibiting tropical fish collecting and "pot hunting" (removal of archeological artifacts); 5) the establishment of mooring stations near corals to reduce anchor damage; and 6) establishment of monitoring stations to detect natural flucuations in environmental factors such as temperature, salinity and wind. In addition, special studies are planned in cooperation with the State of Florida to determine what types of commercial and sport fishing will be allowed, in what magnitude, and what regulatory actions will be necessary.

Outer Continental Shelf Oil and Gas Leasing

The Secretary of the Department of Interior (DOI) is charged with administering mineral exploration and development on the Outer Continental Shelf (OCS), pursuant to the Outer Continental Shelf Lands Act (OCSLA), as amended in 1978 (43 U.S.C §1331 et seq.). This responsibility has been delegated to two offices within the Department: the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS). The BLM serves as the administrative agency for leasing submerged federal lands while the USGS is charged with supervising mineral development operations on the OCS.

Of particular interest to this coral FMP is the Secretary of Interior's ability to withdraw tracts from proposed OCS mineral lease sales for lack of information, aesthetic, environmental, geologic, or other reasons. The presence of coral reefs, hard bottoms, or other marine areas containing significant resources could be reasons for withdrawing tracts. Further, the OCSLA (43 U.S.C §1341) also provides for permanent disposition from leasing; Key Largo coral reef was provided such protection by President Eisenhower, through Proclamation No. 3339 (55 CFR 2552) which established the Key Largo Coral Reef Preserve on March 17, 1960. This disposition served as a precursor to the present Key Largo Coral Reef Marine Sanctuary. (BLM's coral permitting authority under the OCSLA is not considered a site-specific habitat protection program and is instead discussed under Section 7.3).

With respect to oil and gas tract withdrawal, BLM has demonstrated an awareness and interest in preserving coral communities and other significant resources. Several potential lease tracts nominated by oil companies have been withdrawn due to the presence of significant bottom habitats, including some containing coral. For example, the Secretary of Interior rejected oil company bids for a tract off the Georgia coast (Tract #41) in the 1978 South Atlantic OCS Sale #43. The deletion was based on the perceived need to preserve a "live bottom community" (i.e., hard bottom) documented to exist there. Similarly, recent OCS sales in the Gulf of Mexico have prohibited drilling directly over several coral-encrusted hard banks located on salt domes, including areas directly over the East and West Flower Garden Banks (Bureau of Land Management, 1981). Further, BLM lease stipulations require that drilling opertions adjacent to these banks must shunt their drilling discharges directly to the bottom nepheloid (a dense water mass of high turbidity) layer to minimize potential impacts from surface discharges that might otherwise affect bank corals and other bank biota.

The Secretary of Interior's ability to delete lease tracts from oil and gas development and BLM's ability to require certain drilling techniques which minimize environmental damage through lease stipulations represent an important OCS habitat protection authority for protecting localized coral habitats. Further, the USGS must ensure oil company compliance with regulations and lease stipulations once a lease is sold, also represents a key management authority for ensuring protection of coral communities. Although these authorities are not comprehensive, they are significant because of the widespread interest in current OCS oil and gas development and its potential impact on corals.

State Programs

Because significant coral communities within state waters appear to be limited to the southernmost portions of Florida, detailed discussion of site-specific state programs is limited to those actually protecting coral habitat in Florida. The programs identified to be of primary concern include the state's Aquatic Preserve and Park Systems.

Florida Aquatic Preserve System

By special legislative action, the Florida Aquatic Preserve Act of 1975 (Florida Statutes, Sections 258.35-258.44) was created to establish a direct means of permanently preserving submerged, state-owned lands. The Act defined an aquatic preseve as a "biologically, aesthetically or scientifically ... exceptional area of submerged lands and its associated waters set aside for maintaining the area essentially in its natural or existing condition" (Florida Statutes, Sections 258.37-258.38). The Aquatic Preserves created under this Act include only lands and water bottoms owned by the state (Florida Statutes, Section 253.03) and other lands or water bottoms that another government agency might authorize for preservation. No privately owned lands or water bottoms are included in the Act unless by special agreement with that private owner. Other specific exclusions from the Aquatic Preserves are areas altered by channel maintenance of other public works projects and, lastly, lands lost by artifically induced erosion.

The Aquatic Preserve System is administered by the Florida Department of National Resources. Limitations on usage (discussed in Section 258.42 of the Florida Statutes) control: sale, lease, and transfer of preserve lands; water relocation or bulkheading; dredging or filling except a required minimum; drilling for oil or gas; or mineral excavation. Private owners bordering the preserve retain certain riparian rights to construct docks and protect their shoreline, if those actions are deemed necessary.

Although each preserve was to have its own set of rules and regulations to protect water quality and aquatic resources, no preserve rules have yet been developed. In process, however, are rules for the Biscayne Bay Aquatic Preserve which could provide a prototype set of rules for other designated preserves.

The original Florida Aquatic Preserves Act of 1975 outlined boundaries for 31 Aquatic Preserves. Although most of these are in inshore waters, such as rivers and estuaries, ocean areas may also be included. At least three preserves in the Florida Keys probably include coral habitats - the Coupon Bight Aquatic Preserve adjacent to and south of Big Pine Key, Florida; Lignumvitae Key Aquatic Preserve to the south of Key Largo, Florida; and Biscayne Bay Aquatic Preserve in Biscayne Bay, Florida.

Florida State Park System

The relevance of the State Park System is due principally to the John Pennekamp Coral Reef State Park on and off Key Largo, Florida. This outstanding park adjacent to Key Largo Coral Reef Marine Sanctuary contains significant coral reef habitats. The John Pennekamp State Park was established in 1959 and includes over 125 km^2 (36 nm^2) of state waters.

Other Site Specific Protection Programs

Finally, in addition to the above listed active habitat protection efforts, several other governmental programs which could or might be expected to have relevant area specific coral protection authorities have also been considered: state Natural Area Programs; the Outstanding Florida Water System; the federal Estuarine Sanctuaries Program within the Office of Coastal Zone Management; the Geographic Areas of Particular Concern segment of developing state Coastal Zone Management Programs; National Wildlife Refuges operated by the U.S. Fish and Wildlife Service; and the National Natural Landmarks Program administered by the National Park Service.

State Natural Area Programs have not been considered in detail because, with the exception of Florida no significant coral communities have been identified in any other state waters. The Florida Outstanding Florida Waters classification, which took effect January 1, 1979, is the newest aquatic protection initiative mandated by the state of Florida. Since waters so designated presently include only surface waters within existing national and state parks, monuments, aquatic preserves, recreation areas, environmentally endangered lands, and similar systems, and since it is still too early to project how this new classification might relate to coral protection, it is not discussed in detail.

Several estuarine sanctuaries have been considered and established along the coast of the current management jurisdiction. Estuaries however are not typically suitable sites for extensive coral communities. Thus, the relevance of estuarine sanctuary designations will be limited primarily to the extent that they can improve or assure high quality coastal water drainage and not their ability to preserve specific aquatic habitats. High quality coastal drainage is important so as to reduce pollution stress to coastal open water marine habitats including important coral habitats.

As mentioned above, the only state in the management area believed to have jurisdiction over important coral habitat areas is Florida. The coastal zone management program of the state, now being restructured and redirected, has limited its identification of geographic areas of particular concern to areas already established by the state legislature (i.e., Aquatic Preserves, State Wilderness Areas, Areas of Critical State Concern, Environmentally Endangered Lands, and Coastal Shore Front Areas). None of these areas, however, included special provisions to protect corals or coral habitats. Only the above mentioned Biscayne Bay Aquatic Preserve and the Florida Keys Areas of Critical State Concern contain coral habitats.

Three National Wildlife Refuges are located in the Florida Keys which undoubtedly contain coral habitats: the National Key Deer Refuge, the Great White Heron National Wildlife Refuge, and the Key West National Wildlife Refuge. These areas are operated by the U.S. Fish and Wildlife Service. These areas, however, rely on the coral permitting authority of the State of Florida to protect the corals (Shinn, 1979b).

The National Landmarks Program offers federal government protection and preservation of representative examples of the nation's natural history. Landmarks may be either land or water based. The program seeks "to encourage the preservation of areas that illustrate the ecological and geological character of the United States, to enhance the educational and scientific value of the areas thus preserved, to strengthen cultural appreciation of natural history, and to foster a wider interest and concern in the conservation of the Nation's natural heritage" (U.S. Department of the Interior, 1979). There are presently no natural landmarks designated to preserve corals although many landmarks do exist in the management area states.

7.0 FISHERY MANAGEMENT JURISDICTION, LAWS, AND POLICIES

7.1 Management Institutions

7.1.1 International and Foreign

Intergovernmental Maritime Consultative Organization (IMCO)

IMCO was established pursuant to the Convention on the International Maritime Consultative Orgnization (9 U.S.T. 621) to perform an advisory role on issues concerning commercial shipping. It can, on an international basis, establish measures on the routing of ships and recommend standards for vessel design, construction, and operation. IMCO may also function as an overseer of international conventions and agreements on commercial shipping. The various standards and conventions over which IMCO has authority may serve to reduce the impacts of navigational activities (e.g., groundings, vessel discharges) on coral resources.

Philippine Presidential Decree No. 1219 -- This October 1977 decree, titled "Providing for the Exploration, Utilization, and Conservation of Coral Resources", states that "the gathering, harvesting, collecting, and/or exporting of ordinary coral is prohibited ..." with certain special exemptions (Section 5). Exportation of precious and semi-precious corals is similarly prohibited (Section 9.0). These prevlsions could greatly affect the United States' coral market since most corals are imported raw from the Philippines (see Section 9.3).

7.1.2 Federal

National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA) -- The Secretary of Commerce, acting through NMFS, has the ultimate authority to approve or disapprove all fishery management plans prepared by regional fishery management councils (FMCs) pursuant to the FCMA. NMFS has issued regulations to guide the development of fishery plans and the operation of regional FMCs. Where a FMC fails to develop a plan, or correct an unacceptable plan, the Secretary may do so. NMFS also collects data and statistics on fisheries and fishermen as an aid to fishery management.

Office of Coastal Zone Management (OCZM), NOAA -- OCZM asserts authority over the management of corals through National Marine Sanctuaries, pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act. Within the management area, protection of coral reefs, coordinated through OCZM, has been the prime motivation in both the designation of the Key Largo Coral Reef Marine Sanctuary, Gray's Reef National Marine Sanctuary, and Looe Key National Marine Sanctuary and the nomination (and consideration) of ocean areas at the Flower Garden Banks off Texas. The OCZM Estuarine Sanctuary program has designated Rookery Bay in Collier County, Florida, and nominated Apalachicola River and Bay in Franklin County, Florida, as estuarine sanctuaries. Lastly, by setting standards for approving and funding state coastal zone management programs, OCZM may further influence the protection of corals in the management zone.

Bureau of Land Management (BLM), Department of the Interior (DOI) -- BLM's jurisdiction over the outer continental shelf (OCS) and over corals, as a resource of the OCS, is based upon the Outer Continental Shelf Lands Act, as amended in 1978. BLM required a permit for any operation which directly caused harm to a viable coral community located on the OCS. In 1979 a Federal court ruled that BLM lacks authority to adopt regulations (to protect coral) except in connection with mineral leasing activities on the outer continental shelf. BLM, along with the Secretary of Interior, has in the past provided further coral protection by withdrawing lease tracts, for environmental reasons, from OCS oil and gas development. Where OCS oil and gas development does take place, BLM can attach lease stipulations to protect coral communities.

United States Geological Survey (USGS), DOI -- The USGS supervises all drilling development and production operations on the OCS related to oil and gas development. They seek to ensure that such operations are conducted in a manner as safe and pollution-free as possible. No exploratory drilling or development may occur unless plans for such activity have been approved by USGS. USGS also enforces Outer Continental Shelf Lands Act (OCSLA) regulations and BLM stipulations applicable to particular leases. All USGS jurisdiction is pursuant to the OCSLA.

National Park Service (NPS), DOI -- The NPS retains the authority to manage coral primarily through the establishment of coastal and nearshore national parks and national monuments. The Biscayne National Park and the Fort Jefferson National Monument are two examples of ocean areas managed by the NPS. Protection of corals and associated biota are among the management goals in both monuments.

Fish and Wildlife Service (FWS), DOI -- The ability of the FWS to affect the management of coral is based primarily on the Endangered Species Act and the Fish and Wildlife Coordination Act; although no coral species have been listed as endangered or threatened under the Endangered Species Act. Under the Fish and Wildlife Coordination Act, the FWS reviews and comments on proposals for work and activities in or affecting navigable waters that are sanctioned, permitted, assisted, or conducted by federal agencies. The review focuses mainly on potential damage to fish and wildlife, and their habitat.

The FWS, Department Manual 655-1, is also involved with BLM and USGS in outer continental shelf (OCS) leasing and oil and gas operations in the environmental studies program; stipulations to protect hard banks, coral reefs, and other marine studies; and review of permits for OCS wells, pipelines, and platform installations.

Environmental Protection Agency (EPA) -- EPA may provide protection to coral communities through the granting of National Pollutant Discharge Elimination System (NPDES) permits for the discharge of pollutants into ocean waters, and the conditioning of those permits so as to protect valuable resources. For example, EPA has utilized its authority to assure that OCS drilling operations - activities which may require a NPDES permit - do not damage the Flower Garden Banks. Consideration of ecosystem integrity in the granting of ocean dumping permits may also foster the protection of corals.

Corps of Engineers (COE), Department of the Army -- COE jurisdiction over the disposal of dredged material, pursuant to both the Clean Water Act and the MPRSA, could be exercised in a manner protective of coral resources. Proposals to dispose of materials during the construction of artificial reefs, for example, are assessed to assure that the disposed materials do not pollute or physically alter the environment.

United States Coast Guard (USCG), Department of Transportation (DOT) -- The Coast Guard's prime management jurisdiction emanates from the Ports and Waterways Safety Act, as amended in 1978, under which it may regulate shipping in the waters offshore the U.S., in part, to protect the marine environment. USCG may establish and operate shipping lanes and other vessel traffic services, and also establish vessel design and opeation standards, all of which may attenuate the impacts of commercial shipping on coral resources. Under various environmental statutes, including the FCMA, USCG is charged with enforcement responsibility to prevent damage to the marine environment. Also, the Coast Guard, along with EPA, administers the National Oil and Hazardous Substance Pollution Continency Plan. As part of that plan, USCG has final authority over the procedures and equipment used to clean up oil spills. The USCG is also responsible for enforcing BLM and NOAA regulations discussed below in Sections 7.3.1 through 7.3.5, 7.3.7, 7.3.10 and 7.3.15 through 7.3.17.

Fish and Wildlife Service (FWS), DOI, and Customs Service (CS), Treasury Department -- A special management institution involving the Customs Service of the U.S. Department of Treasury and the Fish and Wildlife Service of the U.S. Department of the Interior coordinates the importation of corals. Regulations have been implemented concerning duty percentages for various products and legal ports of entry, among other subjects.

7.1.3 States

Adjacent to each state within the management area, other than Florida, all known extensive domestic coral resources (excluding solitary corals - see Table 5-1) are found beyond the three nm or three league boundary of state jurisdiction, i.e., within the fishery conservation zone. Therefore, with the exception of Florida, which is discussed below, no state management institutions directly affect coral resources.

In Florida, the Department of Natural Resource's (DNR) Divisions of Marine Resources and Marine Patrol are the only state management institutions with direct authority over corals. Aside from several site-specific management programs described in Section 6.4, the primary management authority of the DNR is a prohibition on the taking and/or possession and sale of certain corals (see Section 7.4.2.2).

Should additional coral resources be discovered within the territorial seas of a state other than Florida at some future time, the following state institutions would probably have authority for managing those corals:

Alabama - Department of Conservation and Natural Resources, Division of Marine Resources;

Georgia - Department of Natural Resources, Coast Resources Division;

Louisiana - Department of Wildlife and Fisheries;

Mississippi - Commission on Wildlife Conservation and the Department of Wildlife Conservation, Bureau of Marine Resources;

North Carolina - Department of Natural Resources and Community Development, Division of Marine Fisheries;

South Carolina - Wildlife and Marine Resources Department, Marine Resources Division;

Texas - Parks and Wildlife Department, Fisheries Division, Branch of Coastal Fisheries.

7.1.4 Local

There are no local management institutions that directly relate to corals or coral reef resources. Indirectly, however, coral user groups (Section 10.1) are subject to local ordinances implemented by zoning commissions and other county or town agencies.

7.2 Treaties and International Agreements

7.2.1 Treaty on Maritime Boundaries Between the United States of America and the United Mexican States. Signed at Mexico City, May 4, 1978

This treaty establishes the maritime boundaries between the United States and Mexico for the areas between 12 and 200 nm (22 and 370 km) off their respective coasts. It provides that neither country shall claim or exercise sovereign rights or jurisdiction over the waters or seabed and subsoil on the other country's side of the maritime boundary. The treaty does not affect the nature of the rights claimed by either country within the ocean areas under their jurisdiction.

7.2.2 Maritime Boundary Agreement Between the United States of America and the Republic of Cuba. Signed at Washington, December 16, 1977

This treaty establishes the maritime boundary between the United States and Cuba in the Straits of Florida area and in the eastern Gulf of Mexico where their 200 nm (370 km) zones would overlap. It provides that neither country will claim or exercise sovereign rights or jurisdiction over the waters or seabed and subsoil on the other country's side of the maritime boundary. The agreement does not affect the nature of the jurisdiction claimed by either party in their limited area.

7.2.3 General Provisions on Ships Routing. IMCO Resolution A.378(x), adopted November 14, 1977

This resolution provides for the international sanctioning of measures concerning the routing of ships. Among the objectives, for which a routing system may be established, is the organization of traffic flow in or around areas where navigation by all ships or certain classes of ships is dangerous or undesirable, and the guidance of traffic clear of fishing grounds. Routing systems can include both traffic separation schemes and areas to be avoided by ships. The latter may be established where there is a possibility that unacceptable damage to the environment could result from a casualty. Thus, elevated (e.g., Flower Garden Banks and Florida reef tract) coral outcroppings which pose threats of ship groundings are candidate sites for the establishment of areas to be avoided.

7.2.4 International Convention for the Prevention of Pollution of the Sea by Oil, 1954, as amended. Done at London May 12, 1954; Entered into Force July 26, 1958, for the U.S., December 8, 1961; T.I.A.S. 4900, 6109

This Convention (the Oil Pollution Convention), regulates the intentional discharge of oil and oily mixtures by ships. For tankers of over 150 gross tons, the discharge of oil or oily mixtures within 50 nm (92.6 km) of the nearest land is prohibited. Standards concerning the rate of discharge and the total quantity which can be discharged are also imposed. Ships other than tankers of over 500 gross tons can discharge only when as far as practicable from the nearest land. These discharges are also subject to rate and quantity limitations.

7.3 Federal Laws, Policies, and Regulations

The following federal laws, policies, and regulations are presented in approximate ranking of relevance to the conservation and management of coral and coral reef resources. Memoranda of Understanding (MOU) relevant to the protection of coral, proposed but not yet adopted, are listed last.

7.3.1 Fishery Conservation and Management Act of 1976 (FCMA): 16 U.S.C §§1801-1882

The FCMA mandates the preparation of fishery management plans for important resources within the 200 nm (370 km) fishery conservation zone. Each plan aims to establish and maintain the optimum yield for the subject fishery. The current FMP for corals and coral reef resources in the south Atlantic and Gulf of Mexico regions is among such plans.

7.3.2 Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Title III: 16 U.S.C §§1431-1434

The protection of specific coral reef areas through the establishment of marine sanctuaries is discussed in Section 6.4.

7.3.3 Outer Continental Shelf Lands Act, as amended in 1978: 43 U.S.C §§1331 et seq.

Protection and Management of Viable Coral Communities: 43 C.F.R. 6224 -- A permit from the BLM has been required before any person may engage in any activity which directly causes damage or injury to a viable coral community located on the outer continental shelf. A viable coral community includes living coral and all dead coral formations and associated reef organisms that are part of a coral reef or other ecological community containing living corals. To date, BLM has issued six permits in the management area for the taking of coral for scientific and research purposes (see Section 8.2.1).

A September 24, 1979, 5th Circuit Court of Appeals ruling on U.S. v. Alexander stated that this BLM regulation applied only in areas of mineral leasing and development.

Permanent Withdrawal of Unleased OCS Lands from Disposition: 43 U.S.C §§1341(a) -- Protection of coral areas from the threats of OCS oil and gas development through permanent withdrawals from leasing by the President, as was done in creating the Key Largo Coral Reef Reserve, is discussed in Section 6.4.

Deletion of Tracts from OCS Mineral Lease Sales: 43 U.S.C §§1337(a) -- Temporary protection of coral communities from the impacts of oil and gas development activities through the deletion of tracts from individual lease sales is discussed in Section 6.4.

Regulation of OCS Development Activities: 43 U.S.C §§1334 -- Management of mineral exploration and development activities (primarily oil and gas) on the OCS is conducted by the Secretary of Interior, through the BLM and USGS. Protection of unique OCS areas, such as coral reefs, during oil and gas development is provided through the attachment of special stipulations to leases. At the Flower Garden Banks, for example, stipulations protect coral resources by requiring the shunting rather than surface discharge of drilling effluents and the establishment of a program to monitor the impacts of drilling on Bank resources. Other controls on drilling and production activities, such as testing of blowout preventers, oil spill contingency plans, and proper pollution and waste disposal, will also lend some protection to coral resources near drilling activities.

7.3.4 Biscayne National Park: 16 U.S.C §§450 qq et seq.

Protection of coral reefs within the Biscayne National Park is discussed in Section 6.4.

7.3.5 Fort Jefferson National Monument: Presidential Proclamation No. 2112; January 4, 1935

Protection of coral reefs within the Fort Jefferson National Monument is discussed in Section 6.4.

7.3.6 Clean Water Act (CWA): 33 U.S.C §§1251 et seq.

The CWA requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained before any pollutant is discharged from a point source into waters of the U.S., including waters of the contiguous zone and the adjoining ocean. The disposal of drilling effluents and other wastes from drilling platforms is among the activities for which a NPDES permit from EPA is required. Issuance of such a permit is based primarily on the effluent guidelines found in 40 C.F.R. §435. However, additional conditions can be imposed on permit issuance on a case-by-case basis in order to protect valuable resources in the discharge area. At the Flower Garden Banks, EPA has considered numerous NPDES permit conditions including a monitoring and shunting requirement and a prohibition on bulk discharges in order to protect the Bank's coral reef resources.

7.3.7 Marine Protection, Research, and Sanctuaries Act (MPRSA), Title I: 33 U.S.C §§1401-1444

A permit is required for the transportation of materials for the purpose of ocean dumping. EPA issues all permits, with the exception of those for the transportation of dredged materials issued by the Corps of Engineers. Criteria for issuing such permits include consideration of the effects of dumping on the marine environment, ecological systems, and fisheries resources. Coral resources could, therefore, be protected through this system from the impacts of nearby ocean dumping.

7.3.8 Oil Pollution Act of 1961, as amended: 33 U.S.C §§1001-1016

The Oil Pollution Act regulates the intentional discharge of oil or oily mixtures from ships registered in the U.S., and thus provides some degree of protection to coral resources. Tankers cannot discharge oil within 50 nm (92 km) of the nearest land. Ships other than tankers must discharge as far as practicable from land. The quantity of oil which can be discharged is also regulated. No special provision is made under the Act, however, for the regulation of discharges near valuable and sensitive resources such as coral.

7.3.9 Ports and Waterways Safety Act of 1972, as amended: 33 U.S.C §§1221-1227

Under this Act, the Coast Guard can establish vessel traffic services, designate fairways and traffic separation schemes, and establish vessel equipment, design, construction, and operation standards, in order to, among others, enhance protection of the marine environment. The Act is applicable to vessels registered in the U.S. and foreign vessels destined for or departing from U.S. ports. Foreign vessels violating any regulations adopted under the Act can be denied port access. Under the Act, traffic schemes and various vessel standards could be established which serve to both direct traffic away from coral reefs and minimize the effects of any incidents which may result.

7.3.10 Coastal Zone Management Act of 1972, as amended (CZMA): 16 U.S.C §§1451-1464

Under the CZMA, states are encouraged, with federal funding grants, to develop coastal zone management programs which establish unified policies, criteria, and standards for dealing with land and water use decisions in their coastal zone, an area which includes the states' territorial sea. Approved coastal programs are thus capable of directing activities away from areas possessing particularly sensitive resources, such as coral. Many activities beyond the defined coastal zone may also be influenced by approved coastal programs through operation of the CZMA's federal consistency requirements, under which direct federal activities significantly affecting the coastal zone, including the approval of a FMP, must be conducted in a manner consistent to the maximum extent practicable with approved state programs. Activities requiring a federal license or permit, such as plans for OCS exploration, development, and production activities can effectively be vetoed by a coastal state determined not to be consistent with their approved program. Section 312 of the CZMA also allows for the designaion of estuarine sanctuaries to achieve wise use of coastal resources, including natural resources. Guidelines for these sanctuaries were published at 15 C.F.R. 921 on June 4, 1974.

7.3.11 Endangered Species Act of 1973, as amended: 16 U.S.C §§1531-1543

The Endangered Species Act provides for the listing of plant and animal species as threatened or endangered. Although no corals have yet been listed, various species may qualify for this status. Once listed as a threatened or endangered species, taking (including harassment) is prohibited, and a process is established which seeks to ensure that projects authorized, funded, or carried out by federal agencies do not jeopardize the existence of these species or result in the destruction or modification of habitat determined by the Secretary to be critical.

7.3.12 National Environmental Policy Act (NEPA): 42 U.S.C §§4321-4361

NEPA requires that all Federal agencies recognize and give appropriate consideration to environmental amenities and values in the course of their decision-making. In an effort to create and maintain conditions under which man and nature can exist in productive harmony, NEPA requires that federal agencies prepare an environmental impact statement (EIS) prior to undertaking major actions which might significantly affect the quality of the human environment. Within these statements, alternatives to the proposed action which may better safeguard environmental values are to be carefully assessed. While NEPA does not guarantee the protection of valuable environmental resources, such as coral, it does require that agency decision-makers fully consider the effect of their actions on such resource values. Under NEPA, each fishery management plan must be accompanied by an EIS on the proposed action.

7.3.13 Fish and Wildlife Coordination Act: 16 U.S.C §§661-66c

Under the Fish and Wildlife Coordination Act, the FWS and NMFS review and comment on the fish and wildlife aspects of proposals for work and activities sanctioned, permitted, assisted, or conducted by federal agencies which take place in or affect navigable waters. The review focuses on potential damage to fish and wildlife and their habitat and may therefore serve to provide some protection to coral communities from federal activities, particularly in nearshore waters, since federal agencies must give due consideration to the recommendations of the two agencies.

7.3.14 Fish Restoration and Management Projects Act: 16 U.S.C §§777-777k

Under this Act, the Department of Interior is authorized to apportion funds to state fish and game agencies for fish restoration and management projects. Funds for the protection of threatened coral communities located within state waters, including marine areas, could be made available under the Act.

7.3.15 Memorandum of Understanding for the Management of Marine Resources in the Fishery Conservation Zone Between the Gulf of Mexico FMC and OCZM (NOAA)

An agreement between the Gulf FMC and OCZM has been developed which provides for consultation and coordination between the two agencies regarding the conservation and management of marine resources i the FCZ when they both may have planning jurisdiction. The agreement provides for planning for the orderly development, implementation, and coordination of conservation and management measures utilizing the most practical and effective regulatory system, including the designation of marine sanctuaries where appropriate. It also establishes a framework for the exchange of regional and national marine resource policies and objectives.

7.3.16 Memorandum of Understanding for the Management of Marine Resources in the Fishery Conservation Zone Between the South Atlantic FMC and OCZM (NOAA)

The terms of this agreement are identical to those in the Gulf FMC/OCZM agreement. See above, subsection 7.3.15.

7.3.17 Memorandum of Understanding on Coral Protection Jurisdiction on the Outer Continental Shelf Between the Bureau of Land Management and the National Marine Fisheries Service and the Office of Coastal Zone Management (NOAA): Proposed

An agreement between BLM, NMFS, and OCZM, is currently being negotiated which would: 1) provide for continuing protection and management of all coral communities on the OCS; 2) streamline the procedure by which applications are reviewed and permits issued for activities affecting such coral communities; and 3) define and coordinate the responsibilities of BLM, NMFS, and OCZM for the management of coral communities. Under the agreement, BLM is likely to relinquish part of its authority concerning the regulation of coral as coral FMP's are implemented and as marine sanctuaries which preserve coral resources are designated (see Section 7.3.3).

7.3.18 Regulations and Policies on Importation of Corals

Pursuant to 50 CFR 14.21(n), corals may be imported into the United States at any Customs port of entry. Uncured corals may be imported free (Tarriff Schedule of the United States (TSUS) 190.30) whereas cut but unset pieces of finished (i.e., cured) corals suitable for use in jewelry, are subject to a 2.5 percent duty (TSUS 741.15). However, when finished coral pieces are imported from underdeveloped countries via the "Generalized System of Preference," no duty is imposed. Still another regulation applies to finished coral set in jewelry.

Within the management area, corals may be imported into these U.S. Customs Service ports of entry: Wilmington, North Carolina; Charleston, South Carolina; Savannah, Georgia; Miami, Florida; Tampa, Florida; Mobile, Alabama; New Orleans, Louisiana; Port Arthur, Texas; Galveston, Texas; Laredo, Texas; and El Paso, Texas.

7.3.19 Memorandum of Understanding on Evaluating Permit Applications Between the Army Corps of Engineers and Department of Commerce (NOAA).

All applications for Corps of Engineers permits in a marine sanctuary will be evaluated for impact on the sanctuary. No permit will be issued until the applicant provides a certification from the Secretary of Commerce that the proposed activity is consistent with Title III of the Marine Protection, Research, and Sanctuaries Act of 1972, as amended, and can be carried out within the regulations promulgated for the sanctuary.

7.4 State Laws, Regulations, and Policies

Since coral resources within state waters in the management area are limited primarily to the coastal waters of Florida, the laws, regulations, and policies of Florida are the only state authorities directly applicable to coral resource management. Although Florida has the only direct coral protection statute, the other states in the management area do have several types of authorities which may provide indirect protection to coral resources, including: 1) authorities aimed primarily at other marine resources or the environment in general that may also relate to corals, e.g., fishing gear regulations or pollution control laws; 2) coastal zone management programs and related legislation; and 3) habitat management or protection programs. These authorities are summarized below for each state and detailed in Appendix J.

The first category of authorities has in most cases been implemented for reasons not primarily related to coral. It deals instead with activities that create bottom disturbances and those which could potentially contaminate the marine environment, e.g., dredging or filling of submerged lands, trawling with bottom fishing gears, or discharging pollutants (see related discussion in Section 6.2.2.1).

Coastal Zone Management (CZM) authorities described below are in most cases state responses to the goals and objectives of the federal Coastal Zone Management Act (see Section 7.3.10).

Habitat management and protection programs cited below are general measures applied to habitat in a broad sense and not corals specifically. These programs are distinguished from the site-specific habitat programs discussed in Section 6.4.

7.4.1 Alabama

Alabama has no direct coral management or protection authorities. Numerous laws and regulations concerning fishing (Ala. Code §§9-12-90 et seq.) offer indirect management of coral resources. No provisions of the state Water Pollution Control Act specifically apply to discharges of oils into ocean waters. Similarly, there are no applicable habitat programs. Under the Coastal Area Protection Act, Alabama has developed and has had federal approval of its CZM program (Ala. Code §§9-7-10 et seq.).

7.4.2 Florida

Under Florida's coral law it is unlawful for any person to take, otherwise destroy, sell or attempt to sell the following: 1) any sea fan of the species Gorgonia flabellum, or the species Gorgonia ventalina; 2) any hard or stony coral (Scleractinia); or 3) any fire coral (Millepora). Possession of any fresh, uncleaned, or uncured specimen of these species without a certified invoice of importation from a foreign country or proof that the specimen was taken before July 1, 1976, is also illegal. Sea fans or stony corals may be taken for scientific or educational purposes only by permit from the Department of Natural Resources (Fla. Stat. §370.114). The Florida Marine Patrol must be informed of the time, place, method, quantity, and species to be collected. Dead corals and coral rubble (i.e., coral rock) may be collected without a permit. It is unlawful to take dead or live coral from, or possess it within, John Pennekamp Coral Reef State Park (Fla. Stat. §370.114). By a joint management agreement between the State of Florida and the National Oceanic and Atmospheric Administration (NOAA), state park rangers and Coast Guard personnel patrol both the State Park and the Key Largo Coral Reef Marine Sanctuary (Cooperative Agreement No. 04-6-158-44116 between Florida DNR and U.S. Department of Commerce, NOAA, and 15 C.F.R.929).

Indirect authorities with relevance to corals include fishery gear regulations (Fla. Stat. §370.15), a permit system for the use of chemicals to collect marine specimens (Fla. Stat. §370.08) ocean water contamination regulations (Fla. Stat. §370.09), and dredge and fill regulations (Fla. Stat. §370.03). State habitat programs include Aquatic Preserves (Fla. Stat. §258.35), Areas of Critical State Concern (Fla. Stat. §380.05), Environmentally Endangered Lands (Fla. Stat. §259), and State Parks.

Florida's Coastal Management Program has been approved by the Office of Coastal Zone Management.

7.4.3 Georgia

Georgia does not have any direct coral protection laws. The only habitat authority with potential relevance to corals is derived from the Heritage Trust Act of 1975 (Ga. Code §43-2300). Indirect laws include fishery gear restrictions (Ga. Code §43-900), general water quality criteria, and dredge and fill permits (Ga. Code §43-2400). Georgia does not yet have a draft coastal management plan.

7.4.4 Louisiana

Louisiana has no laws or habitat programs directly applicable to corals. A CZM program received federal approval in 1980, but corals were not addressed specifically. State fishing regu-lations concerning shrimp and other species provide some protection for coral (La. Rev. Stat. §56-495).

7.4.5 Mississippi

Mississippi has no direct coral protection laws. Habitat programs include the Natural Heritage Trust Program (Miss. Code §49-5-141) and protection of habitat for endangered wildlife (Miss. Code §49-5-111); thus far neither program has been applied to coral resources. Fishery and pollutant regulations exist that offer indirect coral protection (Miss. Code §49-15-6205). A CZM program (Miss. Code §49-5-111) received federal approval in 1980.

7.4.6 North Carolina

North Carolina lacks direct coral protection laws but is well represented by laws, regulations and policies providing indirect protection. Besides having a federally-approved Coastal Management Program, North Carolina also has three habitat programs (Nursery Areas, Research Sanctuaries, and Underwater State Parks) and numerous fishing gear regulations (15 N.C. Admin. Code 3B).

7.4.7 South Carolina

South Carolina also lacks direct coral management or protection laws or regulations. General habitat programs are in operation through the Heritage Trust Program to protect natural areas or features (S.C. Code §51-17-10). A state coastal management program with sections on wildlife and fisheries, dredge and fill, and geographical areas of particular concern, among others, has been adopted and received federal approval in 1979. Regulations for fishing gear (S.C. Code §50-17-1000), pollution of ocean waters (S.C. Code §45-1-13) and the use of poison, electricity, and explosives (S.C. Code §50-13-1420 and 1440) also may provide some protection to coral.

7.4.8 Texas

Texas has no direct coral protection laws nor any habitat programs of relevance to coral resources. The state does, however, have regulations on fishing (Tex. P&W Code §77), ocean pollution (Tex. Water Code §26), use of electroshock (Tex. P&W Code §66), and dredge and fill activities (Tex. Nat. Res. §33). The Texas Coastal Management Program has completed a revised plan but has not yet submitted it for federal approval.

7.5 Local Authorities

As mentioned above, of the states in the study area, extensive coral habitats are found only in the territorial seas adjacent to Florida. Furthermore, within the territorial seas adjacent to Florida, extensive coral habitats are limited to the southernmost area of those waters. Therefore, only in southernmost Florida could local authority to manage coral resources be asserted.

Within Florida, the right to regulate the taking or possession of saltwater fish is expressly reserved by the state (Fla. Stat. §370.102). However, since the definition of saltwater fish does not include coral, a county or other local government in Florida could assert the authority to regulate the taking of or provide for the protection of coral resources [Fla. Stat. §370.01(2)]. As of the present time, no county in Florida has chosen to do so. Prior to the passage of the state coral protection statute in 1976, several southern Florida counties, including Dade and Monroe Counties, had considered legislation designed to protect coral resources. It was decided, however, that statewide protective legislation would prove more effective.

Although local fisheries reguations have been preempted by state law since 1973, general state laws of local application were not affected. In fact, in many instances the state code has adopted what were previously local regulations as state laws of local application. An example which may be relevant to coral resources, is the prohibition on spear fishing in certain areas of Collier and Monroe Counties. Spearfishing is prohibited within the boundaries of John Pennekamp Coral Reef State Park, all waters of Collier County and the upper Keys in Monroe County, which includes all saltwaters beginning at the county line between Dade and Monroe Counties and running south, including all of the keys down to and including Long Key [Fla. Stat. §370.172(d)(1)]. The large number of local regulations and general laws of local application, together with the ambiguous language used in many of these statutes, often makes it difficult to determine exactly which regulations are applicable at the present time. For example, the possession of any fishing seine or net in any county in which such possession is prohibited is also illegal by state law [Fla. Stat. §370.08(1)]. From conversations with state and local officials, however, it does not appear that any other regulations are applicable to coral resources.

8.0 DESCRIPTION OF FISHING ACTIVITIES AFFECTING THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

8.1 History of Exploitation

8.1.1 Development of the Industry

Historically, the collection and sale of corals from domestic waters has been centered around the coral reefs and patch reefs of the Florida Keys. Nowhere else within the geographic boundaries of the United States' FCZ is coral diversity and abundance as high, nor coral communities so close to shore.

Commercial interest in Florida corals is a relatively recent phenomenon. Although Indian middens scattered throughout Florida contain coral fragments, the first acknowledged market for shells and corals (which are normally categorized together in the curio business) was in 1829 in Key West. The industry expanded in proportion to the tourist business.

Since the onset of a real coral fishery, a time somewhere post-1900, corals were collected primarily as bycatch with fish and assorted shellfish (lobsters and snapper, mainly). Even during the peak in Florida coral marketing, no more than three or four people earned the bulk of their income from corals. Collectors were often the dealers since the industry was small and undiversified.

In the 1930s and 1940s, coral harvesting was poorly mechanized and highly labor intensive. The most common gear was a dragging hook towed from a small boat. Most participants in Florida were blacks, some displaced from the Bahamas. Divers existed but technology limited their success.

By the 1950s, the industry had expanded only slightly. Most harvesting and marketing was seasonal, limited to the winter months of peak tourism. Even at this time, the Miami area could support only three wholesale dealers. Those dealers concentrated on six Atlantic species: elkhorn (Acropora palmata), staghorn (Acropora cervicornis), fire coral (Millepora alcicornis), flower coral (Eusmilia fastigiata), pillar coral (Dendrogyra cylindrus), and lettuce corals (Agaricia agaricites). Corals were received from the domestic sector via small boats from the Keys or from the Bahamas as a bycatch on a variety of fishing vessels.

An expansion of the coral industry from the mid-1950s to the present accompanied the perfection of compressed air or SCUBA diving systems. Still, most corals were collected part-time by people using them as an income supplement. Investment for special vessels or equipment was low. Use of the diving gear made dives to exploitable areas as deep as 30 m (100 ft) routine. The extent of the harvest is unknown because no statistics were recorded.

Until the 1970s, the vast majority of coral collections were intended to be marketed as curio items. Usually, the pieces were cleaned with bleach and dried to enhance the intricate coral skeletons. Immediately preceding the Florida laws, about 18 to 20 divers supplied shells and corals to retailers in the south Florida area (Casey, 1979, personal communication). Corals were sold mostly (85 to 90 percent) to tourists for both aquarium and curio use. Jaap (1979, personal communication) observed collections of Agaricia agaricites, Eusmilia fastigiata (flower coral) and Acropora palmata from Eastern Sambo Reef. Recent markets, however, have been altered in response to state and federal laws (see above, Section 7.3 and 7.4). Legal prohibitions on coral collection in all Federal waters (prior to the United States v. Alexander decision) as well as Florida's state waters have essentially ended collection of corals in the management area for sale as curios. Concern has been expressed that a black market industry continues to exist based on corals poached from the Florida reef tract and sold in U.S. shell shops; however, little hard evidence exists to substantiate these claims. However, Davidson (1979, personal communication) has observed that Acropora palmata (elkhorn coral) has been poached at Sombrero Reef in the Florida Keys, primarily by local residents and not tourists. Many domestic corals are the same as Caribbean species, and identification as to origin is difficult.

Agatized coral is dredged from a small offshore area on the west coast of Florida. Polished pieces of the fossilized coral are advertised as harvested "fresh daily" from Tampa Bay and sold as "Tampa Bay Coral." Prices of the earrings, necklaces, pins, and other jewelry items range from $5.00 to $15.00 per piece.

A small commercial fishery for octocorals was developed by marine life collectors in the late 1970s for live exhibit in private and public aquaria. Small, specimens were utilized, and the known harvest is probably under 6,000 colonies per year (H. Feddern, 1979, personal communication).

8.1.2 Collection Techniques and Practices

Interviews with participants in the coral industry permit reconstruction of a typical collecting venture. A reef zone with marketable size and quality corals would be located by a diver team, often towed behind the boat by a rope or in an underwater diving sled. The selected area would then be marked by buoys. Using the boat as a base, divers would proceed to collect ten to 30 pieces of coral depending on size and weight. It was generally accepted that a slightly smaller catch would reach port more safely than a larger catch due to reduced breakage in transit.

Because aesthetics are of primary importance in marketing coral, collectors have always claimed to be extremely selective in picking coral specimens. Immediately preceding the 1976 Florida coral law, highest prices were always paid for symmetrical head corals and complete branched species, while medium sized pieces suitable for aquaria or shelves commanded most of the market. With these constraints, divers reportedly rejected 60 to 80 percent of the living corals, usually because of asymmetry or size over the desirable size and weight limit of about 40 cm (16 in) diameter. The highly sought medium-sized pieces, 15 to 20 cm (6 to 8 in) in diameter, commanded prices ranging from $5.00 to $1.00 each at retail, while wholesalers reportedly ranged from $.20 to $.35 per pound (Perez and Dewyer, 1979, personal communication).

During a collecting dive, most divers used a small crow bar, poker, or saw to dislodge the coral piece. Saws were especially useful in removing branches off elkhorn and staghorn corals. After cutting or prying loose the coral pieces, they were either piled in a central location and a net or bucket was lowered to bring the take aboard ship, or each piece was taken to the surface as collected. During transit to the cleansing and processing facility, all pieces were covered by wet burlap to prevent desiccation.

Most collectors in Florida sold cleaned corals to dealers. After returning to port, pieces were soaked in freshwater and/or bleach to remove the polyps, and dried. Cleaned pieces brought higher prices than raw corals. Generally, the freshwater soak lasted one day, followed by one-half day in bleach (sodium hypochlorite).

Corals collected in Florida were usually channeled to customers by the collectors themselves, or by small trucking firms. Dealers from elsewhere in the United States often ventured to the Florida docks where trailers and trucks were filled with freshly cleaned pieces. Regardless of the technique, the fragility of coral usually resulted in an unknown percentage of breakage during transportation.

Many corals sold in domestic curio shops originated in foreign waters. Shop owners frequently imported stocks from Haiti or the Philippines. The continued availability of Philippine corals is in doubt due to the apparent decline in their coral stocks and possible restraints on coral exports (Casey, 1979, personal communication).

Coral harvesting in Florida proceeded unrestrained from its beginning until 1976, whereupon the Outer Continental Shelf Lands Act (OCSLA) regulations prohibited the destruction, alteration, or collection of coral associations in federal waters. Inside state waters (3 nm or 4.8 km on the Atlantic coast, 9 nm or 16.7 km on the Gulf of Mexico coast), collections were legal except in Florida where a series of successively stricter laws were passed in the early 1970s. The federal and state laws served to prohibit coral harvesting without a permit and, hence, collapsed the industry.

8.2 Domestic Commercial and Recreational Fishing Activities

Whereas the preceding Section 8.1 summarized the history of domestic fishing for corals, this section shall address all current activities. Since state and federal law has until recently prohibited collection of corals in most of the management area (unless a permit is obtained), this discussion is necessarily brief.

8.2.1 Participating User Groups

Prior to the decision of United States v. Alexander in September of 1979, all user groups collecting corals legally within the management area did so by permit from the Bureau of Land Management (BLM; under regulatory authorities of the Outer Continental Shelf Lands Act of 1953), or the Florida Department of Natural Resources (DNR; Florida Statutes, Section 370.114).

Collections authorized by a federal permit are summarized in Table 8-1. Note that Table 8-1 also includes activities permitted for altering (e.g., dredging) regions in which corals are known to exist. All user groups either collected or inadvertently disrupted corals for scientific studies. With the exception of the two permits granted to Texas A&M University, which supplied corals to similar contracts, no business or economic relationship exists between the permits or user groups.

Florida permits have been issued on 24 occasions as of December, 1979 (Futch, 1979, personal communication). Each of those permits (see Table 8-2 for examples), was issued to individuals or institutions associated with teaching and/or research. For example, universities and public aquaria owners have been permitted to collect representative specimens of the Florida coral communities. [Note that aquaria owners, e.g., Sea World Shark Institute, are turning increasingly to synthetic corals cast of concrete or plastic to avoid permits and to extend the "life" of their displays.]

Another user group with unquantified but which could have significant impact on the resource are recreational and commercial collectors not holding a valid permit. In Florida, this is an offense and is most commonly enforced in managed areas, such as Key Largo National Marine Sanctuary, where illegal taking accounted for 8.6 percent (seven of 60) of the infractions in 1978 (Gillen, 1979, personal communication). Spearfishing and possession of spearfishing equipment accounted for 73 percent of the 60 arrests. A similar ratio of coral to total arrests was reported in John Pennekamp State Park.

Poaching has been ascribed to both small-scale recreational and large-scale commercial taking. Recreational harvests are mostly by divers and snorkelers who collect pieces of corals as momentos. Conversely, commercial collections could be direct supply channels to shell shops. Very limited data exist on either facet of the poaching issue.

No data are available on the legal harvest of corals in the FCZ since the United States v. Alexander decision relieved BLM of its broad authority to issue coral permits. Because the decision and its effect on federal regulation is not widely known, there has been little evidence of resumption of coral harvest in unregulated federal waters.

Marine life collectors, are presently taking some unregulated octocorals from Florida's territorial sea and adjoining federal waters.

The colonies are usually collected by SCUBA divers, maintained alive and distributed in the aquarium trade along with marine tropical reef fishes. Most of the production is utilized domestically, though one collector reports European sales. Collectors receive one to two dollars per colony from wholesalers.

Collecting is reported from off Palm Beach and Ft. Pierce, Florida. Swiftia and Nicella are reported by divers to be common off Palm Beach in densities of 75 to 100 individuals in a fifty-foot square area. The collector estimates that only five percent of the individuals present are aesthetically suitable for aquarium exhibit.

Off Palm Beach, these deepwater gorgonians (Swiftia, Nicella, Diodogorgia, and Lophogorgia) grow on areas of eroded solid rock ridges essentially devoid of stony corals. These gorgonians do not usually occur on the shallow high-profile reefs and are not used as shelter by fishes, since they offer scant protection from the constant water current of the Gulf Stream flowing across the area. Other inshore species are collected off the Florida Keys and in Dade and Broward Counties, Florida (Henry Feddern, 1979, personal communication).

Although some species may occur just below the low-tide line, apparently most of the collecting is done at depths near 60 feet and in the territorial sea.

Two of the collectors indicated that they used limited quantities of rose coral, Manicina aerolata, in acclimating butterflyfish to laboratory foods (see also Appendix D). Quantities used were reportedly "very small" but unspecified, and none was offered for resale.

All the collectors surveyed are engaged in their trade on a year-round basis. Weather does not seem to interfere with their collecting operations or their market distribution activities. In addition, no significant seasonal variations in product supply or demand were evident. Other industry studies suggest that the most intense collecting activities occur throughout spring, summer, and fall, although demand tends to decrease between June and August (Hess and Stevely, draft manuscript).

A bycatch of octocorals and occasionally stony corals is made by vessels trawling for shrimp, groundfish, and scallops. Leptogorgia (sea whips) and Renilla (sea pansies) may be abundant on the trawling grounds. While shrimpers sort their catch and discard the unwanted bycatch promptly, groundfishermen and scallopers most often land total catches unsorted. In the latter cases the corals are killed. There is no estimate of the coral catch from these vessels. There are approximately 40 scallop and groundfish vessels in the management area.

8.2.2 Vessels and Fishing Gear

As evidenced by permits from the BLM (Table 8-1) and Florida DNR (Table 8-2), corals and other benthos are collected by trawl, dredge, or diver (saw, hammer and chisel, crowbar, hand), by a variety of scientific endeavors on vessels ranging from small fishing boats to larger research vessels. Bottom trawls in the management area often entangle some pieces of corals but nearly always at the expense of the net in the instance of stony corals. Dredges are similarly inefficient and damaging. In summary, divers operating from small craft, often with private ownership, appear to be the major collectors.

8.2.3 Employment in Recreational and Commercial Sectors

The coral-related industry within the management area includes several coral user groups: 1) shell and coral shops which sell mostly imported corals; 2) glass bottom boats; 3) snorkel, and dive boats; 4) tropical fish business; and 5) party boats that depend greatly upon living corals and coral reefs. Since these sectors are almost entirely nonconsumptive resource users and are related to the economics and business aspects of the industry, as well as fishing activities, they are discussed below in Section 10.1.

Table 8-1. Summary of coral permits issued by the Bureau of Land Management, 1977 to 1979.

GROUP PERMITTED	EFFECTIVE DATE OF PERMIT	EXPIRATION DATE OF PERMIT	COLLECTION/ALTERATION AREA	SPECIES	QUANTITY (kg)	USE	EST. VALUE	COLLECTION GEAR
Texas A&M University College Station, Texas.	10/27/77	10/27/78	E. Flower Gardens offshore shelf of Texas/Louisiana	*Madracis mirabilis* *Montastraea cavernosa* *Montastraea annularis* *Diploria strigosa*	18 9	Bioassay research on behavioral and mortal effects of drilling fluids on corals.	$100	Divers, by hand
Texas Instruments, Dallas, Texas.	7/21/78	7/21/79	Southeast Georgia Embayment	no collection proposed, only alteration	--	Dredge and trawl studies of epibenthic and demersal biota.	--	Bottom trawl and tumbler dredge.
Texas A&M University College Station, Texas.	8/18/78	8/18/79	Northwestern Gulf of Mexico hard banks	*Diploria* spp., *Montastraea* spp., *Colpophyllia* spp., *Porites* spp., *Madracis* spp., *Millepora* spp.	2	Study of the geology, ecology, hydrography, and chemistry of hard banks.	0	Divers, by hand
U.S. Geological Survey Miami Beach, Florida.	8/21/78	8/21/79	Offshore Key Largo, Florida	*Montastraea annularis*	360	Cores of coral heads to study growth rates and indices of stress.	0	Corer
Continental Shelf Assoc. Tequesta, Florida.	9/19/78	9/19/79	Southeast Georgia Embayment	no collection proposed, only alteration.	--	Dredge studies of epibenthos and lithotype of substrate.	0	Dredge
Dauphin Island Sea Lab Dauphin Island, Alabama	10/13/78	10/13/79	Florida Middle Grounds	unspecified corals	25	Unspecified studies	0	Divers, by hammer and chisel

Source: Adams, 1979, personal communication.

Table 8-2. Summary of representative coral permits issued by the Florida Department of Natural Resources, 1976 to 1979.

GROUP PERMITTED	EFFECTIVE DATE OF PERMIT	EXPIRATION DATE OF PERMIT	COLLECTION AREA	SPECIES	QUANTITY (kg)	USE	COLLECTION TECHNIQUE
John C. Noyes Fish Collector Ft. Lauderdale, Florida	7/26/76	6/30/79	Patch reefs off Broward County, Florida	Not specified, but "small live specimens"	Not to exceed 30 specimens	In displays at the New England Aquarium, Boston, Massachusetts	Collect semi-annually
Robert Ginsburg, Ph.D. University of Miami Miami, Florida	5/19/78	6/30/79	Reefs and hard grounds near Tavernier Key	Manicina aerolata and other scleractinians	About 4.0 kg of each species	Scientific research and education	Not mentioned
Ester C. Peters University of South Florida St. Petersburg, Florida	7/7/78	6/30/79	Atlantic side of West Summerland Keys; reefs and patch reefs off Key West	Acropora palmata, A. cervicornis, Dichocoenia stokesii, Diploria labyrinthiformis, Favia fragum, Oculina diffusa, Manicina areolata, Meandrina meandrites, Porites spp., Montastraea spp., Siderastrea spp.	Not more than 0.9 kg per species	Scientific research on coral pathology	Not listed
Robert Mannix Florida Department of Transportation Marathon, Florida	7/27/78	6/30/79	Shallow flats in Marathon area	Manicina aerolata	16 mature specimens per month	As a food source for marine species being maintained in laboratory	Not listed
Bruce Chalker, Ph.D. University of Miami Miami, Florida	7/27/78	6/30/79	Key Largo, Pensacola, and Panama City	Montastraea spp. Porites porites, Acropora cervicornis, Manicina aerolata	Not to exceed 25 specimens; 1 kg total wet weight per trip	"Scientific purposes"	By hand with hammer
Charles Morrison, James Espy, and Mabel Miller (3 permits) Dade County Public Schools Environmental Education Center Miami, Florida	10/6/78	6/30/79	Not listed	Only dead coral	Not specified	Place in salt water aquaria	Not listed

Source: Futch, 1979, personal communication.

There is no direct employment in collecting, processing, or marketing domestic corals. Scientists and vessel crews involved in permitted coral collections do not participate in the fishery on a full-time, commercial, or recreational basis. Harvest of octocorals by marine life collectors is in conjunction with fish collection.

8.2.4 Fishing and Landing Areas Utilized Throughout the Range of the Stock(s)

Permitted collections within the management area are concentrated in several zones as determined by scientific interest and biotic diversity. As noted in Table 8-1, BLM permits indicate interest in the hard banks of the northwestern Gulf of Mexico, the Florida Middle Grounds of the eastern Gulf, and the Florida reef tract. Secondary interest is apparent on the Blake Plateau off the southeast United States but research there is directed at epibenthos and finfish, with corals assuming an incidental role.

Corals collected by permit are usually landed at the home port of the research or educational institution. No port is differentiated from another on the basis of fishing areas or other factors.

Marine life collectors of octocorals are mostly restricted to south Florida.

8.2.5 Conflicts Among Domestic Fishermen Involving Competition for Fishing Areas, Gear Damage, etc.

Several conflicts involving corals have been identified. Section 6.2.1 on fishing relationships, discusses some potential repercussions of various man-made impacts on the biotic community. Conflic including commercial and recreational fishing directly over coral assemblages, removal of animals, anc many related impacts are discussed in this section.

Other potential conflicts among users would include those between consumptive and nonconsumptive users. Because corals in the area described in this FMP are unmanaged except for stony corals and sea fans in Florida's territorial sea, a resumption of harvest in the FCZ could bring about major interest conflict between these two groups. Even a moderate level of harvest by commercial and recreational collectors could destroy the aesthetic value for the nonconsumptive users (diver photographers, glass bottom boat viewers, and other coral and fish watchers). This is an example of short-term versus long-term benefits due to the slow recovery rate of coral.

8.2.6 Amount of Landings/Catches

Coral collections governed by permits specify the amount of corals to be collected and where the collection will occur, among other information. Using that information, some landings data can be generated for each species and landing area.

Bureau of Land Management permits show a total harvest of about 387 kg (851 lbs) from at least six species, including one Milleporina and five Scleractinia (Table 8-3). Florida collections, listed as pieces on some permits and weight on others, were 77 pieces and 46.1 kg (101 lbs) from about 28 species (Table 8-4). This harvest was conducted over a three-year period and was used for scientific and educational purposes.

A small commercial harvest of octocorals by marine life fishermen for use in the aquarium trade has been identified through an informal survey of the membership of the Florida Marine Life Association, Inc. by Dr. Henry Feddern, 1979 (personal communication). Approximately 75 percent is estimated to come from Florida's territorial sea, and the remaining 25 percent from the adjoining FCZ. On an annual basis the catch is estimated to be:

	Number colonies per year	
	Total	FCZ
Leptogorgia virgulata	250	63
Briareum asbestinum	120	30
Telesto riisei	240	60
Renilla mulleri	1,250	313
Diodogorgia nodulifera	1,140	285
Nicella schmitti	510	128
Swiftia exserta	1,100	275
Lophogorgia cardinalis	1,200	300
Lophogorgia hebes	35	9
Totals	5,845	1,463

The same group of fishermen had also collected a small, unquantified amount of rose coral for use as food for juvenile tropical fishes. Other small stony corals were collected for aquarium display.

8.2.7 Assessment and Specification of the U.S. Estimated Domestic Annual Harvest

The harvest of coral can be accomplished from small boats as well as larger vessels. Divers and swimmers wading from shore are also able to take coral. Domestic users have the capacity and are fully able to harvest the amount of OY as is provided by this plan.

The expected domestic annual harvest is that amount provided as optimum yield.

8.3 Foreign Fishing Activities

There is currently no foreign coral fishing within the management area.

Table 8-3. Summary of corals to be collected by species and state (as of February 1, 1979).

Species	Approximate Amount Landed (kg)	State(s) Landed
Scleractinia:		
Madracis mirabilis	18	
Montastraea cavernosa	9	
Montastraea annularis	369	Florida, Texas
Diploria spp.	<1	Texas
Colpophyllia spp.	<1	Texas
Porites spp.	<1	Texas
Madracis spp.	<1	Texas
Milleporina:		
Millepora spp.	<1	Texas
Unclassified:		
"assorted species"	25	Alabama
	about 423	

Source: Table 8-1.

8.4 Interactions Between Domestic and Foreign Participants

Because there is no foreign fishing activity, there are no interactions between the foreign and domestic fishing sectors.

8.5 Domestic Processing Capacity

The processing of stony corals for exhibit or display is a simple process which may be done aboard small boats or in the back yard. The domestic annual processing capacity exceeds the present available supply and that which is to be available as optimum yield. Domestic processing relies heavily upon imported corals for ornamental and pharmaceutical use.

TABLE 8-4. Summary of corals collected under Florida DNR permits based upon permit applications. Numbers are approximate. Colonies or pieces referred to in each column are from different collections (Data from Futch, 1979, personal communication).

Species	No. to be Collected (if specified)	Weight to be Collected (if specified)	Species	No. to be Collected (if specified)	Weight to be Collected (if specified)
Milleporina			*Montastraea cavernosa*	-	1
Millepora alcicornis	3	-	*Oculina varicosa*	6	-
Millepora squarrosa	2	-	*Oculina diffusa*	-	1
Millepora complanata	2	-	*Colpophyllia amaranthus*	2	-
			Colpophyllia natans	2	-
Scleractinia			*Solenastrea hyades*	6	-
Cladocera arbuscula	-	<1	*Favia fragum*	2	1
Porites spp.	-	7	*Phyllangia americana*	2	-
Acropora cervicornis	3	1	*Manicina areolata*	5	3
Acropora palmata	1	1	*Scolymia lacera*	2	-
Siderastrea siderea	6	1	*Diploria labyrinthiformis*	1	1
Siderastrea radians	9	1	*Meandrina meandrites*	-	1
Dichocoenia stokesii	6	1			
Agaricia agaricites	2	-	Gorgonia	2	-
Montastraea annularis	7	1			
			Unspecified	6	24[1] 0.1[2]

TOTALS

No. to be Collected (if specified) 77 pieces
Weight to be Collected (if specified) 46.1kg

1. Including *Montastraea annularis*, *M. cavernosa*, *Porites porites*, *Aeropora cervicornis*, and *Manicina areolata*. Measured in wet weight.

2. Including *M. annularis*, *M. cavernosa*, *P. porites*, and *A. cervicornis*. Measured in dry weight.

9.0 DESCRIPTION OF ECONOMIC CHARACTERISTICS OF THE FISHERY AND RESOURCE

9.1 Domestic Use Sector

The coral resource differs from the traditional fishery resource because its principal value lies in nonconsumptive uses where it provides habitat for other fishery resources and recreation for coral watchers.

Much of the data used for preparing this section were obtained through informal telephone interviews tailored for use with each business type or user group. Table 9-1 illustrates the 100 percent target survey sample (138 firms) as well as those parties contacted (68 or 49 percent) and finally interviewed (53 or 38 percent). The Councils attempted to contact approximately 87 firms. These businesses were selected randomly from telephone directory yellow page listings and supplemented by additional references provided by survey participants themselves. Approximately 78 percent of the coral user groups contacted were interviewed.

Table 9-1. User group (firm) sample, contacts made and interviews conducted by state within the management area.

STATE	TARGET SAMPLE				TOTAL	FIRMS CONTACTED*				TOTAL	FIRMS INTERVIEWED**				TOTAL
(No. Localities)	A	B	C	D		A	B	C	D		A	B	C	D	
N. Carolina (2)	1	2	2	2	7	0	1	1	1	3	0	1	1	1	3
S. Carolina (1)	2	2	2	2	8	0	0	0	1	1	0	0	0	1	1
Georgia (1)	2	1	3	3	9	2	1	1	3	7	1	1	1	2	5
Florida (14)	26	18	14	17	75	14	9	5	8	36	12	9	2	8	31
Alabama (1)	2	2	2	2	8	1	1	1	1	4	0	0	0	0	0
Mississippi (3)	1	3	1	1	6	0	1	1	1	3	0	1	1	1	3
Louisiana (3)	1	1	1	3	6	0	0	1	2	3	0	0	0	2	2
Texas	6	4	5	4	19	4	3	2	2	11	1	3	2	2	8
TOTAL	41	33	30	34	138	21	16	12	19	68	14	15	7	17	53

* 48 percent of Target Sample (does not include all attempted contacts)
** 41 percent of Target Sample

Legend: A - Tropical Specimen Enterprises
B - Diving Shops and Schools
C - Charterboat Operators
D - Coral Wholesalers and Retailers

9.1.1 Harvest and Consumptive Uses

Available data indicate the present harvest of corals from the fishery described within this plan involves scientific and educational use, and some limited commercial use of octocorals in the aquarium trade. The potential exists, however, for harvest of corals from the FCZ where not prohibited by Florida's possession law.

9.1.1.1 Scientific and Educational Harvest

Based on permitting systems which provided for most of the known use for scientific and educational purposes during a three-year period, the harvest of stony corals is only about 140 kg. per year. Another 2,500 colonies of octocorals is estimated to be used annually for this purpose. The value of the individual colonies ranges from $1.50 for sea pansies to much higher prices for stony corals depending on the size and condition (see Table 9-7).

There is a potential use of octocorals in the pharmaceutical industry where research is presently underway. Prostaglandins, typically mammalian compounds, were a major discovery from a gorgonian (Plexaura homomalla). They are among the most potent biological materials known. Upon purification, these remarkably versatile wide spectrum drugs stimulate uterine contractions to induce labor and/or therapeutic abortion, speed healing of stomach ulcers and reverse effects of cyanotic congenital heart disease. They may be used in the future to induce heat in livestock, treat nasal congestion, asthma, and rheumatoid arthritis and lower blood pressure (Arehart-Treichel, 1975). Pike (1974) remarked that in considering the merits of obtaining a drug from the sea, it is worth weighing the ecological factors against the potential benefit. The discovery that three species of Pseudoplexaura contain compounds active against human carcinoma of the nasopharynx and lymphocytic leukemia is also significant. Research on these compounds continues to increase exponentially.

Current level of collection is generally undocumented. Harvest of P. homomalla was discussed during the 1974 prostaglandin symposium. Feasibility of a ton a month, or ten tons a year of P. homomalla was suggested for short term needs. Opresko stated his data from Bache Shoal indicated four acres of whole P. homomalla colonies would have to be cleared to meet that requirement; if colonies were only pruned, required acreage would increase ten fold or more.

9.1.1.2 Aquarium Trade Harvest

Some nine species of octocorals have been identified as being harvested commercially for the marine aquarium trade (Section 8.2.6). Depending on size and quality of the specimen, the value may range from $2.00 to $15.00 each. The value of the known fishery is probably in the range of $15,000 to $25,000 per year.

9.1.1.3 Other Commercial or Recreational Harvest

Since 1979 when the court decision in effect left corals in the FCZ without management or protection, the stocks have been open to harvest. Florida's prohibition of possession of uncured specimens is the principal deterrent to a wholesale harvest of corals from the Florida reef tract beyond the territorial sea. This resource has the potential to fill the market demand now provided by imported specimens. Because of the slow growth of most stony corals, however, the resource cannot be considered to be renewable in the sense of other fisheries. Its exploitation would be more comparative to a one-time extraction as in mining.

TABLE 9-2. Selected data from interviews with charter boat operators in the management area, April - July, 1979.

STATE/FIRM CODE	TYPE	AGE	EXTENT OF TRIPS TO CORAL AREAS	EST. TOTAL ANNUAL INCOME	% CORAL-RELATED INCOME (est)	NO. EMPLOYEES	CHARTER RATES	FAVORITE CORAL AREAS*	OTHER REMARKS
1. Florida									
A.	Sport fishing	n/a	regularly	n/a	70%	family-run	1/2 day ($160) full day ($250)	n/a	peak load: 200 people/week grouper catch
B.	Glass-bottom observational	n/a	100%	n/a	100%	5-6	$6 trip	Key Largo/ Key West	60-75,000 customers per annum open all year
2. Texas									
A.	Diving & Sport fishing	11	50% SCUBA	$70,000 ($9000 net)	n/a	2	$108/weekend	Flower Gardens	±1000-1200 passengers/yr.; June/ July;August peak; Sponsors package tours to Caribbean serves broad regional market.
B.	Sport fishing	n/a	seldom; 2 per year	n/a	minimal	n/a		n/a	
3. Mississippi									
A.	Sport fishing	22	indicentally while fishing (20%)	n/a	minimal		$300/day (8 people)	Horn Island Pass	100 charters/year
4. Georgia									
A.	Sport fishing	7	irregular	n/a	minimal	family-run	$210/day (6 persons)	35 mi. SE of Savannah	95% fishing charters Red snapper is popular species; Peak--March-October.

n/a = not available

* Charter captains will seldom, if ever, disclose their favorite fishing grounds.

9.1.2 Recreational and Other Associated Nonconsumptive Uses of Coral

9.1.2.1 Charterboat Operators

Throughout the management area boat charters are available for sport fishermen and divers who desire access to offshore recreational activities. In the waters from North Carolina through Dade County, Florida, some 620 charter boats have been inventoried (South Atlantic Fishery Management Council, 1978). This does not contain Monroe County which includes the Florida Keys. With the exception of Florida, however, very few trips are aimed explicitly toward coral habitat areas. Assemblages evident elsewhere are normally dispersed and fairly small, far enough from the mainland to discourage widespread public use, situated at depths often prohibitive to casual divers, and subject to rather unpredictable weather conditions. Few deep-sea fishing charter operators frequent known or suspected coral reef and hard bank areas and then only if their traditional trolling areas prove unproductive. Hard bottoms such as Gray's Reef off Georgia, and the continental shelf west of Florida, provide more substantial fishing areas.

The most popular and productive sport fishing reportedly occurs around artificial reefs, oil rigs, and sunken shipwrecks. Off Texas, for example, artificial underwater structures collectively accounted for more fishing use than natural reef or bank sites, even though the latter areas were fished by approximately 87 percent of all trips (Ditton and Graefe, 1978).

Of the primary four user groups, this industry sector has been the most difficult to cover adequately with the firm survey instrument, especially in the State of Florida. In part, the recent commencement of high tourist activity (late April to September), has pressed charter operators into peak action such that personal in-depth interviews with boat captains were difficult to gain.

Seven charter operators - one of which takes people out to view coral in shallow waters through a glass bottom boat - have been contacted. Table 9-2 portrays select business characteristics of these commercial enterprises. The majority of firms are strictly sport fishing-oriented, and only one reported having a dual fishing and diving function (this firm also claims to be the primary supplier of trips to offshore coral assemblages in the entire Gulf of Mexico). It is likely, however, that most charter operators consistently service more than one user group. Except for the lone glass bottom boat respondent, charter outfits appear to be small, and predominantly family-run businesses employing no more than two to three persons. Despite the lack of income estimates in virtually every case sampled, a clear impression was conveyed that barely "breaking even" is all too often the dominant financial characteristic of this user group. Seasonality of business and, in effect, part-time income earning capabilities, may be the major reason for this sentiment. Other studies of charter operations have identified similar structural conditions in this industry (see Pybas, 1978).

Sport fishing charter schedules ranged from one-half and all day offerings to two-day weekend trips to zones quite far from shore such as the Flower Gardens 200 km (110 nm) off Texas and Louisiana. Daily charter charges quoted were variable, but hovered at between $210 (six persons) and $300 (eight persons). This price normally included necessary equipment and bait, but not food and refreshments.

Although exvessel values are difficult to attach to corals, some data do exist on the fees for visiting living coral communities. In Texas, where the Flower Garden Banks are located over 200 km (108 nm) offshore, dive boats with about 40 passengers charge $100 per person for a two- or three-day trip (Blood, 1978, personal communication). Where corals are nearer shore, as in the Florida reef tract, charter fees average about $20 but reach $40 per person for a daily trip. Snorkelers are usually charged about $10 to $20 for a half-day trip. Scenic glass bottom boat cruises average $3 to $10 for a three-hour trip. At these rates, many shops carry 20 to 100 charter divers to the reefs each day during the peak seasons of December to April, and June through September. Such shops may operate two or three boats simultaneously.

9.1.2.2 Diving Shops and Schools

Offshore areas along the entire management area's coast are becoming increasingly popular for a wide range of SCUBA and snorkeling activities. Outside of Florida, dives to coral habitats still appear quite limited and are normally incidental to other underwater explorational activities. This is not only due to the paucity of sizeable assemblages off other Gulf and south Atlantic states, but also because of their distance from the mainland. Off Texas, for example, the Flower Garden Banks lie some 110 nm (200 km) and ten trip hours from the nearest port (Port Arthur). Far more diving in nearshore zones is conducted around oil rigs, shipwrecks, and other artificial reefs than coral assemblages per se (Pybas, 1978). A similar situation is found in south Atlantic states north of Florida.

In southern Florida, however, abundant coral tiers of varying species types and sizes are far more accessible. In fact, some areas can be reached easily by wading from shore. This one factor alone helps to make Florida a primary destination for divers originating not only from Florida, but also from throughout the management area and the other sections of the country.

The economic value derived from coral resources is exemplified by the following data from Monroe County, Florida, encompassing all of the Keys. Informal interviews with operators revealed a total of approximately 44 dive shops operate in that county, including 14 that run once or twice daily during the season diving and snorkeling charters to coral reefs. Numerous other private citizens offer diving, snorkeling, and glass bottom boat excursions to reefs. Most of these shops and services are located in the Key West, Marathon, and Key Largo areas. In the latter locale, most boats visit the adjacent John Pennekamp State Park and Key Largo Marine Sanctuary. Numerous restaurants, hotels, trailer parks, campgrounds, and souvenir shops parallel the main roads near the dive shops; these businesses claim a heavy dependence upon tourism generated by corals and coral reef resources.

As Table 9-3 illustrates, diving equipment outlets (mainly retail) and professional instruction firms are frequently integrated within one business. Diversification into salvage and underwater construction operations is a characteristic of very few enterprises; however, many shops throughout the management area regularly sponsor package diving tours of either weekend or full week duration to coral sites in Florida. This all-inclusive type of service appeals primarily to out-of-state diving clubs and schools. For example, Davidson (1979, personal communication) estimates that 60 to 65 percent of his trip clientele in the Florida middle Keys are students from high schools and colleges who come in organized groups.

Florida and other Gulf states are also the main domestic staging points for dive trips abroad throughout the Caribbean region (e.g., San Salvador and the British Virgin Islands). However, most firms surveyed indicated that these trips do not contribute significantly to their total income, especially when compared to equipment sales.

Without continued opportunities for diving in high quality coral areas, it is likely that Florida's enterprises would suffer more seriously (in economic terms), than those located in other management area states. Direct equipment sales or rentals as well as dive boat charters (i.e., firm-owned boats) specially designed for coral enthusiasts represent a significant portion of their trade. Professional instruction and certification functions supplement this income to a great extent. Respondents frequently indicated that out-of-state participation in all these markets has been expanding rapidly over the last few years.

Although southern Florida dominates the provision of diving access to coral areas (e.g., the Keys), there are indications that recent extraneous factors could cut into market demand in the future. In number of interviews, reference was made to the potentially adverse impact of escalating gasoline prices upon frequencies of dive trips into south Florida and the Keys. Apparently, would-be customers (especially from out-of-state) are already making fewer full-length treks and, as an alternative, are

TABLE 9-3. Selected data from interviews with dive schools and shops in the management area, April - July, 1979.

STATE/FIRM CODE	TYPE	AGE	ANNUAL INCOME/ SALES ESTIMATE TOTAL	% CORAL-RELATED	BOAT SERVICES OWNED	CHART.	EMPLOYEES FULL-TIME	PART-TIME	DIVE SPECIFICS	PACKAGE TOURS SPONSORED ELSEWHERE	OTHER REMARKS
1. Florida											
A.	sales/rentals/ instruction/ trips	1	$225,000	40%	2	0	2	2	$12 (1 tank) $18 (2 tank)	Bahamas occasionally	cater increasingly to out-of-state groups
B.	Full professional shop	10	n/a	n/a	0	3-4	n/a		n/a	n/a	
C.	Retail/wholesale/profes-	5	$300,000	n/a	2	0	4	8	$20 (1/2-day, 2 tank); $30/ all day	San Salvador; British Virgin Islands	east coast of Fla.; educational programs in photography & tropical fish collection
D.	Professional shop	n/a	n/a	90% equipt. sales	0	1	n/a		n/a	Caribbean; Florida Keys	no natural reef habitats in immediate vicinity (No. Fla.)
E.	Retail/instruction rentals	7	$250,000	n/a	0	3 (peak)	4	4-5	n/a	San Salvador 4 times /year.	demand up sharply; diver favor photography & spear fishing in shipwreck areas
2. Texas											
A.	SCUBA School	n/a	n/a	1%	0	varies	n/a		n/a	none	
B.	Retail shop	11	n/a	20%							
C.	Equipment sales/trip organizer	3	n/a	20							
3. Mississippi											
A.	Professional retail shop	n/a	n/a		n/a		n/a		n/a	Florida (1-2/mo); British West Indies (1/mo.)	photography and spear fishing near oil rigs
4. North Carolina											
A.	Retail sales/ underwater construction; charters	1	$80,000	1%	1	varies in peak periods	6		$15 (1 tank) $40 (2 tank)	none	favor local shipwrecks; some spearfishing & amateur tropical fish collecting
5. Georgia											
A.	Sales & instruction	20	n/a	n/a	1	0	3	--	1/2 day; weekend ($25)	To Florida 2-3 time per month	

n/a not available

turning to noncoral diving sites situated further northward (e.g., on wrecks and artificial reefs). So, while there has been no significant decrease overall in coral-related diving to date, individual divers seem to be gradually shifting their activity to the more accessible coral areas in the north of the state. Group activities are increasing in frequency (Davidson, 1979, personal communication).

Besides out-of-state consumers, many local dive clubs and associations utilize shops and schools throughout the management area. Club memberships affiliated with retail outlets are especially popular and often carry certain discount benefits on equipment either bought or rented. Other more informally organized groups are linked to both foreign and domestic package travel tours sponsored by dive shops.

9.1.2.3 Tropical Marine Life Enterprises

Throughout the management region, both individuals and commercial firms are active in the collection, shipment and/or marketing of tropical marine fish, invertebrates and (to a considerably smaller degree), octocorals, and plants native to coral areas. A few enterprises deal in specimens which are imported from abroad, but transactions are at the wholesale level. Pet shops function as the chief retail distributor of tropical fish to the general public. In addition, many people (so-called "jobbers") dive for specimens independent of any formal business affiliation (on a full- or part-time basis) and regularly sell them to wholesale operations or pet shops, who carry out further marketing functions. Public and home marine aquaria are the ultimate destinations for most specimens collected and sold commercially, and serve a variety of ornamental, scientific, and educational purposes (Hess and Stevely, draft manuscript).

Exclusive of southern Florida (roughly the coastal zone south of Fort Pierce on the east and below Tampa on the west), there are few, if any, specimen collectors who take coral-associated species. The majority of participants in this user group are concentrated within Broward, Dade and Monroe Counties. The remaining portion of Florida, as well as the other seven management area states, may support tropical collecting businesses, but certainly none quite as dependent primarily upon living coral assemblages.

Monroe County, encompassing most of the Florida Keys, is an especially active commercial collection zone (an estimated 60 full-time collectors in 1978), due to its proximity to extensive reef and hard bottom assemblages. Shallow inshore areas, for example, yield mainly invertebrate species, whereas bridge pilings have long been popular collection sites for angelfishes, surgeon fishes, and wrasses.

Inshore coral heads also frequently have tropical fish densities sufficient enough to justify commercial collection. Perhaps the best collecting areas lie on the Atlantic Ocean side of the Keys along nearshore channels and outer reefs. Ironically, however, certain areas of extensive coral growth (e.g., Sand Key, Looe Key) are often less productive in terms of collection due to the availability of a multitude of hiding places for fishes. Even the widespread usage of quinaldine, an anesthetic drug which slows fish movement to facilitate capture by clear plastic nets, cannot totally neutralize the reef's function as a provider of cover. Still, coral reef assemblages offer the best opportunities to collectors in and around the Florida Keys (Hess and Stevely, draft manuscript). Table 9-4 illustrates a few of the more commonly collected reef fishes in Monroe County. Angelfishes, damselfishes, and butterfly-fishes continue to lead all other species in terms of catch reaching market; between 1974 and 1977, their percentage shares ranged from 25 to 30 percent, 12 to 15 percent, and 10 to 14 percent respectively.

Recent industry growth trends observed in Monroe County may be expected to approximate - if not to exceed - comparable development patterns for other primary collecting counties in southern Florida. After a 76 percent increase in commercial and recreational quinaldine permits granted here between 1974 and 1976, growth in registered collection efforts by this method decreased to only two percent between 1977 and 1977. Commercial use (i.e., activities involving collection of more than 100 fish per permit year) alone rose less sharply over each survey interval (33 percent and 20 percent). Two final Florida Keys trends of particular relevance to the entire management area are an apparent increase of noncounty resident collectors and the persistence of high turnover rates in the industry as reflected by requests for permit renewals (Hess and Stevely, draft manuscript).

In addition to the individuals and firms harvesting fish and invertebrates directly from coastal waters such as those surrounding the Keys, one company in Florida also collects reproducing stocks of marine fish for use in aquaculture operations. Although out-numbered by actual collecting companies, these recent aquaculture ventures have indicated that reasonable profits may be recovered from laboratory tropical specimen operations without continually having to visit and harvest in coral areas.

However, at this time, many problems still exist in the culture techniques of raising tropical fishes (e.g., nitrogen waste poisoning, cannibalism, and nutrition).

Table 9-4. Examples of commonly collected reef fishes in Monroe County, Florida.

Family Chaetodontidae: Angelfishes and Butterflyfishes	
Queen angelfish	Holacanthus ciliaris
Blue angelfish	H. bermudenis
Rock beauty	H. tricolor
French angelfish	Pomacanthus paru
Gray angelfish	P. arcuatus
Four-eye butterfly	Chaetodon capistratus
Spotfin butterfly	C. ocellatus
Banded butterfly	C. striatus
Reef butterfly	C. sedentarius
Family Serranidae: Groupers and Sea Basses	
Harlequin bass	Serranus trigrinus
Tobaccofish	S. tabacarius
Butter hamlet	Hypoplectrus unicolor
Barred hamlet	H. puella
Blue hamlet	H. gemma

Source: Hess and Stevely, draft manuscript.

As shown in Table 9-5, tropical specimen collectors contacted during the Councils' informal Florida survey depend very heavily (50 to 90 percent of catch) upon "coral areas" (i.e., coral reefs, hard bottoms, solitary corals) for their fish collections. Most of the animals captured are sold to wholesalers or retailers (shipped via air freight) outside Florida, although this trend was found to be variable between collectors. Several people also regularly export animals to customers in Canada and Europe. Employment in the industry is quite limited; most businesses seldom employ more than one or two people. Gross income estimates consistently ranged from about $20,000 to as much as $50,000 per annum; net income quotations, on the other hand, declined sharply (to only 20 to 50 percent of gross on the average) largely due to outlays for business expansions and other capital improvements.

TABLE 9-5. Selected data from interviews with tropical specimen collectors in Florida, April - July, 1979. All collectors resided in Broward, Dade, and Monroe Counties.

FIRM CODE	BIOTA COLLECTED	% COLLECTED IN CORAL AREAS	MARKET EXTENT	MARKET TYPES	EMPLOYEES ANNUAL	EMPLOYEES SEA-SONAL	APPROX. GROSS ANNUAL SALES
A	fish, anemones, gorgonians, worms, sponges, plants, and many invertebrates.	95% on hard bottom (corals, rocks, rubble, etc.)	Almost all shipped to other states in management area, in U.S., exported; <5% in state.	85% wholesalers 15% retailers	1	0	$40,000
B	fish & invertebrates.	75% in corals	n/a	n/a	n/a		n/a
C	fish (50%) and invertebrates (50%)	98% in live corals or hard bottoms	70% out-of-state, 25% export; 5% in Florida	100% to retailers and wholesalers	1	0	$30,000
D	fish & invertebrates	60% in corals, 40% in grasses	100% in Florida, mostly in Dade Cty.	100% to wholesalers	1	0	$20-30,000
E	fish & invertebrates	some from reefs & grassy areas	About 33% in state, 67% outside management area	100% for display or research	5	0	n/a (about 2000 fish annually)
F	fish (50%) and invertebrates (50%)	About 50-60% of fish and invertebrates from coral areas	Georgia, Texas, Louisiana and elsewhere in U.S.; Canada	All wholesale now, formerly retail	2	0	$40-50,000

n/a = not available.

At the lower end of this income scale, reported net figures compare favorably with annual profits calculated by Hess and Stevely (draft manuscript) from a small survey of Monroe County collectors. Net incomes were projected at $9,500 for an average yearly work effort of 2,000 hours or some $4.75 per hour. Together, fixed and variable expenses totaled $3,900, thereby reducing annual gross dollar returns on catch by an estimated 29 percent.

Except for certain uncommon species or foreign varieties which must be imported, Florida's domestic collection industry clearly functions as a major tropical specimen supplier for each of the remaining states adjoining the management area and the rest of the country.

Most collectors contacted emphasized a marked preference for small business hierarchies. In many cases, by doing all the collecting, shipping, and marketing, they are able to earn substantially higher than average incomes; however, they must also work long hours. The latter element seems to effectively limit new industry entrants and to drive many marginal operations away from the collecting sector. Many respondents have established extensive supply channels with foreign markets (e.g., Canada, England), other collectors who dive elsewhere in Florida, commercial fishermen (e.g., trawlers who incidentally catch marketable animals), and certain retail outlets.

A final noteworthy characteristic of Florida's tropical specimen collection industry - as well as comparable businesses located throughout the remainder of the management area - is their subjection to increased pricing competition from foreign imports. Exotic species originating from the Pacific region, for example, continue to arrive on the American market sometimes more cheaply than domestically-caught fishes, although they may be different species. However, due to air shipment times and the use of drugs, foreign stocks often arrive in poor condition. To date, therefore, importation has been pursued in order to alleviate domestic supply shortages, to provide different species, and not purely due to foreign market price differentials compared to American tropicals. On the contrary, some of the more rare and exotic species bring premium prices.

9.1.3 Associated Businesses

The coral market is deeply intertwined with trade in seashells from foreign importation stages right through wholesale distribution and retail sales processes. To a lesser extent, the specialty jewelry sector is also linked to trade in coral products, but primarily for "finished" items. Close proximity to thriving coral assemblages has historically served to concentrate most coral wholesalers and retailers in Florida. Despite the fact that increased reliance upon importation theoretically frees businesses located elsewhere in the Gulf and south Atlantic area from being dependent on these suppliers, both marketing traditions and the ability of Florida wholesalers to import in large (and therefore relatively economical) quantities helps to maintain their lead role in regional distribution. These well-established operations also have reliable import connections, a critical factor in a time when rumored threats of foreign coral export restrictions are regularly surfacing among domestic users.

The interview data (see Table 9-6 for select interview details) indicate that there are a handful of coral wholesalers in the management area who control most large-scale importation and distribution functions. One of the largest is located in Florida, employs over 100 people, and has an annual total sales figure of well over $1 million; however, coral-related income comprises only eight to ten percent of this particular firm's gross income estimate. On the other hand, some small (largely two to three person) wholesale businesses continue to survive, although their dealings in coral appear to be declining, both in absolute quantity and as a percentage of annual firm income.

Most retail outlets surveyed reportedly derive a small portion of their sales income (generally, less than 15 percent) from coral product trade. Gift shops in particular tend to deal in only a few pieces of polished coral or coral jewelry settings at any one time and seldom import those directly. Not surprisingly, those firms selling directly to the public and which regularly import from abroad maintain more extensive stock levels and estimate higher coral-related income contributions.

TABLE 9-6. Selected data from interviews with coral wholesalers and retailers in the Management Area, April 1979.

STATE/FIRM CODE	TYPE	AGE	ESTIMATED SALES INCOME TOTAL	ESTIMATED SALES INCOME CORAL RELATED	CORAL IMPORTATION DETAILS	PRIMARY MARKET	EMPLOYEES NORMAL	EMPLOYEES SEASONAL	OTHER REMARKS
1. Florida									
A.	Small wholesaler	20	$60-100,000	1%	95% Philippines; 5% Haiti	Florida gift shops	2-3	--	
B.	Medium-sized wholesaler	n/a	n/a	n/a	95% Philippines China & Haiti	Retail outlets; 50% in-state; 50% out-of-state	15	--	
C.	Large retailer	40	over $1 million	8-10%	Philippines ($30,000 worth per annum)	Florida and southeast USA	100+	--	Wholesale seashell oriented firm
D.	Retail shop	40	$340,000	20%	100% Philippine ($15,000/year)	Florida tourist	5-6	15-18	
2. Texas									
A.	Limited wholesale; some retail	11	n/a	miniscule	none since 1977	mainly in-state	3	--	
B.	Gift shop	n/a	$100,000	2%	none; via wholesaler	local tourism	2	8	
3. Mississippi									
A.	Retail shop	18	n/a	25%	24 foreign countries; mainly India & Pacific	other retailers; tourists	3	6	
4. Louisiana									
A.	Retail shop	n/a	n/a	1%	Polished settings (eg. Italy)	local	7	--	Coral jewelry mainly
B.	Retail curio shop	2 1/2	$130,000	1%	None direct (via wholesaler	local	n/a		Coral jewelry only
5. North Carolina	Retail gift shop	7	n/a	1%	none direct (via wholesaler)	local	2	--	
6. Georgia									
A.	Retail gift shop	3	$20,000	1%	none direct (via wholesaler)	50% local; 50% tourist	2	--	Coral necklaces and custom jewelry
B.	Retail gift shop	4	n/a	10-15%	none direct (via wholesaler)	local tourism	4	--	

n/a not available or not applicable.

The primary import source for wholesalers and retailers alike continues to be the Pacific region, with most coral products originating in the Indian Ocean and Philippines vicinities. Custom-ordered cases are exported to the United States by boat for destinations at select west coast, Gulf and south Atlantic ports of entry, with the exception of special piece orders and already polished jewelry settings. Miami is the study area's primary offloading point. Coral normally arrives in its raw (or at most minimally cleaned) form, thus escaping import duties. Occasionally, import crates contain various combinations of shells and coral mixed together. Wholesalers in Florida either do their own cleaning prior to distribution, or else resell unprocessed coral cases to smaller wholesalers and retailers who, in turn, prepare products for sale themselves. The technology of processing is fairly simplistic and relatively inexpensive. Depending upon the particular retail market destined to be served, coral is offered for sale either as unmounted pieces, or in a variety of more stylized (e.g., polished, inlaid, etc.) product forms.

Income generated from coral sales varies according to volume and the type of coral sold. Corals vary in price depending on the species and size of the piece (see Table 9-7 and text). An aesthetic factor is doubtless also involved in price setting. Generally, wholesale prices are marked up two or three times over prices paid to collectors, with the latter receiving about $1.00 to $6.00 per piece. Highest prices are commanded by selected pieces of elkhorn (Acropora palmata) and colonies removed with bases intact so they can be used as centerpieces or in aquaria (see also discussion in Section 8.2).

9.2 Domestic Processing Sector

Most of the businesses involved in coral industries within the management area process their own corals, because imported corals are much cheaper when raw than when cleaned and bleached. In addition, processing of raw corals is a low technology activity. Thus, the domestic sector can process as much of the resource as becomes available to it. It is expected that the domestic sector will process a volume equal to OY plus imports.

9.3 International Trade

9.3.1 Present Status

The domestic coral industry within the management area is supported by corals from the Pacific, the Mediterranean, and Haiti. Although a small percentage of the coral jewelry is made from domestic precious coral stocks in Hawaii, all other corals are foreign imports. The results of a random sampling of ten dealers and invoices revealed that the Philippines are the primary source of imports (Table 9-2). Further discussion of coral imports and sales is presented in Section 10.1.

Pacific corals are imported primarily from the Philippines, where coral abundance and the costs of labor have combined to yield much lower prices than existed in Florida before the coral law of 1976. Table 9-9 identified the more commonly imported species. Other economic data on Philippine imports (amount and value of corals on invoices, relative importance of Pacific corals to the import market, and the mean wholesale price of corals by species and size) are presented in Tables 9-7 to 9-10. Wells (1981) reported over 1.6 million kgs of coral imported into the United States from the Philippines over the three-year period 1976 through 1978. These stony corals are primarily for sale as curios. However, a recent interview with Philippine officials indicates that the Philippines have restricted coral exports (Philippine Embassy, 1979). A small amount of coral remains available but may be limited to that already harvested.

Mediterranean corals, red corals (Corallium rubrum) from Italy and "the Mediterranean Sea" were seen in several Florida, Georgia, and Maryland jewelry stores as polished beads for bracelets, necklaces, rings, and earrings.

Table 9-7. Wholesale price lists for Caribbean corals from domestic or Haitian waters based on 1972 and 1973 invoices reviewed during informal interviews of Florida shell shop personnel.

Elkhorn coral, _Acropora palmata_	15 cm pieces $ 1.50 to $ 3.00 35 cm pieces 5.00 to 10.00 60 cm pieces 10.00 to 21.00
Fire coral, _Millepora alcicornis_	15 cm pieces $ 1.00 to $ 3.00 50 cm pieces 9.50 to 19.00
Lettuce coral, _Agaricia agaricites_	15 cm pieces $ 1.00 to $ 3.00 46 cm pieces 10.00 to 20.00
Eye coral, _Oculina arbuscula_	15 cm pieces $ 1.00 to $ 3.00
Brain coral (includes _Dichocoenia_, _Diploria_, _Meandrina_, _Montastraea_)	Small pieces 6 to 8 cm in diameter $ 4.00 to $9.00.
Pillar coral, _Dendrogyra cylindrus_	15 cm pieces $ 1.50 to $ 3.00 30-63 cm pieces 4.50 to 23.00

Other Caribbean corals that sporadically appeared in the marketplace in similar price ranges were:

Flattened pieces of low brain coral, _Diploria clivosa_
Eye coral, _Dichocoenia stokesii_
Delicate finger coral, _Porites furcata_
Regular finger coral, _Porites porites_
Star coral, _Eusmilia fastigiata_
Encrusting fire coral, _Millepora complanata_
Atlantic cluster coral, _Oculina diffusa_
Moon coral, _Colpophyllia natans_
Stump coral, _Solenastrea hyades_

Source: Thomas, 1979, personal communication.

Table 9-8. Compilation of dealer invoice data for corals imported into Miami, Florida, between October 1976 and October 1978 by ten dealers.

Dealer #	Total Invoices	Invoices w/Coral	Coral Invoices from Philippines	Coral Invoices from Haiti	Period Covered by Invoices
1	46	14	11	3	4/3/76 - 9/4/78
2	39	8	8	0	2/8/77 - 9/21/78
3	103	8	8	0	May 1977 - 9/13/78
4	58	21	20	1	4/12/77 - 9/19/78
5	57	12	11	1	-
6	20	11	9	2	12/21/76 - 4/4/78
7	23	7	5	2	-
8	23	2	2	0	10/11/76 - 9/7/78
9	31	14	10	4	10/11/76 - 10/15/78
10	59	22	22	0	6/29/77 - 10/31/78

Proportional value of Pacific coral to other items (shells, curios, etc.) on the invoices:

range - 23 to 100 percent
mean - 59 percent

Haitian corals represent the only significant recent source of Atlantic species to the domestic market. However, as shown in Table 9-8, domestic imports from Haiti have been greatly curtailed by a 1976 Haitian government ban on export of corals. Hence, although an industry of collection and shipment thrived with the closure of Florida grounds, there is currently no legal coral fishery in Haiti.

Table 9-9. Pacific corals imported from the Philippines into the United States.

Finger:	*Acropora millepora*
Branch:	*Acropora arcuata*
Brush:	*Acropora vaughani*
Cluster:	*Pocillopora verrucosa*
Lace:	*Pocillopora danae*
Organ Pipe:	*Tubipora musica*
Birdnest:	*Seriatopora compresca*
Blue:	*Favona vaughani*
Bowl:	*Parahalomitra philippensis*
Cauliflower:	*Pocillopora* sp.
Catspaw:	Unknown
Mushroom:	*Fungia* sp.

Table 9-10. Quantity and value of imported corals as listed on 15 invoices on file with the U.S. Fish and Wildlife Service in Miami, Florida. Invoices cover 1976 to 1979.

Inv. #		Pieces of Coral	Dollar Value	Value per Piece
1		11,609	$2,347.80	$0.20
2		20,360	2,168.80	0.11
3		10,555	1,603.45	0.15
4		3,402	703.43	0.21
5		4,465	716.35	0.16
6		23,315	3,687.80	0.16
7		34,422	3,286.40	0.09
8		9,802	2,520.45	0.26
9		17,602	1,828.25	0.10
10		11,236	1,848.52	0.16
11		9,554	1,909.05	0.20
12		15,456	4,509.05	0.29
13		10,187	1,678.50	0.16
14		13,750	1,574.50	0.11
15		3,446	1,143.45	0.33
	TOTALS	199,161	$31,526.15	

Mean price/piece for all invoices = $0.16

Source: Thomas, 1979, personal communication.

9.3.2 Future Projections

With the severe decline of Philippine and closure of Haitian stocks to exports, the sources of most corals sold in the management area are apparently no longer available. The most likely result of these export laws will be a shift to undeveloped markets elsewhere in the Pacific and/or Caribbean. Increased poaching pressure on domestic stocks may also occur if foreign stocks can not support demand. In addition, if foreign supplies are severely restricted, there is a large potential for increased pressure to harvest domestic corals.

10.0 DESCRIPTION OF BUSINESSES, MARKETS, AND ASSOCIATED ORGANIZATIONS WITH THE RESOURCE

10.1 Relationships Among Harvesting, Brokering, and Processing Sectors

The harvesters and nonconsumptive users were described in Section 9.0. The commercial domestic harvest has been described as small with the product used largely in the scientific and educational field or in the aquarium trade.

In the aquarium trade, the live product is usually sold to retail aquarium shops by wholesalers. Some diver-collectors who provide specimens to biological supply houses and pharmaceutical companies in the scientific and educational use, also serve as wholesalers.

So far as is known, the specimen stony corals in shell shops is imported. It is conceivable that some is taken from the FCZ off Florida and sold in violation of state law, but the extent of this is probably small.

From conversations with Florida coral distributors and retailers, it seems that many coral-associated businesses situated out-of-state annually make a vacation trek southward (during their off season), at which time bulk supplies of coral and shells are purchased. In addition, so-called coral "jobbers" originating in Florida are also known to conduct wholesale marketing tours in south Atlantic coastal resort areas and cities on a regular basis. Very few Florida-based wholesalers offer large order shipment/delivery services themselves.

Perhaps the most significant business trends in this user group relate to a gradual movement out of wholesaling functions accompanied by the expanded stockpiling of coral products to support retailing operations. In part, this reflects an undercurrent of suspicion - particularly by major wholesalers - that existing foreign supplies may soon dry up completely. Consequently, bulk coral supplies are reportedly in some instances being increased to last at least two to three years. Most small retail firm respondents, however, even those importing coral directly, expressed little concern over supply endangerment and to date have encountered no problems (except for steep price rises) in getting most all coral species they require.

In Florida itself, the coral merchandising market has had several years to adjust to the 1976 law prohibiting most taking in state waters and possession of most uncured specimens. While it is likely that certain wholesalers and retailers (especially one-person operators) may have left the coral marketing sector in the interim, no drastic alterations in business entry or exit rates have yet been reported. Most firms appear to have compensated for the loss of an easily accessible domestic fishery by increasing foreign importation and expanding the scale of their sea shell sales capacity.

The relationship among the nonconsumptive users is less clearly defined due to the absence of a tangible product following a trade route. Individuals who patronize charter boats and dive shops may combine their coral watching with other recreational activities such as fishing or photography.

In addition to the user groups described above, one other industry sector is indirectly dependent upon the management of living coral assemblages for economic revenue. The Newfound Harbor Marine Institute (NHMI) operation at Big Pine Key - a private, nonprofit, scientific and educational, and recreational organization, - offers one of the most comprehensive marine education opportunities in the entire Florida Keys. Founded in 1966, NHMI's diverse year-round programmatic offerings range from summer camp, research, and community education efforts, to workshops and intern programs for both students and teachers at all instructional levels. Special emphasis on most NHMI programs is placed on corals and coral reef resources (Becker, 1979, personal communication).

Nearly all NHMI programs eventually focus upon the nearby Looe Key coral reef's ecosystem as well as other assemblages located in the general vicinity. The opportunity to make day-long diving trips out to coral habitat areas for educational, recreational and scientic purposes is undoubtedly a key factor in NHMI success and expansion over the last 13 years. Clearly, a substantial portion of their operating income is dependent upon continued access to, and cautious activity in and around, thriving coral concentrations.

10.2 Cooperatives and Associations

Collectors of tropical reef fishes, both professional and amateur, utilize the coral reefs as a habitat source for specimens. Many of the professionals are members of the Florida Marine Life Association; however, almost all market their catch independently as wholesalers.

Amateur collectors may often be members of tropical aquarium societies which sponsor field collecting trips to coral reef areas.

There are also local and statewide associations of charterboat operators, divers, and recreational and commercial fishermen. All of these may be at some time nonconsumptive users of the coral reefs.

10.3 Labor Organizations

Survey respondents reported no formal affiliations wi-- any state, regional, or national labor organizations. Along with the apparently deliberate preference for nonunionized labor by firm owners, this finding reflects the predominately small size of coral resource-associated businesses located within the management area.

10.4 Foreign Investment

In the sense of there being parent companies based outside the United States which own, or substantially control, domestic, commercial enterprises associated with coral resources, no evidence of foreign investment has been determined.

11.0 DESCRIPTION OF THE SOCIAL AND CULTURAL FRAMEWORK OF USER GROUPS AND THEIR COMMUNITIES

As described above in previous sections, there is not a direct coral fishery nor any associated industries that rely upon harvested domestic corals as a major income source. Therefore, instead of discussing the social and cultural characteristics of coral fishermen, Section 11.0 is necessarily redirected toward the various users of the resource (divers and snorkelers, dive shops, shell shops, visitors to coral assemblages, e.g., party boats, tropical specimen collectors, shell collectors, lobster fishermen) and the general population of the coastal area. In lieu of tabulating data on all counties in the management area, 15 representative coastal counties near Onslow Bay (North Carolina), Gray's Reef (South Carolina and Georgia), the Florida reef tract (Florida), the Florida Middle Grounds (Florida), the topographic highs and corals of the eastern Gulf of Mexico (Alabama, Mississippi, Louisiana, and Texas), and the Flower Garden Banks (Louisiana and Texas), have been selected (Figure 11-1). Extrapolations of these data to all coral users or to all coastal counties in the management area must be made with caution.

Little detailed information exists focusing on the socio-cultural framework of coral user groups. Nonetheless, this section of the plan can, to a limited extent, describe these groups and outline relevant social statistics. For example, the significance of SCUBA divers and snorkelers is portrayed in Table 11-1. Clearly, portions of the management area, especially those near corals, are favorite destinations of diving enthusiasts. Supportive users and industries such as dive shops, shell shops, charter boats, and the hotel/restaurant trade also benefit economically from the attractiveness of coral areas to tourists. Tropical specimen collection, an industry valued in excess of one million dollars annually in Florida (Bright and Jaap, in press), relies heavily upon reef fishes.

The following discussions must also be qualified to reflect the relationship between the general population of the coastal counties and coral user groups; direct parallels are difficult to establish. Secondly, many users may not live in the coastal counties. Mertens (1977), for example, found that only four percent of 191 respondents to a charter fishermen survey in Texas resided in coastal counties, excluding Houston in Harris County. Some businesses indirectly dependent upon coral, e.g., hotel owners near the Florida reef tract, may never visit the corals personally. Other users may derive only a portion of their total gross income from coral-related activities yet visit coral assemblages regularly.

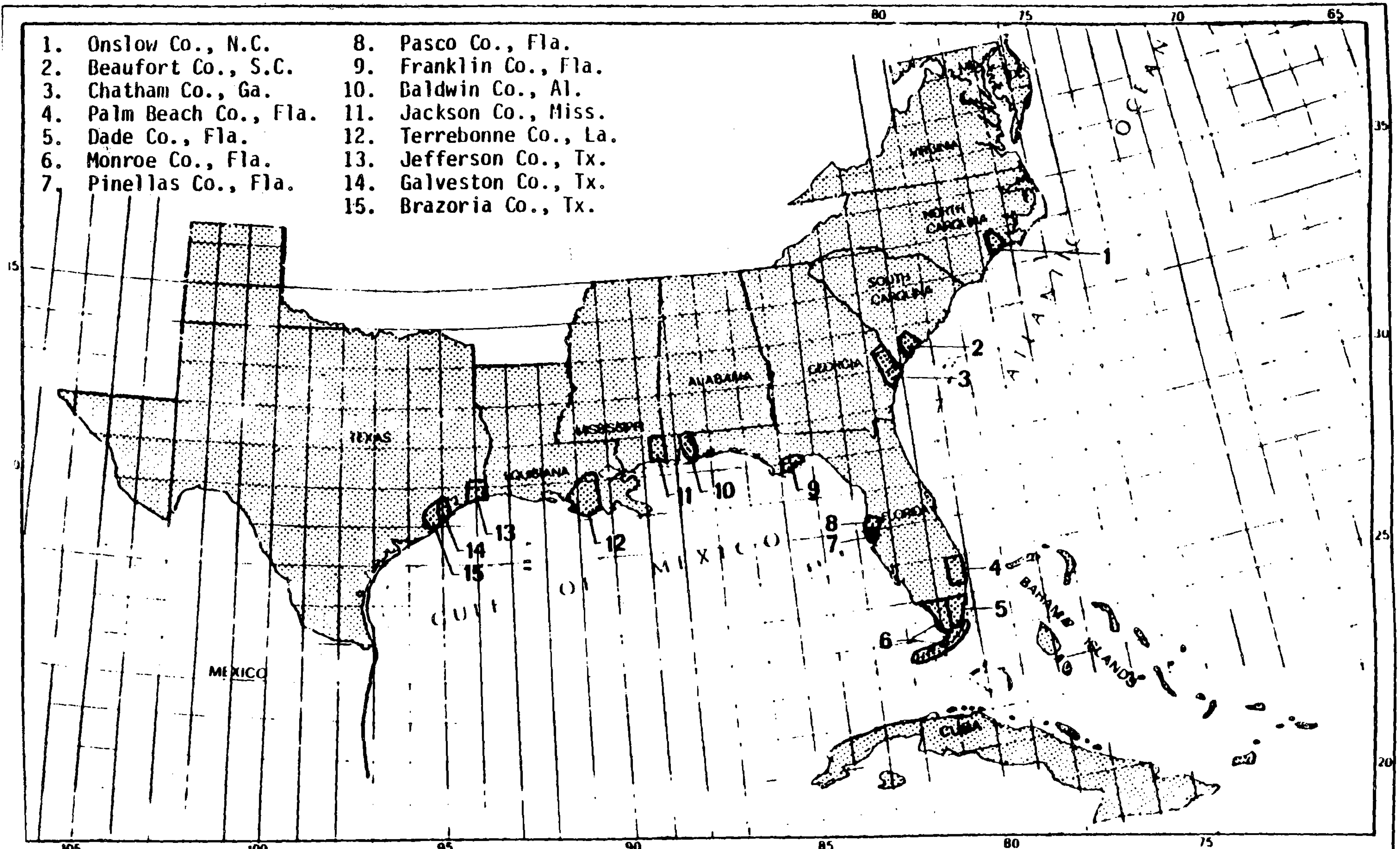
11.1 Ethnic Character, Family Structure, and Community Organization

11.1.1 Ethnic Character

The ethnic character of the general population within states bordering the management area is included in the 1970 Census of Population compiled by the U.S. Department of Labor. Generally, the populations in the 15 selected coastal counties are American-born and white (Table 11-2). The ethnic mix varies between states with blacks, Cubans, and Mexicans comprising most of the minority populations in South Carolina/Georgia, Florida, and Texas, respectively. Populations of French descent are uniquely common in the delta region of Louisiana.

Specific information on the ethnic charcter of most coral user groups is lacking. Many users are tourists originating from outside the state (e.g., divers visiting the Florida Keys [see Skin Diver Magazine, 1979]) or outside the coastal county (e.g., charterboat passengers [see Ditton, et al., 1978]). Hence, county ethnicity data in Table 11-2 may not accurately portray some user groups. Furthermore the ethnic character of the tourists has not yet been assessed. Unfortunately, there have been no user group studies that identify both origin and destination.

Based upon limited observations and informal interviews, many Florida shell shops (retail sales of shells, corals, and other items) appear to be owned, managed, and/or operated by American white families. Collectors of the shells and corals may be members of a minority or national group other



'IGURE 11-1. Coastal counties in the states under Gulf of Mexico and South Atlantic Fishery Management Council jurisdiction that are summarized in Sections 11.i-iii on social and cultural characteristics.

Table 11-1. A *Skin Diver Magazine* national poll of 2,451 subscribers (1,424 responses) revealed the following breakdown by state of where readers travel for out of state diving trips. Based on multiple answers (adapted from *Skin Diver Magazine*, 1979).

DESTINATION	PERCENT WHO TRAVELED
- in management area	
Florida coast	32.9
Florida Keys	35.6
Texas	6.3
North Carolina	4.1
- outside management area	
California - south	14.6
- north	6.2
- offshore	8.8
New Jersey	9.9
Wisconsin	5.4
New York	7.2
Michigan	5.1
Rhode Island	5.4
Illinois	3.0
Massachusetts	5.1
Connecticut	2.5
Maine	1.8
Washington	3.3
- other* (inside or outside management area)	20.2
Total Nationwide Percent Traveling Out-of-State on Dive Trips Annually	38.8

* Destination not state-specific, e.g., "to Great Lakes" or "to Gulf of Mexico"

than American white, e.g., Philippine coral collectors, Cuban shell collectors. Similarly, dive shops are mostly white-owned throughout the Florida Keys. Reviews of historical records, ledgers, and books in the south Florida area revealed that American blacks, Cubans, Bahamians, and Haitians were active to varying extents in legally harvesting corals within the fishery conservation zone between 1890 and 1970.

Monroe and Dade Counties in Florida adjacent to the reef tract and coral-related industries, include several ethnic or minority groups (see Table 11-2). The 1970 population of 52,586 in Monroe County included 4,222 blacks (eight percent) and 5,650 residents with Spanish surnames (eleven percent). Dade County includes a higher percentage of ethnics, primarily of Cuban descent.

Among spiny lobster fishermen in Florida, data on state licenses granted in 1977 to 1978 show 24.1 percent of the 1,701 licensees to have a Spanish surname; in 1965 to 1966, the seasonal percentage was only 8.2 percent (Centaur Associates, Inc., 1979). Most licensees lived and fished in the Miami, Marathon, and Key West areas of Dade and Monroe Counties.

Table 11-2. General population ethnic characteristics for 15 coastal counties adjacent to the FCZ.

COUNTY, STATE	COUNTY POPULATION TOTAL	COUNTY POPULATION DENSITY/mi^2	WHITE	BLACK	OTHER	PERCENT FOREIGN BORN
Onslow, North Carolina	103,126	134.8	86,516	15,180	1,430	1.3
Beaufort, South Carolina	51,136	88.3	33,864	16,868	424	1.0
Chatham, Georgia	187,767	421.9	123,295	63,676	796	1.1
Palm Beach, Florida	348,753	172.4	286,460	61,015	1,278	7.9
Dade, Florida	1,267,792	620.9	1,071,662	189,666	6,464	24.2
Monroe, Florida	52,586	50.9	42,690	4,222	674	5.3
Pinellas, Florida	522,329	1,971.1	478,043	42,765	1,521	7.5
Pasco, Florida	75,955	102.4	71,924	3,781	250	7.3
Franklin, Florida	7,065	13.2	5,730	1,323	12	1.4
Baldwin, Alabama	59,382	37.6	48,650	10,569	163	1.3
Jackson, Mississippi	87,975	119.5	73,547	14,258	170	0.9
Terrebonne, Louisiana	76,049	55.6	62,251	11,423	2,375	0.4
Jefferson, Texas	244,773	257.4	183,100	61,064	609	1.2
Galveston, Texas	169,812	425.6	135,480	33,314	1,018	2.7
Brazoria, Texas	108,312	76.1	97,685	10,137	490	1.5

Source: Adapted from U.S. Department of Commerce, 1973 - Tables 9, 34, and 43.

Table 11-3. General population characteristics related to family structure of people in 15 coastal counties from North Carolina to Texas.

COUNTY, STATE	TOTAL POPULATION	TOTAL PEOPLE IN HOUSEHOLDS	MALE	FEMALE
Onslow, North Carolina	103,126	77,409	63,667	39,459
Beaufort, South Carolina	51,136	41,579	29,517	21,619
Chatham, Georgia	187,767	182,929	89,940	97,827
Palm Beach, Florida	348,753	342,380	166,382	182,371
Dade, Florida	1,267,792	1,244,337	602,095	665,697
Monroe, Florida	52,586	48,549	28,181	24,405
Pinellas, Florida	522,329	513,834	240,397	281,932
Pasco, Florida	75,955	74,589	36,387	39,118
Franklin, Florida	7,065	7,057	3,429	3,636
Baldwin, Alabama	59,382	58,772	29,032	30,350
Jackson, Mississippi	87,975	87,458	43,898	44,077
Terrebonne, Louisiana	76,049	75,788	37,822	38,227
Jefferson, Texas	244,773	241,239	118,638	126,090
Galveston, Texas	169,812	167,346	82,884	86,928
Brazoria, Texas	108,312	104,016	56,357	51,955

Source: Adapted from U.S. Department of Commerce, 1973 - Tables 9, 34, and 36.

11.1.2 Family Structure

The only information available on family structure pertains to the general population, summarized here for 15 coastal counties (Table 11-3). Those census data show over 90 percent of the citizens to be living in households in all counties except Onslow, North Carolina, and Beaufort, South Carolina. In Dade and Monroe Counties, Florida, the 1970 Census of Population listed 329,695 and 13,565 families or mean family sizes of 3.8 and 3.9, respectively.

Population ratios of males to females vary between counties but fall within national ranges; females slightly outnumber males (Table 11-3). Among divers, 90.2 percent of the respondents to a national survey were male (Skin Diver Magazine, 1979). Nearly half (49.4 percent) of those same respondents were married, 42.4 percent single, and 8.2 percent widowed or divorced.

The 1970 Census of Population also tabulated indicators of economic well-being on a county basis. These data are summarized in Table 11-4 for the 15-county sample and presented in greater depth for Dade and Monroe Counties (near the Florida reef tract) in Table 11-5. Table 11-6 lists the household incomes of divers (SCUBA and snorkel) from the 1979 nationwide survey. Over 64 percent of the recreational diver respondents were members of households earning over $20,000 per year while nearly 30 percent made more than $35,000 annually. Among charterboat clients in Texas, Mertens (1977) reported that 78 percent earned over $20,000 per year and 21 percent over $50,000; the average income was $33,000. Inferences to the various other coral user groups in this management area must be made cautiously from the general information presented here.

Table 11-4. Median and per capita incomes in the 15 sample counties adjacent to the management area.

COUNTY, STATE	MEDIAN INCOME ($)	PER CAPITA INCOME ($)
Onslow, North Carolina	6,471	2,205
Beaufort, South Carolina	6,590	2,243
Chatham, Georgia	8,245	2,671
Palm Beach, Florida	9,112	3,893
Dade, Florida	9,245	3,467
Monroe, Florida	7,334	2,842
Pinellas, Florida	7,642	3,300
Pasco, Florida	4,998	2,342
Franklin, Florida	4,338	1,654
Baldwin, Alabama	7,338	2,268
Jackson, Mississippi	8,548	2,528
Terrebonne, Louisiana	8,338	2,182
Jefferson, Texas	9,024	2,928
Galveston, Texas	9,778	3,036
Brazoria, Texas	10,435	2,964

Source: Adapted from Tables 44 and 124 from U.S. Department of Commerce, 1973.

Table 11-5. Income breakdown for Monroe and Dade Counties, Florida, for the total population.

PERCENT BY INCOME LEVEL	DADE COUNTY	MONROE COUNTY
0 - 1,999	6.2	8.6
2,000 - 4,999	15.8	20.5
5,000 - 6,999	13.0	18.4
7,000 - 9,999	19.5	20.6
10,000 - 14,999	23.9	19.5
15,000 - 24,999	15.1	9.3
25,000 - 49,999	5.1	2.4
50,000 - more	1.3	0.6

Source: Adapted from U.S. Department of Commerce, 1973.

Table 11-6. Household income of divers responding to a nationwide survey conducted for *Skin Diver Magazine* (1979).

HOUSEHOLD INCOME BRACKET	PERCENT OF RESPONDENTS
UNDER $8,000	5.3
8,000 - 9,999	2.3
10,000 - 11,999	3.7
12,000 - 14,999	8.2
15,000 - 17,499	6.9
17,500 - 19,999	8.4
20,000 - 24,999	15.3
25,000 - 34,999	18.7
35,000 - and up	20.6

Median Household Income: $24,479

11.1.3 Community Structure

User groups near coral resources include residents, in-state travelers, and out-of-state tourists. Areas of highest coral-related activity (fishing, diving, shell shops, etc.) range from residential communities with strong fishing influences such as Marathon and Key West in Monroe County, Florida, to tourist/recreation centers like Key Largo. More indirect coral users such as commercial fishing boats tend to concentrate in the northern and eastern Gulf of Mexico (e.g., Apalachicola Bay and the Middle Grounds) and off Georgia and South Carolina.

Throughout the management area, community structure dynamics reflect shifts in business opportunities and economic development. Many of those changes have occurred over the last census decade. Community changes have been very evident in the popularized retirement centers in Dade, Pinellas, and Pasco counties in Florida (see median age data in Table 11-7). In Monroe County, the Key West population decreased 18.8 percent between 1960 (33,956) and 1970 (27,563), due primarily to a decreased personnel commitment at the military installation. Marathon and Key Largo, although too small to be listed in the 1960 census, contained 4,397 and 2,866 people in 1970 and about 10,000 and 12,000, respectively in 1978 (U.S. Department of Commerce, 1973; Key Largo, Florida, Chamber of Commerce, 1979, personal communication; Marathon, Florida, Chamber of Commerce, 1979, personal communication).

Table 11-7. General age and education profiles for the total population of 15 coastal counties adjacent to the manaement area.

COUNTY/STATE	TOTAL POPULATION	AGE UNDER 18	AGE 18 - 65	AGE 65-OVER	MEDIAN AGE	MEDIAN SCHOOL YEARS
Onslow, North Carolina	103,126	33,249	67,555	2,322	21.1	12.1
Beaufort, South Carolina	51,136	18,651	30,199	2,286	20.8	11.9
Chatham, Georgia	187,767	66,554	105,609	15,604	25.9	11.6
Palm Beach, Florida	348,753	103,547	184,791	60,415	35.5	12.2
Dade, Florida	1,267,792	370,656	724,419	172,717	34.2	12.0
Monroe, Florida	52,586	15,701	32,389	4,496	27.3	12.2
Pinellas, Florida	522,329	120,167	248,239	153,923	48.1	12.1
Pasco, Florida	75,955	16,032	35,902	24,021	53.4	11.3
Franklin, Florida	7,065	2,455	3,525	1,085	30.9	10.2
Baldwin, Alabama	59,382	22,047	31,002	6,333	27.7	11.0
Jackson, Mississippi	87,975	36,523	47,179	4,273	23.3	12.1
Terrebonne, Louisiana	76,049	33,543	38,622	3,884	21.5	9.8
Jefferson, Texas	244,773	86,212	137,456	21,105	28.1	11.8
Galveston, Texas	169,812	61,506	95,578	12,728	27.6	11.6
Brazoria, Texas	108,312	40,909	61,657	5,746	26.0	12.1

Source: Adapted from U.S. Department of Commerce, 1973 - Tables 35 and 120.

11.2 Age and Education Profiles

11.2.1 Age

Select county age profiles (Table 11-7) show median ages ranging from 20.8 to 53.4 in the 15 sample counties. Not surprisingly, areas with aged retirement communities tended to be concentrated near Miami (Dade County) and Tampa-St. Petersburg (Pasco and Pinellas Counties).

Detailed data on age distributions of coral user groups in the management area, however, are limited. In the diving sector, 74.6 percent of the respondents to a nationwide 1979 survey were younger than 35 years old (Table 11-8). Prochaska and Cato (1977), in a survey of commercial fisheries boat captains in Florida, calculated an average age of 48 years (Table 11-9). Another canvas by Mertens (1977) of Texas charterboat fishermen revealed an average participant age of 45 years (range: 14 to 79); 74 percent of the respondents were between 30 and 59 years old.

Educational achievement tables derived from the 1970 Census of Population show a rather uniform median school years-attended figure ranging from 9.8 to 12.2 years (Table 11-7). In the above-mentioned diving sector, 72.7 percent of the respondents reportedly had attended college or better (Table 11-8).

Table 11-8. Age and education statistics for SCUBA and snorkel divers responding to a Skin Diver Magazine (1979) survey.

AGE	TOTAL RESPONDENTS
Under 18 years	9.0
18 - 24	27.9
25 - 34	37.3
35 - 49	20.7
50 - 64	4.7
65+	0.4

Median Age: 28.0 years
Average Age: 29.5 years

EDUCATION	
Grade School	1.2
Attended/Attending High School	10.9
Graduated High School	12.3
Attended/Attending College	37.4
Graduated College	18.8
Post-Graduate	19.4

75.6 percent have attended college or better

Table 11-9. Age and education profiles for commercial fishery boat captains in Florida.

	AGE (yrs)					
	16 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61-Over
Distribution by age	4	7	18	24	28	19
Years of school completed	12.7	12.5	11.8	11.2	11.6	8.7

11.3 Employment Opportunities and Unemployment Rates

The economic structure of the sample of coastal counties in the management area varies greatly, as evidenced by income levels and employment opportunities (see Tables 11-4 and 11-10). Generally, the 1970 data aggregated in those tables disguise the fact that great differences in the employment market exist between counties. Urbanized areas such as Chatham, Palm Beach, Dade, Galveston, and Brazoria Counties, have considerably greater employment opportunities than semirural or rural areas like Onslow, Monroe, and Terrebonne Counties. Conversely, commercial fishing jobs are far less numerous in urban areas (Dade County - 552 positions in 1975 or less than 0.1 percent of the work force), than in more rural areas (Monroe County - 3,096 positions in 1975 or 13.6 percent of the total work force) (Table 11-11). And, as noted above, these same fisheries positions normally result in expanded employment in related sectors (restaurants, supplies, etc.) through the so-called "multiplier effect."

Employment trends (1971 to 1975) in fishing and all other sectors of the economy are presented in Table 11-11. The data show that in commercial fishing total employment has decreased in Dade County, Florida, since 1973 (-37.6 percent) and increased slightly in Monroe County (+6.6 percent). Total numbers of proprietors and employees have risen marginally and decreased slightly, respectively, over that same time period. Ditton, et al. (1978) identified 88 charterboat businesses in the coastal counties of Texas, with concentrations in the Port Aransas (Nueces County) and Freeport (Brazoria County) regions. In the spiny lobster fishery, the number of licensees increased 80 percent between 1971 (1,149) and 1975 (2,067) (Centaur Associates, Inc., 1979).

Unemployment rates throughout most of the management area have paralleled national trends (Tables 11-10 and 11-12). For example, Florida data in Table 11-12 show the seasonal progression in unemployment with highest rates in the first quarter. Since no single unemployment rate can realistically be applied to the coral fishery, no comparison is made between different fisheries.

In the Texas charterboat user sector, customer demand is concentrated in the summer months, especially June to August (Ditton, et al., 1978). The lobster fishery is seasonal, peaking between August and November (Centaur Associates, Inc., 1979). Most other coral user groups are tourist related and therefore parallel the peak tourist seasons in winter and spring. Tropical fish and shell collecting users may operate year round but weather patterns often limit dive time in winter months. These seasonal trends may have important repercussions on such indirectly related user groups as hotels, restaurants, and fishing tackle suppliers.

11.4 Recreational Users

As noted in Sections 11.1 to 11.3, recreational activity is the major use of coral and coral reef resources. Major participants are divers (SCUBA and snorkelers), glass-bottom boats, charterboats, and others. Where possible, data on each group is summarized below. Supplementary information on marine recreation is also offered as an introductory note.

Table 11-10. Employment and unemployment data from Table 44 of the 1970 Census of Population for 15 coastal counties.

COUNTY, STATE	NONWORKER: WORKER RATIO	UNEMPLOYMENT RATE FOR CIVIL LABOR FORCE
Onslow, North Carolina	0.88	6.5
Beaufort, South Carolina	1.07	5.4
Chatham, Georgia	1.49	4.3
Palm Beach, Florida	1.53	3.0
Dade, Florida	1.32	3.5
Monroe, Florida	1.29	4.3
Pinellas, Florida	2.00	3.5
Pasco, Florida	2.90	4.8
Franklin, Florida	1.70	3.7
Baldwin, Alabama	1.74	4.3
Jackson, Mississippi	1.70	4.6
Terrebonne, Louisiana	2.15	3.3
Jefferson, Texas	1.57	4.3
Galveston, Texas	1.46	3.7
Brazoria, Texas	1.61	2.9

Source: Adapted from U.S. Department of Commerce, 1973.

Table 11-11. Population and employment trends in Dade and Monroe Counties, Florida.

	DADE COUNTY			MONROE COUNTY		
	1971	1973	1975	1971	1973	1975
I. Population[1]	1,301,700	1,371,400	1,438,600	52,300	53,900	51,400
II. Employment (total)[1]	625,813	714,957	676,577	23,530	24,138	22,699
Proprietors'	45,106	46,811	46,983	2,437	2,531	2,542
Farm	762	741	699	6	6	6
Nonfarm	44,344	46,070	46,284	2,431	2,525	2,536
Wage and Salary	580,707	668,146	629,594	21,093	21,607	20,127
Farm	4,490	4,616	3,425	5	5	4
Nonfarm	576,217	663,530	626,169	21,008	21,602	20,123
Government	75,549	83,787	96,643	10,603	9,242	8,142
Private	500,668	579,743	529,526	10,485	12,360	11,981
III. Commercial Fishermen[2]	531	885	552	2,060	2,904	3,096
Regular[3]	106	99	65	448	599	796
Casual[3]	39	45	18	114	338	544
Crew	386	741	469	1,498	1,967	1,756

1 Obtained from U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System.

2 Obtained from U.S. Department of Commerce, National Marine Fisheries Service, unpublished data.

3 Regular fishermen are defined as those earning 50 percent or more of their income from fishing, while casual fishermen earn less than 50 percent of their income from fishing.

Source: Adapted from Centaur Associates, Inc., 1979.

Table 11-12. Unemployment rates for Dade and Monroe Counties and the State of Florida at two-year intervals.

Area/Year		PERCENTAGE UNEMPLOYMENT QUARTER First	Second	Third	Fourth	Annual Average
Dade County	1971					5.2
	1973					4.1
	1975	11.5	13.5	12.9	12.2	12.6
	1977	10.0	9.4	8.1	8.1	8.9
Monroe County	1971					2.8
	1973					3.8
	1975	10.4	10.6	9.5	10.4	10.2
	1977	11.0	8.7	7.3	8.4	8.9
Florida	1971					4.9
	1973					5.3
	1975	10.2	11.2	10.9	10.4	10.7
	1977	9.4	8.9	7.6	7.4	8.2

Source: Adapted from Florida Division of Employment Security statistics.

Specific data on recreational activities have been summarized in surveys conducted by the U.S. Fish and Wildlife Service (U.S. Department of the Interior, 1977). Both national and state surveys apply to recreation in general, not people identified as users of corals. From that research, Table 11-13 summarizes the socioeconomic structure of marine anglers in Florida and in the general management area. Most users are male, less than 40 years old, and middle income wage earners, although these generalizations could be somewhat skewed since the survey population was of predominantly middle income people.

The occupational mix of recreational anglers in the southeast has been shown by Horvath (1974) to be quite diverse (Table 11-14). Over 90 percent of the respondent household's members were employed, with professional, management, and skilled crafts personnel numbering more than 36 percent of the sample.

A Skin Diver Magazine (1979) national reader survey addressed the issue of multiple diver activities, including "reef exploration" and several others directly applicable to coral assemblages (Table 11-15). Nearly 94 percent of the respondents participated in "special interest underwater activities" during the previous 12 months; almost 90 percent of the divers participated in other watersports.

Glass-bottom boat operators are restricted geographically to areas adjacent to shallow-water corals - namely the Florida reef tract. Most of this type of sight-seeing use is concentrated near Key Largo, Florida, and the state park and marine sanctuary.

The charter and party boat industries are two quasi-recreational user groups that often utilize fishery resources near corals. In 1970, an estimated 15 percent of the sport fishermen in the Gulf region used a charter or party boat at least once; charter fees exceeded $20 million (Bureau of Sport Fisheries and Wildlife, 1972). These users also generate considerable income spinoff effects in the process of preparing for charterboat trips, especially where they remain beyond one day, e.g., consumption at hotels, restaurants, equipment shops, etc.

Table 11-13. Socioeconomic data on percent participation of marine recreational anglers in Florida and in the management area generally.

AGE GROUP	FLORIDA	SOUTH ATLANTIC AND GULF OF MEXICO REGIONS
9 - 17	17.6	20.2
18 - 24	10.8	12.2
25 - 34	27.6	24.9
35 - 44	12.7	12.0
45 - 54	8.5	14.4
55 - 64	13.4	10.3
65 - older	9.4	6.0
	100.0	100.0
SEX		
Male	73.4	72.6
Female	26.6	27.4
	100.0	100.0
INCOME		
Under $2,000	6.6	9.4
$ 2,000 - 4,999	6.0	6.6
$ 5,000 - 7,499	4.7	7.7
$ 7,500 - 9,999	21.4	14.0
$10,000 - 14,999	21.8	17.2
$15,000 - 24,999	25.9	25.7
$25,000 - 34,999	12.1	13.9
$35,000 - 39,999	1.3	2.8
$50,000 - or more	0.2	2.7
	100.0	100.0

Source: Adapted from U.S. Department of the Interior, 1977.

Table 11-14. Occupation distribution of marine recreational anglers in the southeast.

OCCUPATION	PERCENT OF HOUSEHOLDS SURVEYED
Professional	13.9
Technical	6.8
Manager-Foreman	11.4
Clerical	3.4
Sales	5.8
Service	5.6
Farmer-Rancher	3.1
Construction	6.2
Laborer	3.9
Skilled Crafts	11.5
Operative	6.1
Proprietor	7.9
Student	1.1
Armed Forces	2.8
Retired - Full Time	7.6
Homemaker	1.8
Not in Labor Force	1.1
Other	0.2
	100.0

Source: Adapted from Horvatch, 1974

Because the many benefits of recreational use are at least in part, intangible commodities, they are difficult to assess objectively. Among others, they may be psychological (a desire for solitude), emotional (the thrill of catching a trophy fish), monetary (catch fish or enhance business associations), or combinations of all three. Spaulding (1970), for example, ranked the "fishing experience" as the foremost reason why recreational fishermen pursue their hobby. Charter fishermen rank "having fun," "relaxation," and "being with friends", as key rationales for chartering a day of fishing (Mertens, 1977). As an example of the economic worth values of these activities to the fishermen, Horvath (1974) noted a 1971 study that valued saltwater fishing benefits in southeastern U.S. waters at $59.80 per fishing day.

Table 11-15. Particpation of divers in (1) related activities and (2) other water sports, based on multiple answers (adapted from Skin Diver Magazine, 1979).

	% TOTAL RESPONDENTS
1. PARTICIPATION IN DIVING-RELATED ACTIVITIES	
General Recreation	81.1
Reef Exploration	48.1
Shell Collecting	34.5
Spearfishing	32.5
Underwater Photography	29.7
Lobster or Abalone	32.3
Wreck Diving	36.7
Cave Diving	11.7
Treasure Hunting	11.0
Tropical Fish Collecting	5.8
Competitive Diving	3.4
2. PARTICIPATION IN OTHER WATER SPORTS	
Fishing	73.2
Boating	71.9
Water Skiing	57.3
Sailing	36.9
Surfing	9.4

11.5 Economic Dependence on Commercial or Recreational Fishing and Related Activities

Within the management area, no one person or firm is totally economically dependent upon harvesting or harvested corals. However, numerous businesses derive significant portions of their income from boat rentals, gear sales, dive/boat trips, tropical fish sales, shell/coral sales, and related hotels and restaurants that cater to users of corals or coral reef resources.

A prime example of the dependence of an area upon coral resources is Key Largo, Florida. Due in large part to the offshore reefs, John Pennekamp Coral Reef State Park and Key Largo Marine Sanctuary, the Key Largo vicinity supports 34 boat ramps, 22 marinas, 13 dive shops, and 22 dive boats; park facilities alone can accommodate up to 529 dive/snorkel/glass bottom boat customers per day (Office of Coastal Zone Management, 1978). In total, the State Park and Marine Sanctuary are visited by well over 400,000 users each year (Gillen, 1979, personal communication), many of whom spend at least several days shopping in adjacent business districts. Similar, though smaller pockets of coral-related industries exist near Marathon and Key West, Florida. Although the total monetary benefit of these visitors has never been assessed, it is undoubtedly very significant to local, county, and even state economy in Florida's case.

Despite the absence of a coral harvesting industry, corals are directly related to numerous commercial fisheries. Foremost among individual fisheries is the spiny lobster in southern Florida, an industry that has an average annual harvest value since 1972 of nearly $10 million (Centaur Associates, Inc.). Mackerel, yellowtail snapper, and some grouper, are also taken from patch and coral reef areas. On hard grounds, sponges are collected for market. Shrimp is the major fishery from soft bottom near Dry Tortugas. Throughout many coral communities, tropical fish consititute another important fishery. The Marine Extension Service of Monroe County, Florida, in Key West, has estimated that tropical fish represented $389,979 in 1974 value to collectors. This is a low estimate of the real value since it is not retail, and since it excludes plants and invertebrates which the Florida Marine Life Association calculates to be worth about one million dollars. Within the purview of the Florida coral law (see Section 7.4) and the Florida Department of Natural Resources, some tropical fish collectors also collect and sell live and dried gorgonians (other than sea fans), for aquaria (Causey, 1979, personal communication; Feddern, 1979, personal communication).

Many of these "coral uses" exhibit no significant seasonal variation in popularity. Still, some fisheries may be more economically lucrative at some times (e.g., lobsters and shrimp), and others (e.g., tropical fish) may be landed on a nearly year-round basis.

The nearby presence of domestic corals also plays an important role in generating interest in shell shops throughout the management area but especially in the Florida Keys. Both tourists and residents purchase shells, corals, and other marine specimens from the numerous small shops situated in coastal areas (see also discussion in Section 10.1). Although corals sold in these shops are nearly all imported (some gorgonians are collected and sold legally within the Florida coral law (Causey, 1979, personal communication)), interest in domestic corals may be a major reason for their popularity.

Glass-bottom boat proprietors depend heavily upon coral resources, although many owners also operate dive boats or work in unrelated fields. Some boats charge $10 to $20 per person, take up to 125 people per trip, and make an average of two or three trips per day to coral areas.

The indirect economic dependence of Florida Keys motel/hotel and restaurant owners on living coral resources is enormous. Many such businesses are concentrated quite near to the offshore corals of Key Largo and Key West; a third area near Looe Key is currently expanding at a rapid rate. Elsewhere in the management area, tourist-related enterprises abound but cater largely to parties other than coral enthusiasts, e.g., those seeking amusements, large cities, sports events, sun, fish, etc.

11.6 Distribution of Income Within the User Community

General distributions of income in communities which include coral users may be derived from census and economics statistics maintained by the Bureaus of Census and Economic Analysis, respectively, within the U.S. Department of Commerce. At the county level, personal income is categorized both by type of payment (e.g., wage and salary, nonfarm proprietors, and others) and by industry. Within the latter class, private sector income in "wholesale and retail trade" and "services" probably best reflects income generated in shell shops, restaurants, boating, and other coral user-related businesses. A broad category termed "other" includes forestry, agriculture, and fisheries; in some coastal regions, such as Monroe County, Florida, fisheries may be assumed to contribute most of the "other" income due to the absence of much significant forestry and agriculture work.

In the two counties within the management area that are most dependent upon income derived from coral users, "wholesale and retail trade" and "services" constitute the majority of earned personal income in the private sector (Table 11-16). Most of this income is paid by direct wages and salaries. Government income is also important to county economies but is unlikely to be related to corals. Government-generated monies to user groups via small business loans and tourist development may also contribute to community income structure. Between 1971 and 1975 income in the trade and services classes has risen significantly.

Table 11-16. Personal Income in Monroe and Dade Counties, Florida, by type of payment and type of industry for 1971, 1973, and 1975.

	DADE COUNTY			MONROE COUNTY		
	1971	1973	1975	1971	1973	1975
TYPE						
Wage and Salary Disbursements	4,326,584	5,688,500	6,220,418	134,543	160,311	165,718
Other Labor Income	230,874	322,955	395,070	3,569	5,118	6,454
Proprietors' Income	406,446	495,561	493,891	10,432	13,266	13,150
Farm	37,782	40,409	37,559	111	152	182
Nonfarm	368,664	457,152	456,332	10,321	13,114	12,968
BY INDUSTRY						
Farm	50,716	55,673	54,778	125	169	201
Nonfarm	4,913,188	6,453,343	7,054,601	148,419	178,526	185,121
Private	4,245,426	5,596,169	5,937,577	67,679	94,179	99,482
Manufacturing	567,744	775,336	812,162	(D)	(D)	5,773
Mining	14,989	25,645	30,623	(D)	(D)	(L)
Contract Construction	394,026	591,037	413,388	7,803	16,607	9,177
Wholesale and Retail Trade	1,013,386	1,306,572	1,452,621	21,844	27,340	32,385
Fin., Ins. and Real Estate	385,118	514,815	551,567	4,867	5,583	7,044
Trans., Comm. and Pub. Utilities	726,717	912,678	1,007,188	6,162	7,073	8,743
Services	1,130,407	1,449,715	1,648,874	20,986	27,617	31,304
Other[1]	13,039	20,371	21,154	1,702	9,476	5,056
Government	667,762	857,174	1,117,024	80,650	84,347	85,639
Federal, Civilian	151,710	178,479	217,901	15,913	16,040	18,201
Federal, Military	80,503	92,377	106,006	49,808	48,279	41,774
State and Local	435,549	586,318	793,117	14,929	20,029	26,664
TOTAL	4,963,904	6,509,016	7,109,379	148,544	178,695	185,322

(D) Not shown to avoid disclosure of confidential information.

(L) Less than $50,000.

1 Includes fisheries harvesting sector.

Source: Adapted from Centaur Associates, Inc., 1979.

12.0 OPTIMUM YIELD

12.1 Problems in the Fishery

The Council has developed management objectives and management measures to address the following problems associated with the coral resource.

(1) Degradation of stocks through natural and man-made occurrences.

Corals and coral reefs in the management unit are frequently plagued by a wide variety of impacts, as detailed in Section 6.2.2. The cumulative effect of these stresses has apparently been a degradation of stock size, areal distribution, and coral health generally. This problem hampers efforts to study the resource and to ascertain its suitability for harvest.

(2) Limited scientific information on many species and many sections of the management unit, which includes the inability to assess the impact of coral harvest.

The existing biological data presented in Section 5.4 show that there is very little information on growth, mortality, abundance, and recruitment for the management unit. This information or catch effort from a directed fishery is absolutely necessary to estimate MSY (and then OY) for each species. Without this information, estimated MSYs are uncalculable.

(3) Susceptibility to stress because of many corals being located at the northern limit of their distribution.

Many corals in the management unit are located at the northern end of their natural distributions. This means that they are subjected to water temperature extremes that stress them to the limit of their ability to survive. In fact, in some instances water temperature drops and/or other natural occurrences (such as hurricanes), have killed large segments of reefs in the management unit. These natural stresses are uncontrollable by man. However, because of these natural stresses, corals in the management unit are more susceptible to man-induced stresses.

(4) Inability of corals to escape stress because of their sedentary nature.

Corals, unlike finfish, crustaceans, and most mollusks, cannot move to escape stress. Instead, the polyps must retract. Resulting disruptions in energy flow may interfere with normal biological functions such as reproduction and feeding.

(5) Complexity and inconsistency of existing management regimes.

As summarized by Shinn (1979b, and 1980), the management area is covered by numerous federal and state authorities with jurisdiction over coral and coral reef resources. This presents problems in overlapping authorities (States, BLM, OCZM, FWS, etc.), differing regulations (e.g., concerning tropical fish collecting in Florida Keys parks, monuments, etc.), and more. The resulting regime is complex, burdensome, and inconsistent; a single coordinating authority such as NOAA may offer a solution via the FMP within the mandate of the FCMA.

(6) Lack of adequate public understanding of the importance of coral and coral reefs.

Dead coral is sold extensively in the management area both for use as curio items and aquarium decorations. On the other hand, living coral is important both ecologically and economically to the management area. Living coral provides habitat for many species of finfish and shellfish. Many of these species are commercially valuable. Living coral also provides a major tourist attraction to south Florida and to a lesser extent in other states.

(7) Present lack of jurisdiction over most coral and coral reefs by a federal agency which has traditionally executed authority and jurisdiction.

In a recent decision (U.S. v. Alexander) the court ruled that the Bureau of Land Management only had authority to manage corals threatened by oil lease operations. This decision has left the majority of coral and coral reef resources in the FCZ unprotected and unmanaged by any federal regime. Much of Florida Reef Tract from American Shoal off Sugarloaf Key to Star Reef off Key Largo lies in the FCZ. Thus, spectacular assemblages of corals are afforded little protection from harvest and no protection from diliberate destruction by human activity. Florida law (see Section 7.4.2) allows possession of cured coral after what can be an on-board process of bleaching and does not prohibit the destruction of reefs beyond the territorial sea.

12.2 Recommended Management Objectives

12.2.1 Recommended General Management Objective

Optimize benefits generated from the coral resource while conserving coral and coral reefs.

This is both the short-term and long-term overall objective of this fishery management plan. The coral resource in the FCZ of the Gulf of Mexico and South Atlantic Councils is unique in the continental United States. Corals in the management area tend to be at the northern limit of their range; this makes these corals more susceptible to environmental stresses than the same species located in more tropical climates. The coral resource also makes a significant contribution to the economy in the management area. Additionally, the presence of coral assemblages attracts many tourists to the area. Coral and coral reef assemblages also provide necessary habitat for many valuable species of shellfish and finfish.

12.2.2 Recommended Specific Management Objectives

The general objective is, in effect, a statement of the concept of Optimum Yield as embodied in the Fishery Conservation and Management Act. The specific management objectives recommended below apply to coral and coral reef resources in the fishery conservation zone of the Gulf of Mexico and South Atlantic Fishery Management Councils.

(1) Develop the scientific information necessary to determine the feasibility and advisability of harvest of coral.

As is discussed in Section 5.4, the scientific data necessary to calculate reliable (or even adequate) MSYs for coral and coral resources do not currently exist. The MSY calculations (required by law) shown in Section 5.4 are based upon data from incomparable areas and assumptions that render the calculations completely unreliable for guiding management unit OY and harvest decisions. The Councils intend to develop the scientific data necessary to determine the optimum level of harvest if any, consistent with long-term conservation of the coral resource. Achievement of this objective involves both the implementation of a monitoring system and a recommendation to the National Marine Fisheries Service (NMFS) that coral research be given priority.

This objective addresses problem (2) above.

(2) Minimize, as appropriate, adverse human impacts on coral and coral reefs.

Because many corals in the management unit are at the northern limit of their distribution, they are unusually susceptible to stress. By minimizing stress resulting from controllable human activities, the effects of natural impacts should be decreased.

This objective addresses problems (1), (3), and (4) above.

(3) Provide, where appropriate, for special management for coral habitat areas of particular concern (HAPC).

Provide special management measures for selected, localized coral areas which the Councils identify as sensitive, particularly significant, or susceptible to either present or potential damage.

This objective addresses problems (1), (3), and (4) above.

(4) Increase public awareness of the importance and sensitivity of coral and coral reefs.

Inform and educate the general public concerning the importance of the coral resource in the maintenance of habitat for other fisheries and in the economic base of the states adjacent to the management area.

This objective addresses problem (6) above.

(5) Provide a coordinated management regime for the conservation of coral and coral reefs.

There presently exists no consistent or uniform management of coral and coral reefs in the FCZ. Various agencies exercise responsibility in limited areas.

This objective addresses problems (1), (3), (4), (5), and (7) above.

12.2.3 Alternative Management Objectives Considered But Not Recommended

During the development of this FMP, the Councils considered the following management objectives but, for the reasons indicated under each, did not recommend them at this time. In some cases (rejected objectives (2), (4), (5), (6), and (7)) the rejected objectives were reworded as recommended objectives or included as management measures.

(1) Allow unrestricted harvest of coral.

This objective is not recommended because there are not enough scientific data on the population dynamics of the coral resource to determine the impact of unrestricted harvest. Adopting this management objective would serve to aggravate problems (1), (2) and (6) identified in Section 12.1.1 above.

This objective does not address any of the above problems.

(2) Allow limited harvest of corals while maintaining habitat and aesthetic values in corals' natural environment.

This objective was moved and revised to objectives (1) and (2).

This objective would address problems (2) and (6) but would aggravate problem (1).

(3) Protect corals from natural environmental events.

This objective is not recommended because this plan cannot change or influence natural occurrences.

(4) Preserve coral and coral reefs.

This objective was moved and revised to objective (2) for two reasons. First, just as data do not exist to support unlimited harvest, data do not exist to support a total prohibition of harvest or impact. Second, total prohibition of harvest or impact on coral could cause severe economic impact on at least recreational diving, fishing, commercial lobstering, and shrimping sectors.

This objective addresses problems (1), (3) and (4) above, but would prevent addressing problems (2) and (6).

(5) Permit limited harvest of corals for scientific/educational purposes.

This objective has been reworded and become Management Measures (1) and (2).

(6) Emphasize coral habitat management.

This objective was revised to objective (4).

(7) Establish a monitoring system capable of determining trends in the health and condition of vital coral resource areas.

This objective was eliminated after determined to be too costly.

(8) Establish a permit system for harvest of octocorals.

This objective is not recommended as a separate objective because it is included in specific objective number (1).

12.3 Description of Alternative Optimum Yields

12.3.1 Recommended

OY for all corals is the level of harvest specified or as may be authorized pursuant to the permitting criteria established in this plan. Based on available data it is the Councils' intent to allow the existing level of legal, reported harvest consistent with the objectives of this plan.

OY for stony corals and sea fans is to be zero (0) except as may be authorized for scientific and educational purposes. The current and expected level of harvest for this purpose is estimated to be about 140 kilograms per year.

OY for octocorals is the amount of harvest which is authorized pursuant to this plan. It is to be all octocorals (except sea fans) that are harvested by U.S. fishermen. Octocorals, except for sea fans, are identified as presently being harvested without apparent stock damage (Section 8.2.6). Present and expected level of harvest is estimated to be about 5,845 colonies annually, 1,463 of which come from the FCZ.

Because of the value of some species of octocorals as a source of hormones, there exists the potential for localized or even widespread overfishing (see Section 5.5). For this reason, the Councils are proposing that the condition of the stocks and the harvest be monitored so that the Secretary may take appropriate specified action should there be an impending threat of overfishing.

This Optimum Yield is recommended for several reasons. First, because of their slow growth and value in non-consumptive capacities, stony corals and sea fans may be considered for practical purposes to be non-renewable resources which should not be harvested. Second, as is discussed in Section 5.4.8, there is not enough knowledge of corals in the management unit to calculate MSY. Therefore, permits are recommended for scientific and educational harvest of prohibited species in order to help develop the necessary information, as well as to restrict the harvest. Third, there is a relatively small commercial harvest of octocorals now taking place. This FMP recognizes and will allow this harvest in order to maintain this industry and gather the information necessary to evaluate its impact.

12.3.2 Alternative Optimum Yields Considered But Not Recommended

Establish a series of separate OYs for all individual coral species or groups or separate areas.

This alternative would allow the Councils to recognize differences in the OYs for different species of coral. However, it is not recommended at this time because there are not enough data to calculate MSY for each species; reasonably specific OYs can not be established for all species because the environmental consequences are not fully understood.

Establish a single OY that applies to all corals.

This alternative is not recommended because different species of coral have different growth, reproduction, and mortality rates. Thus, such species will have a different MSY. Using a single OY for all coral species is therefore not scientifically defensible and could lead to serious overharvest of some species while underutilization of others.

Establish an OY of zero (0) for all corals.

This alternative is not recommended because there are not enough data to suggest that it is necessary or advisable at this time. It is possible that under this alternative incidental catch would be prohibited. This could cause serious economic impact on some fishing activities. There is a small existing fishery for octocorals which is sustainable through natural growth and recruitment.

Set OY for rose coral at 100 kg (220 lbs) per year;

Set OY for gorgonians (except sea fans) at 2,000 individuals or 260 kg (527 lbs) per year;

Set OY at zero (0) for all other corals.

While industry sources indicated that these amounts could be used each year, this alternative is not recommended at this time because data do not exist to support these levels of OY. The growth of rose coral is not known and the resource could be damaged by overfishing. Octocorals, except for sea fans, are generally abundant and can sustain the present level of fishing.

Establish an OY of 1,463 colonies of nine species of Octocorals.

This option was rejected because the current level of harvest gives no evidence of overfishing of stocks. These species are difficult to identify so few individuals would know the species harvested. Harvest is unrestricted in the territorial sea.

12.4 Analysis of Beneficial and Adverse Impacts of Potential Management Options

This section and Section 12.5 evaluate economic, social, environmental, and biological impacts of the proposed and alternative management measures listed below and relates the Councils' rationale for proposing certain measures and not proposing the alternatives. The sections fulfill the requirements of Executive Order 12291. The procedure used in estimating the impacts includes a systematic discussion of both adopted and rejected management measures. The analysis is based on the best available information in all instances.

Executive Order 12291 "Federal Regulation" established guidelines for promulgating new regulations and reviewing existing regulations. Under these guidelines each agency, to the extent permitted by law, is expected to comply with the following requirements: (1) administrative decisions shall be based on adequate information concerning the need for and consequences of proposed government action; (2) regulatory action shall not be undertaken unless the potential benefit to society for the regulation outweighs the potential costs to society; (3) regulatory objectives shall be chosen to maximize the net benefits to society; (4) among alternative approaches to any given regulatory objectives, the alternative involving the least net cost to society shall be chosen; and (5) agencies shall set regularly priorities with the aim of maximizing the aggregate net benefit to society, taking into account the condition of the particular industries affected by regulations, the condition of the national economy, and other regulatory actions contemplated for the future.

In compliance with Executive Order 12291, the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA) require the preparation of a Regulatory Impact Review (RIR) for all regulatory actions which either implement a new fishery management plan or significantly amend an existing plan, or may be significant in that they affect important DOC/NOAA policy concerns and are the object of public interest.

The RIR is part of the process of developing and reviewing fishery management plans and is prepared by the Regional Fishery Management Councils with the assistance of the National Marine Fisheries Service (NMFS), as necessary. The RIR provides a comprehensive review of the level and incidence of impact associated with the proposed or final regulatory actions. The analysis also provides a review of the problems and policy objectives prompting the regulatory proposals and an evaluation of the major alternatives that could be used to solve problems. The purpose of the analysis is to ensure that the regulatory agency or Council systematically and comprehensively considers all available alternatives so that the public welfare can be enhanced in the most efficient and cost effective way.

The RIR also will serve as the basis for determining whether the proposed regulations implementing the fishery management plan or amendment are major/non-major under Executive Order 12291, and whether or not the proposed regulations will have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (5 U.S.C. 601 et seq.).

In order to achieve the management objectives of this plan and an optimum yield, the Councils have analyzed the effects of various conservation and management measures and recommend eight measures.

<u>Measures Recommended by the Councils</u>

<u>Measure 1</u>: Prohibit the taking of stony coral or sea fans or destruction of these corals and coral reefs in the FCZ of the Gulf and South Atlantic Fishery Management Councils' geographical are of authority, except as provided for by permit in this plan.

Should harvest of other octocorals become accelerated and which in the Council's judgement is threatening the habitat in localized or widespread areas, the Councils may request the Secretary to take available measures designed to eliminate such threat of damage to the resource and fishery habitat.

The following procedure may be used: On the advice of its Scientific and Statistical Committee or other sources that one or more species of octocorals may be endangered from widespread or localized depletion from overharvest or threat of overharvest, the Councils may notify the Secretary of the threat and recommend that he take one or more of the following actions.

a. Restrict by regulatory amendment or through promulgation of emergency regulations the harvest of one or more species of octocorals to a recommended level or amount.

b. Restrict by regulatory amendment or through promulgation of emergency regulations the area from which one or more species of octocorals may be taken.

c. Restrict by regulatory amendment or through promulgation of emergency regulations the method of harvest by which one or more species of octocorals may be harvested.

d. Utilize any procedures other than regulatory amendment or promulgation of emergency regulations which may be within the realm of authority of the Secretary and which will achieve the results of action proposed in options (a) through (c) above.

Analysis: Corals, especially most of the stony corals, grow slowly; though growth rates for many species are not well documented. A principal value of coral and coral reefs is in a nonconsumptive capacity where they serve as an aesthetic resource and provide shelter and habitat for other marine animals. This measure would allow the known existing level of harvest, which will not endanger the stocks or the aesthetics of the resource.

This measure would prohibit the destruction of coral reefs for unauthorized harvest or the salvage of artifacts. This measure is intended to prohibit the use of explosives, dredging, or lift pumps to remove or displace coral reefs. It is not intended to restrict the use or removal of marine equipment (such as that used in petroleum extraction) on which corals may have recently grown.

The Councils have determined that the present level of harvest of other octocorals supports a small fishery which does not threaten the stock, and it should be allowed to continue so long as overfishing does not occur. The framework measure to provide for regulatory amendment will provide a safeguard to prevent local or widespread depletion of octocorals. The Councils recognize that some scientific collecting activity does not fall within the regulatory jurisdiction of the MFCMA (see Measure 2 below). The alternative action "d" above is therefore included to guide the Secretary to use any other authority to protect the resource and habitat from destruction.

This measure addresses the general management objective and Objective (2).

Measure 2: Establish a permit system for taking prohibited corals for scientific or educational purposes.

Analysis: The Regional Director should be authorized to allow the collection of the prohibited species (stony coral and sea fans or all corals in protected areas) for these purposes. The Councils recognize that scientific research activity conducted by a scientific research vessel is specifically excluded from the term "fishing" in Section 3(10) of the Fishery Conservation and Management Act of 1976. It should be noted, however, that the following specific activities are considered to be fishing within the meaning of the Act, and therefore require a permit:

> Any activity involving the catching, taking or harvesting of fish in commercial quantities, or the use of gear capable of catching, taking, or harvesting fish in commercial quantities, including:
>
> 1) the conducting of tests of fishing gear; or
>
> 2) fishing carried out for the purpose of training fishermen.

It is the Councils' desire to provide guidelines for other similar collecting which may be equally justified.

Council Permit Guidelines:

(a) Scientific and educational permits are permits which may be issued for taking prohibited species of coral or corals from protected areas such as HAPCs for the purpose of gaining knowledge of coral for management and for the benefit of science and humanity.

Stony corals or sea fans (or parts thereof) which are taken for the purpose of sale should not be construed as having been taken for scientific research. This is not intended, however, to prevent a contractor or agent from collecting corals on behalf of a research or educational institution holding a scientific or educational permit.

(b) Permits should not allow localized or widespread depletion of stocks.

(c) Permits should require mandatory reporting of harvest on a timely basis.

(d) Permit issuance should be fair and equitable.

(e) Incidental catch of prohibited species does not require a permit so long as it is returned to the water in the general area of capture as soon as possible (in accordance with Management Measure 3).

The reef building stony corals and sea fans are protected in Florida waters where they occur in their greatest abundance in state waters within this management area. Although they are not presently protected in the FCZ, this fact is not generally known. there are reports, however, of reef damage from collectors (Fuss, 1981, personal communication).

Permits would provide harvest data presently not available. This measure addresses the general management objectives and Objectives (1) and (2).

Measure 3: Stony corals and sea fans taken incidently in other fisheries must be returned to the water in the general area of capture as soon as possible. An exception is provided for the groundfish, scallop, or other similar fisheries where the entire unsorted catch is landed. In such instances the corals may be landed but may not be sold.

Analysis: The Councils recognize that an unavoidable bycatch of some corals occurs with bottom trawls used to take groundfish, scallops, and shrimp. The catch of the latter is usually sorted with unwanted bycatch returned to the water. In the groundfish and scallop fishery, however, the entire catch is usually landed without sorting. Some corals occur on trawlable bottom and have been taken and landed without apparent damage to the stock. The Councils do not wish to disrupt these fisheries; however, they do not wish to provide a legal opening for the development of a fishery for prohibited corals.

This measure addresses the general management objective and Objective (2).

Measure 4: Prohibit the use of toxic chemicals in taking fish and other marine organisms which inhabit coral reef areas except under permit as may be specified in this plan or any other fishery management plan.

Establish a permit system for use of toxic chemicals in collecting fishes in coral reef areas.

Analysis: This measure is intended to protect corals from death or damage from toxic chemicals used in the collection of fishes and other marine organisms in coral reefs. Some tropical fish collectors utilize chemicals to remove specimens from within coral reefs. When used with care the chemicals can be used effectively with little effect on the corals. Improper use, however, can result in loss of corals. Restriction to permitted users would provide a degree of control to limit use to approved chemicals and individuals knowledegable in their use.

The Florida Department of Natural Resources requires a permit for the collection of marine fishes with chemicals and is revising the regulations and procedures. The expected number of permit holders is estimated initially to be 40 to 50 (A. Huff, 1981, personal communication). The Councils recommend that a compatible permit system be developed with the states where practicable and that those states serve as designees of the Secretary for issuance of permits.

This measure addresses the general management objective and Objectives (1) and (2).

Measure 5: Identify habitat areas for corals which may be threatened or subject to degradation and provide a management program for them. These habitat areas of particular concern (HAPCs) are recognized as providing habitat to valuable or special assemblages of coral or coral reefs. Some of these areas are presently under jurisdiction of management programs, some are under consideration for inclusion in such programs, and others are presently without management. Identified coral habitat areas of particular concern:

a. East and West Flower Garden Banks (nominated national marine sanctuary). Within the HAPC defined as being that portion within the 50-fathom contour, the taking or destruction of all corals is prohibited except as authorized by permit. Traditional, historical fishing methods are allowed but the use of bottom longlines, traps and pots, and bottom trawls is prohibited. Anchoring shall also be prohibited within this HAPC, except for vessels less than 100 feet in registered length. (The proposed restriction on anchoring has been disapproved by NOAA as being beyond authority of MFCMA.)

Analysis: These management measures are intended to protect the coral habitat areas of the Flower Gardens Banks from damage that would be caused by nonhistorical fishing activities and from anchor damage caused by large vessels such as freighters and tankers (see Section 6.2.1).

As far as is presently known, there has been no use of bottom longlines, traps, pots, or trawls on these banks. There is, however, a developing bottom longline fishery for reef fishes along the Texas coast. It is conceivable that this gear could be used on the Banks and in doing so could damage the corals (see Section 6.2.1).

b. Florida Middle Grounds - the northernmost hermatypic (shallow reef-type) coral community in the Gulf of Mexico. The HAPC (see Figure 6-10) is bounded by a line beginning at Point A (latitude 28° 42.5' N, longitude 84° 24.8' W), proceeding due east for approximately 7.4 nm to Point B (latitude 28° 42.5' N, longitude 84° 16.3' W); then proceeding in a southeasterly direction for approximately 34.6 nm to Point C (latitude 28° 11' N, longitude 84° 0' W); then proceeding due west for approximately 7 nm to Point D (latitude 28° 11' N, longitude 84° 07' W); then proceeding in a northwesterly direction for approximately 22.3 nm to Point E (latitude 28° 26.6' N, longitude 84° 24.8' W); then proceeding due north for 15.8 nm to origin at Point A. The taking or destruction of all corals is prohibited within the HAPC except as may be authorized by permit. Within the HAPC the use of bottom longlines, traps and pots, and bottom trawls is prohibited to prevent damage to corals (see Section 6.2.1).

Analysis: This area containing the topographic highs of the Florida Middle Grounds is a top producer of reef fish. Electric reels and handlines are most frequently used by fishermen. The bottom is very rough and not suitable for a standard bottom longline operation or for use of standard otter trawls.

Although some sea bass traps are used in the general area, there is no evidence that they are presently being set on the Middle Grounds. The Florida Middle Grounds were nominated to be a National Marine Sanctuary but are not an active candidate at this time.

c. Oculina Bank. This four by 23 nm HAPC contains coral reefs composed of banks and thickets of the ivory tree coral, Oculina varicosa. It is bounded by latitude 27° 30' N to latitude 27° 53' N, and longitude 79° 56' W to longitude 80° 00' W. Within the area the use of bottom trawls, bottom longlines, dredges, fish traps and pots is prohibited in order to protect the coral from damage (See Section 6.2.1).

Analysis: This fragile coral is a unique coral formation, and it provides valuable habitat for recreational and commercial fishes. Continued use of the traditional hook and line fishing gear will inflict minimal damage to the corals while allowing harvest of the fish. The recent introduction of roller trawls and bottom longlines to this area provides the potential for inflicting damage to the fragile coral. The proposed measure would restrict the potentially damaging gear from the narrow strip containing some of the outstanding examples of the Oculina formations. HAPC boundary lines have been drawn to displace a minimum area for the prohibited gear fisheries.

d. Dry Tortugas (Fort Jefferson National Monument). This national monument is managed by the National Park Service. No other special management measures are recommended by the Councils.

e. Looe Key Reef (National Marine Sanctuary). Designated in January, 1981, this sanctuary consists of five square nautical miles. Sanctuary regulations prohibit or regulate anchoring, coral collection and damage, wire trap fishing, lobster fishing, tropical specimen collecting, spearfish, and discharge of certain substances.

f. Biscayne National Park. Management is provided by the National Park Service. No additional management measures are recommended.

g. Key Largo Coral Reef National Marine Sanctuary. Designated in 1975 and administered by NOAA's Office of Coastal Zone Management. No additional management measures are recommended.

h. Gray's Reef National Marine Sanctuary. Designated in January, 1981. This diverse coralline hard bottom encompasses about 17 square miles off Sapelo Island, Georgia. Regulations prohibit alteration of seabed, discharge of certain substances, bottom trawling and dredging, wire fish trapping, and marine specimen collecting.

The establishment of the HAPCs would address the general management objective and Objectives (1), (2), (3) and (4).

Special Recommendations of The Councils

Measure 6: Special recommendation that the Secretary establish a communication program to inform the public of the reasons for coral management and regulations which protect corals and coral reefs.

Analysis: This special recommendation is made to the Secretary in recognition of the lack of public understanding of corals. This public information program would increase the public awareness of the importance and fragile nature of the coral reef ecosystem. Such action would decrease the enforcement requirements while conserving the resource.

This measure addresses the general management objective and Objectives (2) and (4).

Measure 7: Special recommendation that the Secretary establish a procedure to coordinate coral management activities in the FCZ and territorial sea within the Councils' geographical area of authority. Memoranda of Understanding or similar arrangements among the Bureau of Land Management, and National Park Service (Department of Interior), OCZM, the Councils, and other appropriate state and federal agencies could serve this purpose.

Analysis: Each of the above entities has some level of responsibility in permitting, administering, or planning for the management of corals. A uniform, coordinated federal policy would provide the public with more efficient and consistent management of the resource.

This measure addresses the general management objective and Objectives (2), (3), and (5).

Measure 8: Recommended that the states and NMFS monitor at least at the present level of effort the condition of the octocorals so that they may be able to detect and report damage or threat of damage to their habitat. The Councils believe that under the existing, informal monitoring regimes these agencies can effectively carry out this request without an increase in costs.

Analysis: This special recommendation provides data for the triggering mechanism to initiate regulation under Measure 1 to protect octocorals from overharvest.

This measure would complement Measure 1 and address Problems 1 and 2.

Measures Considered and Not Recommended By The Councils:

Measure 9: Provide for a fishery for rose coral.

Analysis: Rose coral has been utilized by fish collectors as a food source for some aquarium species, particularly butterfly fishes. This small stony coral is found on the flats where its harvest by divers would not damage coral reefs. It is, however, protected from harvest in Florida waters. A trial fishery under permit could provide data on growth and yield from a fished population, however, data are not available to allow for an open fishery without risk of local depletion.

This measure would address the general management objective and Objectives (1) and (2).

Measure 10: No action. (No management or regulation.).

Analysis: The problems which exist with this resource were described in Section 12.1. Corals and coral reefs in the FCZ have been virtually without protection since 1979. While the resource does have a salable commercial value, its principal value is in nonconsumptive use. To maintain the corals and coral reefs and prevent their mutilation and destruction a management regime providing regulation is required. The regime proposed provides for the needed conservation of this resource which in turn provides habitat for other important species of fish and shellfish as well as recreation for nonconsumptive users.

This management option would address no management objectives or problems in the fishery.

Measure 11: Include for special management purposes as habitat areas of particular concern the following:

a. Sand Key and Sambo Reefs.

Analysis: These well developed coral reefs are part of the Florida reef tract and are located near Key West. While they are prime examples of the coral reef ecosystem, they are not included as HAPCs at this time because of their similarity and proximity to other HAPCs in the Florida reef tract and are both within Florida's territorial sea and are subject to state management.

b. Onslow Bay, North Carolina.

Analysis: A live bottom off Bogue Bank in Onslow Bay is an area of ecological interest, particularly because of its northern location. Available data are insufficient to make a recommendation at this time for inclusion as a HAPC. It may be considered at a future time.

c. Larger areas for the Florida Middle Ground and Oculina Bank HAPCs.

Analysis: The sizes of the areas were reduced to allow multiple fishery use in areas of lower coral density, thus eliminating unnecessary restriction of fishing activities while meeting plan objectives.

12.5 Tradeoffs Between the Beneficial and Adverse Impacts of the Preferred or Optimal Management Options

Optimum yield is to be obtained by trading off the short-lived gain from the harvest and sale of stony corals and sea fans for a long-term nonconsumptive use in situ. Because the extent of coral bottom is for the most part unsurveyed, an estimate of the market value of stony and octocorals is not known. Section 9.1 has described what is known of the extent of domestic use, both consumptive and nonconsumptive.

Protection of corals and coral reefs as provided by Management Measures 1 through 4 would provide for maintaining the resource for nonconsumptive purposes while maintaining the small existing fishery for octocorals at its present known level. This fishery is estimated to be valued at $15,000 to $25,000 per year.

The restriction of octocorals beyond the present small fishery is not deemed to be justified at this time. Localized depletion of species could occur should a pharmaceutical use be developed; however, this action could occur as the result of scientific research collection which is beyond jurisdiction of any FMP. Furthermore, scientific collection of needed species may be taken from state waters where they are for the most part unprotected.

The establishment of the HAPCs would maintain the status quo of unique areas providing habitat for corals. Five of the seven areas identified as being worthy of special management are presently under management of some appropriate federal agency. Two are unprotected and are subject to damage from developing fisheries or other activities. At the present time, no existing fisheries would be displaced.

The establishment of a public information program in Measure 6 to inform the public of the nonconsumptive value of coral would be a cost effective method of providing compliance with the regulations. As individuals become aware of the purpose of the regulations, the need for enforcement will lessen.

Coordination of coral management activities among agencies with varying responsibilities would be cost effective by providing complimentary programs and eliminating conflicts and unnecessary duplication of effort.

12.6 Specification of Optimum Yield

OY for all corals is the level of harvest specified or as may be authorized pursuant to the permitting criteria established in this plan. Based on available data it is the Councils' intent to allow the existing level of legal, reported harvest consistent with the objectives of this plan.

OY for stony corals and sea fans is to be zero (0) except as may be authorized for scientific and educational purposes. The current and expected level of harvest of stony corals for this purpose is estimated to be about 140 kilograms per year and for sea fans, less than 100 colonies per year.

OY for other octocorals is the amount of harvest which is authorized pursuant to this plan. It is to be all octocorals (except sea fans) that are harvested by U.S fishermen. Octocorals, except for sea fans, are identified as presently being harvested without apparent stock damage (Section 8.2.6). Present and expected level of harvest is estimated to be about 5,845 colonies, 1,463 of which come from the FCZ.

13.0 MEASURES, REQUIREMENTS, CONDITIONS, OR RESTRICTIONS SPECIFIED TO ATTAIN MANAGEMENT OBJECTIVES

13.1 Permits

See Section 12.4, Measures 2 and 4 for Guidelines.

Establish a permit system for:

A. the use of toxic chemicals in taking fish or other marine organisms which inhabit coral reefs,

B. for taking stony corals and sea fans and for prohibited corals in HAPCs for scientific and educational purposes.

13.2 Time and Area Restrictions

See Section 13.5 for special regulations applicable in habitat areas of particular concern.

13.3 Catch Limitations

A. Total Allowable Level of Foreign Fishing - none. The expected domestic annual harvest will equal the optimum yield.

B. Types of Catch Limitations:

1. Prohibit the taking of stony coral and sea fans (*Gorgonia flabellum* and *G. ventalina*) or the destruction of these corals and coral reefs in the FCZ of the Gulf and South Atlantic Fishery Management Councils' geographical area of authority, except as provided for by permit in this plan.

2. Prohibited corals taken incidentally in other fisheries must be returned to the water in the general area of capture as soon as possible. An exception is provided for the groundfish, scallop, or other similar fisheries, where the entire unsorted catch is landed. In such instances the prohibited corals may be landed but may not be sold.

3. Should harvest of octocorals become accelerated which in the Councils' judgement is threatening the habitat in localized or widespread areas, the Councils may request the Secretary to take available measures designed to eliminate such threat of damage to the resource and fishery habitat.

The following procedure may be used: On the advice of its Scientific and Statistical Committee or other sources that one or more species of octocorals may be endangered from widespread or localized depletion from overharvest or threat of overharvest, the Councils may notify the Secretary of the threat and recommend that he take one or more of the following actions.

a. Restrict by regulatory amendment or through promulgation of emergency regulations the harvest of one or more species of octocorals to a recommended level or amount.

b. Restrict by regulatory amendment or through promulgation of emergency regulations the area from which one or more species of octocorals may be taken.

c. Restrict by regulatory amendment or through promulgation of emergency regulations the method of harvest by which one or more species of octocorals may be harvested.

d. Utilize any procedures other than regulatory amendment or promulgation of emergency regulations which may be within the realm of authority of the Secretary and which will achieve the results of action proposed in options (a) through (c) above.

13.4 Types of Vessel, Gear, and Enforcement Devices

Prohibit the use of toxic chemicals in taking fish and other marine organisms which inhabit coral reef areas except under permit as may be specified in this or any other fishery management plan.

13.5 Habitat Preservation, Protection, and Restoration.

Measures are proposed for the coral habitats of particular concern.

A. East and West Flower Garden Banks (nominated National Marine Sanctuary). The taking of corals and the use of bottom longlines, traps and pots, bottom trawls, and anchoring by vessels 100 feet or more in registered length is prohibited within the 50-fathom contour.

B. Florida Middle Grounds - the northernmost hermatypic (shallow reef-type) coral community in the Gulf of Mexico. The area is bounded by a line beginning at Point A (latitude 28° 42.5' N, longitude 84° 24.8' W), proceeding due east for approximately 7.4 nm to Point B (latitude 28° 42.5' N, longitude 84° 16.3' W); then proceeding in a southeasterly direction for approximately 34.6 nm to Point C (latitude 28° 11' N, longitude 84° 0' W); then proceeding due west for approximately 7 nm to Point D (latitude 28° 11' N, longitude 84° 07' W); then proceeding in a northwesterly direction for approximately 22.3 nm to Point E (latitude 28° 26.6' N, longitude 84° 24.8' W); then proceeding due north for 15.8 nm to origin at Point A. Within the HAPC the taking or destruction of all corals and the use of bottom longlines, traps and pots, and bottom trawls is prohibited.

C. Oculina Bank. A four by 23 nm strip containing banks and thickets of the ivory tree coral, *Oculina varicosa*, bounded by latitude 27° 30' N to latitude 27° 53' N and longitude 79° 56' W to longitude 80° 00' W. Within the HAPC the use of bottom longlines, dredges, bottom trawls, and fish traps and pots is prohibited.

13.6 Other Measures to Achieve OY

A. Recommended that the Secretary establish a communication program to inform the public of the reasons for coral management and the regulations which protect coral and coral reefs.

B. Recommended that the Secretary establish a procedure to coordinate coral management activities in the FCZ and territorial sea within the Councils' area.

C. Recommended that the states and NMFS monitor at least at the present level of effort the condition of the octocorals and report damage or threat of damage to their habitat. We believe under existing monitoring regime, these agencies can effectively carry out this request without a significant increase in current expenditure.

13.7 State, Local, and Other Laws and Policies

The State of Florida has laws regulating the taking and possession of corals. These are explained in Section 7.4. Regulations of other federal agencies which apply to coral are contained in the appendix.

13.8 Limited Access Systems

None.

13.9 Development of Fishery Resources

None.

13.10 Management Costs and Revenues

Estimates of enforcement and administrative costs were provided in part by the National Marine Fisheries Service. These cost estimates are necessarily based on full availability of funds and equipment. Actual expenditures in the real world can be expected to be lower. For details see the Regulatory Impact Review in the Appendix K.

Enforcement

1. Enforcement of protection of the Florida Reef Tract (Measures 1 through 4):	$116,500
2. Random patrol of Flower Garden Banks and Florida Middle Grounds (Measure 5):	$ 65,268
3. Random patrol of *Oculina* Banks HAPC (Measure 5):	$ 25,165
Investigation of complaints: (NMFS)	$ 15,750
TOTAL ENFORCEMENT COSTS	$222,683
Statistical reporting and data collection	$ 1,700
Permit administration	180
Anticipated direct revenues	none

14.0 SPECIFICATION AND SOURCE OF PERTINENT FISHERY DATA

14.1 General

To keep accurate records of the coral fishery and to help fill data gaps, several types of information should be gathered from industry participants. Pertinent and up-to-date data from all sectors are a requisite for proper management over the short- and long-term time frame. Portions of the information may be gathered from the harvesting or processing sectors; other facts must be generated through research. Each of these sources are described in the following subsections.

The mechanisms of data collection are vitally important to the success of the collecting effort. Caution must be taken to assure industry participants that: 1) their cooperation is vital to management of the resource, and 2) their answers will remain confidential. Similarly, the wording of the permit forms or reporting sheets should be simple yet thorough.

None of the fishery data listed below to be collected is currently gathered by any private, state, or federal agency. Historically, in the absence of a coral fishery and the presence of laws protecting many corals, no data at all has been collected; NMFS, usually the major source of fishery data, has no data on the coral fishery.

14.2 Domestic and Foreign Fishermen

As portrayed by the discussions of OY in Section 12.0, the coral fishing industry is limited in size and quantity. Hence, the following information need apply only to domestic fishermen.

Most of the relevant fishery data from fishermen can be collected via the mandatory permit reports recommended in Section 13.1. Reports may supply:

1. Name and address of permittee
2. Name and address of company, institution, affiliation, etc.
3. Species collected
4. Area of collection
5. Collection techniques (vessel types, gear, number of trips, etc.)
6. Quantity of each species
7. Size of each species
8. Disposition or use of each species
9. Other data as may be needed for management as determined by the Regional Director.

Fishermen may also be able to provide observation data on other aspects of the fishery as a result of voluntary interviews:

1. Health (percent living) and size of coral beds
2. Existence of particular stresses in spec fic coral beds
3. Evidence of standing stock changes as harvests continue
4. Changes in level of effort by species, area, or time
5. Quantities of corals sold to wholesalers, retailers, directly, etc.

Additional information that could strengthen Sections 8.0, 9.0, and 10.0 (economics, socio-cultural, and business aspects) could also be requested on a voluntary, interview basis. Since this informati[illegible] is crucial to calculating OY, most participants should respond positively. Data could include:

1. Economic dependence (percent of total earnings) derived from corals (for crew, owner, and vessel)
2. Outlook for future expansion of harvesting
3. County of vessel registration and residence
4. Age of fishermen
5. Education status
6. Participant in other fisheries
7. Crew size and variability (employment trends)

14.3 Processors

Information on species and quantities of corals handled by processors are as important to resource management as fishermen reports. However, the lack of fisheries data extends to this sector as well.

Information should be gathered from all levels of the processor sector - cleaners and bleachers, wholesalers, retailers, shippers, exporters, and importers since their trade affects the domestic market so greatly. Where applicable, each firm involved in processing (i.e., involved in any activity after collecting the corals) should supply the following information:

1. Name and address of the firm and respondent
2. Reporting period
3. Source of corals (harvested, purchased as wholesale, imported, etc.), name of supplier, area collected
4. Amount of corals processed by species
5. Value upon purchase and sale, i.e., value added
6. Type of processing done if any (clean, bleach, cut, polish, etc.)
7. Number of employees
8. Seasonality of employment
9. Supply and demand trends
10. Location of outlets
11. Percent of business related to corals

14.4 Data Gaps

The two Councils have identified numerous gaps in the existing coral data. Some gaps may be bridged by information generated from fishermen and processors as described in the preceding two subsections; other data will need to be collected during detailed scientific studies. As noted below, many of the missing facts are crucial to the preparation of this FMP.

Each data gap acknowledged below includes recommendations for research to fill the information needs and a reference to the particular FMP section to which the new data would contribute. For ease in establishing future research budgets, the following data gaps are arranged in approximate decreasing order of priority within each subject area: scientific, socioeconomic/cultural, and manage al/administrative. In some cases, the need for information negates a true prioritization since all needs are major.

14.4.1 Scientific

14.4.1.1 Ecological Data - Distribution and Abundance

Corals within the management area have been studied in disjunct areas for numerous research projects. The net result has been an accumulation of sporadic data that leaves many geographic areas, species, and topics unstudied. To solve this problem, and to provide the data so vital to the MSY calculations in Section 5.4 and OY in Section 12.5, a thorough survey of the physiology, biology, and ecology of corals in the management area is needed.

Distribution and abundance data must be collected by field surveys. In many cases, the field collections have been completed; samples now await identification and analysis of distribution patterns. Where surveys are necessary, efforts should concentrate in areas void of existing information (e.g., most waters in the management area deeper than about 50 m or 165 ft, areas of suspected deepwater banks, much of the south Atlantic region, the continental shelf off southwestern Florida, and other smaller areas) and areas of special interest such as habitat areas of particular concern (HAPCs). Experimental design of the surveys will very according to depth. In shallow waters, diver visits should provide most of the necessary data. However, in progressively deeper waters, more dependence must be placed upon submersibles rather than potentially damaging gears such as trawls and dredges.

In shallow regions, diver surveys along transects as employed by Jaap and Wheaton Lowry (in preparation) are highly advisable. Such designs provide continuous data across numerous microhabitats – a key concern in communities with high diversity and great variations in physical characteristics. Where vessel towed gear or submersibles are to be used, depth recorders and bathymetric maps should provide preliminary guidance for transect placement. For example, to verify the occurrence of deepwater banks and lithotherms in the Straits of Florida and Blake Plateau, a surface vessel should conduct a series of transects from the 100 m (330 ft) contour to the edge of the management area. Similar transects have been run before but collections have not been classified. In areas of special emphasis (500 to 725 m or 1,650 to 2,400 ft), a submersible with protractable collecting gear should be used. Limited distribution data could be derived on the basis on occurrence in collections or direct sightings.

Abundance and/or density of corals is best calculated by direct diver observation or, in deeper waters, by towing an underwater camera from a vessel. Submersibles could also be used but the costs involved are much higher than towing a camera. This information could also contribute to filling gaps in biological data.

14.4.1.2 Biological Data - Growth Rates, Mortality Rates, Age at Maturity, etc.

In conjunction with the field surveys recommended in the preceding subsection on ecological data, a thorough review and study of growth, mortality, reproduction, and other biological data is needed also. Since corals most likely exhibit species and areal trends in these parameters, significant portions of the management area should be studied for many species. For example, MSY data is extremely scarce outside the Florida Keys for all coral groups.

Due to the size of this particular data gap, it will most likely be necessary to establish priorities in species, areas, or parameters. Highest priority should probably be given to species with acknowledged commercial value and those most sensitive to damage or subject to collection (Appendix D), to areas where research may be most efficient (nearshore areas, dense beds, on least studied species, etc.), and to data that are is especially necessary to manage the resource (e.g., growth and mortality rates of precious corals, natural mortality rates of most species, and fecundity).

These data may be generated by diver or vessel transects and field or laboratory research. If laboratory studies are used, care must be taken to enhance confidence with field populations. Corals studied in the laboratory may be collected by trawl and held alive in refrigerated aquaria for over a year. Use of a radio beacon, as employed in deepwater petroleum explorations, could increase response time. Lastly, settling plates could be placed near larval accumulations to measure growth and skeletal banding.

With growth rates and maximum/mean sizes, a rough estimate of longevity and mortality could be deduced. Percent living and dead data (Antonius, et al., 1978) is helpful in MSY but more precise data of deaths due to natural phenomena and man-made impacts are more applicable.

14.4.1.3 Fishery Conflicts - Territorial and Gear Issues

One possible issue within the fishing community of the management area is conflict between various users of the resource. Regarding corals, the absence of published reports has limited the data base to observations and personal communications of users. As outlined in Section 6.2.2.1, conflicts have apparently arisen between shrimp, reef fish (snapper and grouper), tropical specimen, lobster, and scallop fishermen and the coral resource. The extent of damage attributable to each fishery is variable and in some cases may be negligible. Nonetheless, to manage corals and the habitat they create, quantitative and qualitative information must be gathered. Each fishery should be contacted and their prime fishing areas and gears assessed for potential conflicts.

14.4.1.4 Natural and Human Induced Damage

Coincidental with the above surveys of human-related damage, a study of background natural changes in coral health must also be initiated. Previous studies have suggested that coral growth may be cyclic and that natural stresses of temperature and storms may greatly affect overall resource health. The limits of such perturbations must be defined.

Analysis of natural stresses may be difficult. Portions of the work suggested above on ecological and biological data may accumulate some information on the relationships of distribution to temperature, predator-prey relationships, and other natural processes. Larger scale processes such as sedimentation, cold/warm front movements, and sewage outfalls may be studied by satellite; frequent orbits and occasional ground truthing could provide both short- and long-term information. Such data should be valuable in assessing coral health in the Florida reef tract.

14.4.2 Socioeconomical/Cultural

14.4.2.1 User Groups - Dependence of Coral and Coral Resources

Section 9.0 identified user groups (tropical specimen enterprises, charterboat firms, coral marketers and dive shops or schools), and several associated businesses dependent upon corals. However, except for the tropical fish sector (Hess and Stevely, draft manuscript), no attempt has been made to describe their operations. Similar studies must be undertaken of other users to represent accurately their needs in OY decisions.

The information accumulated by Hess and Stevely represents a solid base model for similar studies on other groups. Telephone and personal interviews utilizing an established survey approach (i.e., interview schedule) should be conducted with representative portions of each user group. Possible questions to be asked of each user are presented in Appendix K. Preliminary studies should also be done to determine if other user groups have been ignored or their importance incorrectly assessed.

14.4.2.2 User Groups - Cultural Characteristics

Aside from the business and market aspects of each user group, this FMP also includes (Section 11.0) a discussion of the ethnicity, education, family structure, income, sex, etc., of people living in 15 representative coastal counties flanking the management area. Except in a few instances, very little of the data pertains to direct coral users; most of the information concerns fishermen or the general population.

14.4.2.3 Coral Prices - Piece Prices from Various Sources

As noted in Section 10.1, several informal interviews revealed that certain corals may be imported at lower costs than they could be harvested domestically. This statement is apparently based on coral availability, collection labor, and the supply sector. However, import invoices and the domestic price structure (before and after existing coral protection laws) have not been analyzed. Is it true that corals can be collected and transported halfway around the world at lower costs than the domestic resource could be exploited? How will this structure vary if either foreign sources are limited or domestic harvesting is allowed on a trial basis for some species? These questions need to be answered to comprehend the current United States' coral market.

14.4.3 Management

14.4.3.1 Habitat Areas of Particular Concern - Administration

The habitat area of particular concern (HAPC) idea is a rarely used component of all FMPs. No fishery council has had to develop either criteria for their recommendation/designation, nor limits on the regulatory power available in their administration. However, because corals are sedentary and are habitat themselves, the HAPC concept seems especially applicable to this FMP.

To utilize effectively the HAPC idea, studies of qualifying criteria, surveys of possible nominations, and reviews of available data must be completed. Criteria suggested in Section 6.3 provide a baseline from which official regulations should evolve. Nominations should be generated from the data in this FMP and solicited from coral user groups and specialists in coral studies. The existing data bank and research proposed herein must be assessed to assess nominations based on ecological, recreational, economic or other rationales.

The HAPC concept also needs financial and enforcement support. Investigations should be initiated into funding sources and levels, equipment purchase, vessel and officer availability, and other administrative issues. The idea of managing special areas will not be successful unless money and manpow are appropriated.

15.0 RELATIONSHIP OF THE RECOMMENDED MEASURES TO EXISTING APPLICABLE LAWS AND POLICIES

15.1 Fishery Management Plans

Management measures contained in this FMP are compatible with those in other FMPs in the area. Certain fishing gear is excluded to protect corals in the specified habitat areas of particular concern. The impact of the exclusion will be minimal, because the gear is not presently deployed in these areas. Provision is made for unavoidable bycatch in the scallop and groundfish fisheries.

15.2 Treaties or International Agreements

Since no foreign fishermen harvest corals and the recommended total allowable level of foreign fishing (TALFF) is zero, treaties and international agreements are not expected to affect this FMP.

15.3 Federal Laws and Policies

The objectives and measures of the FMP will compliment the Bureau of Land Management, National Marine Sanctuary, and National Park Service management of coral communities.

Magnuson Act

The proposed regulations are consistent with and are authorized by the Magnuson Act. The administrative record developed prior to submitting the document to the Secretary of Commerce adequately demonstrates their consistency with the National Standards of the Magnuson Act and the necessity and appropriateness thereof.

National Environmental Policy

In accord with NEPA this document contains all elements of a draft environmental impact statement. It concludes that the human environment would be enhanced by the protection and management of coral and coral reefs.

Regulatory Flexibility Act (5 U.S.C. 601 et seq.)

A review of this FMP indicates that there will be no significant economic impacts from its implementation on small business entities in the coral and coral reef fishery, or other related fisheries. The statistical reporting and permit requirements are not major impediments to business activity and, in almost all cases, the requirements are already in place through State of Florida regulations.

Paperwork Reduction Act (44 U.S.C. 350 et seq.)

The proposed management measures will not increase the reporting burden for commercial, scientific, and educational users significantly, or over present amounts (Florida requires reporting of its permit holders, and FDNR may be the Regional Director's designee). The major change will be a shift from voluntary to mandatory reporting for permit holders and the addition of needed information.

Endangered Species Act of 1973

During the preparation of the FMP, the Councils requested a Section 7 consultation with the Fish and Wildlife Service and NMFS. The consultation concluded that the proposed regulations under the FMP were not likely to affect the continued existence of any threatened or endangered species or result in the destruction or adverse modification of habitat determined to be critical to such species.

Marine Mammals Protection Act

Proposed regulations under the FMP will not adversely affect marine mammals.

Executive Order 12291

In accord with this order a Regulatory Impact Review has been prepared and submitted separately.

Coastal Zone Management Act

This plan must be consistent with approved coastal zone management programs for states within the geographical area of authority of the two Councils. the appropriate state agencies have been provided with copies of the plan and notified that the Councils believe it to be consistent with the state programs. Having received no objection from any state after 60 days, the Councils have determined the plan to be consistent with the state programs.

15.4 State, Local, and Other Applicable Laws and Policies

By definition, the FCMA and FMPs apply only within the fishery conservation zone. Inside the 3 nm (5.6 km) limit of state jurisdiction (three marine leagues on coastal Texas and Florida on the Gulf of Mexico coast), state law prevails. The Councils recommend close coordination with state governments to manage the coral. This is especially appropriate with Florida where most of the corals in state waters are located.

16.0 STATEMENT OF COUNCIL INTENTION TO MONITOR THIS PLAN AFTER APPROVAL BY THE SECRETARY

The Councils will, after approval and implementation of this plan by the Secretary, maintain a continuing review of the fishery. Delineation of monitoring actions noted are briefly summarized.

1. New data developed by the National Marine Fisheries Service and other researchers which may improve MSY calculations and affect OY considerations will be reviewed.

2. In accordance with Management Measure 2 the Councils will review permitted harvesting activities and data obtained from them.

3. The system of localized coral habitat areas of particular concern will be reviewed to make needed adjustment in management, and to consider additions or deletions in the designated areas.

4. The Councils may conduct public hearings at appropriate times and places regarding the need for changes in the plan or its regulations, in order to increase effectiveness.

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APPENDIX A: Geographical distribution of Octocorallia on the continental shelf (shallower than 200m or 660 ft.) of the southeastern United States and territorial waters of the Gulf of Mexico. Symbols are: x = present; x^{ND} = present but no depth recorded; x^{+} = deeper than 200m, found shallower in other zones; x? = tentative identification.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carolina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Octocorallia						
Stolonifera						
Clavulariidae						
Clavularia bathyblus (Saville Kent)		x				
Sarcodictyon rubens (Verrill)	x					
S. rugosum Pourtales	x					
Telestacea						
Telestidae						
Telesto corallina Duchassaing	x	x				
T. riisei (Duchassaing & Michelotti)		x		x	x	x
T. flavula Deichmann	x	x				x
T. sanguinea Deichmann	x	x	x		x	x
T. fruticulosa Dana	x	x	x			
T. nelleae Bayer			x	x	x	
Alcyonacea						
Alcyoniidae						
Bellonella rubistella (Deichmann)		x				
Nidaliidae						
Nidalia occidentalis Gray	x	x	x	x	x	x
Siphonogorgia agassizii (Deichmann)	x	x	x			
Nephtheidae						
Pseudodrifa nigra Pourtales			x	x^{+}	x^{+}	
Neospongodes agassizii (Deichmann)			x			
Gorgonacea						
Scleraxonia						
Briareidae						
Briareum asbestinum (Pallas)				x	x	x

APPENDIX A: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol+ ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Anthothelidae						
Icilligorgia schrammi Duchassaing				x	x	x
Anthothela tropicalis Bayer	x					
Diodogorgia nodulifera (Hargitt)		x		x		x
Erythropodium caribaeorum (Duch. & Mich.)				x	x	x
Titanideum frauenfeldii (Kölliker)		x	x	x		x
Anthopodium rubens Verrill	x		x			
Holaxonia						
Keroeididae						
Lignella richardii (Lamouroux)		x				
Acanthogorgiidae						
Acanthogorgia aspera Pourtales		x	x+			
Paramuriceidae						
Villogorgia nigrescens (Duch. & Mich.)	x	x				x+
Echinomuricea atlantica (Johnson)	x					x+
Trachymuricea hirta (Pourtales)	x	x				
Bebryce grandis Deichmann	x	x				
B. cinerea Deichmann	x	x				
B. parastellata Deichmann		x				
Hypnogorgia pendula (Duch. & Mich.)		x				
Scleracis guadalupensis (Duch. & Mich.)	x	x	x	x		x+
Thesea grandiflora Deichmann	x	x				x+
T. rugosa	x	x				x
T. nivea Deichmann	x	x				
T. rubra Deichmann	x					
T. parviflora Deichmann	x					
T. plana Deichmann	x	x				x
T. citrina Deichmann						x

APPENDIX A: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carolina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Torgugas
Swiftia exserta (Ellis & Solander)	x	x	x*	x	x	
S. casta (Verrill)	x	x	x*			
Placogorgia mirabilis Deichmann	x	x^{ND}				x^{ND}
P. tenuis (Verrill)	x	x				x^{ND}
Callacis nutans (Duch. & Mich.)	x					
Plexauridae						
Plexaura homomalla (Esper)					x	x
P. flexuosa Lamouroux		x		x	x	x
Pseudoplexaura porosa (Houtuyn)		x		x	x	x
P. flagellosa (Houtuyn)		x		x	x	x
P. wagenaari (Stiasny)		x			x	x
P. crucis Bayer				x	x	
Eunicea laxispica (Lamarck)				x?		
E. pinta Bayer & Deichmann				x		
E. palmeri Bayer				x	x	
E. mammosa Lamouroux				x	x	x
E. succinea (Pallas)		x		x	x	
E. fusca Duch. & Mich.		x		x	x	x
E. laciniata Duch. & Mich.		x		x	x	x
E. tourneforti Milne Edwards & Haime		x		x	x	x
E. asperula M-E & H		x		x	x	x
E. clavigera Bayer				x	x	
E. knighti Bayer		x		x	x	x
E. calyculata Ellis & Solander		x		x	x	x
Muriceopsis flavida (Lamarck)					x	x
M. petila Bayer			x*	x	x	
Plexaurella dichotoma (Esper)				x	x	x
P. nutans (Duch. & Mich.)		x		x	x	x
P. grisea Kunze		x		x	x	x
P. pumila Verrill				x?		
P. fusifera Kunze		x		x	x	x

APPENDIX A: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol-ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Muricea muricata (Pallas)				x	x	x
M. atlantica (Kükenthal)				x	x	x
M. laxa Verrill		x		x	x	x
M. elongata Lamourous		x		x	x	x
M. pendula Verrill	x	x	x	x		
Gorgoniidae						
Lophogorgia cardinalis Bayer		x		x		x
L. punicea (Milne Edwards & Haime)	x	xND		x		x
L. hebes (Verrill)	x	x	x		x	
Leptogorgia virgulata (Lamarck)	x	x	x			
L. setacea (Pallas)	x	x	x			
L. medusa (Bayer)	x	x				
L. stheno (Bayer)	x	x		x		
L. euryale (Bayer)	x	x				
Pseudopterogorgia bipinnata (Verrill)				x	x	x
P. kallos (Bielschowsky)					x	x
P. rigida (Bielschowsky)		x		x	x	x
P. blanquillensis (Stiasny)					x?	
P. acerosa (Pallas)		x		x	x	x
P. americana (Gmelin)		x		x	x	x
P. hummelincki Bayer				x?		
P. elisabethae Bayer				x	x	
P. navia Bayer				x		
Gorgonia ventalina Linnaeus				x	x	x
Pterogorgia citrina (Esper)		x		x	x	x
P. anceps (Pallas)		x		x	x	x
P. guadalupensis Duch. & Mich.		x		x	x	x
Ellisellidae						
Ellisella funiculina (Duch. & Mich)	x	x				x+
E. atlantica (Toeplitz)	x					

APPENDIX A: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carolina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
E. barbadensis (Duch. & Mich.)	x		x	x	x	
E. elongata (Pallas)	x	x				
Nicella americana Toeplitz	x					
N. flagellum (Studer)	x					
N. schmitti Bayer	x			x	x	
N. guadalupensis Duch. & Mich.)	x					x+
N. obesa Deichmann	x					
Riisea paniculata Duch. & Mich.	x	x				
Primnoidae						
Calliogorgia verticillata (Pallas)	x					xND
Chrysogorgiidae						
Stichogorgia viola Deichmann						x
Pennatulacea						
Sessiliflorae						
Renillidae						
Renilla reniformis (Pallas)		x	x			
R. mülleri Kölliker	x	x				
Kophobelemnidae						
Sclerobelemnon theseus Bayer		x				
Subselliflorae						
Virgulariidae						
Virgularia presbytes Bayer	x	x	x			
Stylatula antillarum Kölliker	x	x				
Acanthoptilum agassizii Kölliker	x	x			x	
A. oligacis Bayer	x	x				
TOTAL SPECIES 113	51	69	21	52	50	53

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APPENDIX B. Distributions and habitat types from collections of 22 families of Octocorallia in the Gulf of Mexico. (Giammona, 1978, compared to U.S. Bureau of Land Management, 1978; Goldberg, 1979, personal communication).

FAMILY	DISTRIBUTION AND HABITAT TYPE
Paramuriceidae	Continental shelf from Baffin Bay, Texas, east and north along entire Gulf coast to the Florida Keys and Dry Tortugas; found on many sediment types, including various combinations of sand, silt, and clay and water depth from about 30 m (100 ft) to over 200 m (660 ft).
Plexauridae	Occasionally found nearshore and on the shelf near Texas but much more common in shallow, high carbonate environments off Florida.
Gorgoniidae	Found throughout the shelf from Texas to the Dry Tortugas; recorded most often on inner-shelf, often nearshore in sandy bottom areas.
Ellisellidae	Recorded mostly on the outer shelf off Texas and Louisiana near the 200 m (660 ft) isobath and nearer shore off Alabama and the Florida Panhandle; some species common on carbonate banks.
Telestidae	Entire shelf from Texas to Florida; usually found growing on mollusc shell fragments on the inner shelf.
Chrysogorgiidae	Not very common; found in outer shelf and deeper oceanic waters along Texas, Louisiana, and Florida.
Renillidae	Recorded near shore (less than 100 m or 330 ft) off southern Texas, the Mississippi Delta, and the Florida Panhandle; inhabits soft, muddy substrates, often quite abundant.
Primnoidae	Found only occasionally in the Mississippi Delta region (clay and silky clay substrate), on the outer shelf off Texas, and the Dry Tortugas.
Isididae	Found in deep waters on outer shelf and slope; most common near outer Keys and Dry Tortugas but also shelf and slope off Alabama, Mississippi, Louisiana, and Texas.
Virgulariidae	Collected on inner shelf in northern Gulf (with one exception off Dry Tortugas) in association with soft bottoms.
Clavulariidae	Found only on inner shelf in northern Gulf; often grows on mollusc shells.
Briareidae	Found from Palm Beach to Dry Tortugas; also recorded in shallow reefal environments in the southern Gulf.
Funiculinidae	Found once at 950 m (3,135 ft) off the southern Texas coast on silty clay.
Nephtheidae	Found once at Dry Tortugas.
Nidaliidae	Collected from the coral reefs at Flower Gardens, along the Texas-Louisiana shelf on other hard banks (topographical highs), and the Tortugas.

Paragorgiidae	Not observed in the FCZ; found only off northern Cuba.
Acanthogorgiidae	Found once on clay substrate off the Mississippi Delta at about 700 m (2,310 ft).
Alcyoniidae	Collected only at the Flower Garden reef at about 30 m (100 ft).
Pennatulidae	Found off the coast of Alabama on sandy bottom on the inner shelf and off Port Aransas, Texas, near a topographical high at about 80 m (265 ft).
Protoptilidae	Recorded on two topographical highs off Kenedy County, Texas, at 80 m (265 ft) and off the Mississippi Delta in clay and silty clay bottoms.
Umbellulidae	Observed near Mysterious Bank (80 m or 265 ft) off Kenedy County, Texas, on the outer shelf off Louisiana (1,500 m or 4,950 ft), and near the Delta area in clay bottom areas.
Anthothelidae	Some species are prominent, as listed in Appendix A (pg. A-2).

APPENDIX C: Geographical distribution of stony corals on the continental shelf (shallower than 200m or 660 ft.) of the southeastern United States and territorial waters of the Gulf of Mexico. Symbols are: x = present; x^A = abundant; x^R = rare; and x^+ = also found deeper than 200m (660 ft.)

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol-ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Class HYDROZOA						
Order MILLEPORINA						
Family Milleporidae						
Millepora alcicornis Linne	x^A	x		x	x^A	x
M. complanata Lamarck					x^A	x^A
M. squarrosa Lamarck					x	
Class ANTHOZOA Ehrenberg						
Subclass HEXACORALLIA Haeckel						
Order SCLERACTINIA Bourne						
Suborder ASTROCOENIINA Vaughan & Wells						
Family Astrocoeniidae Koby						
Stephanocoenia michelinii Milne Edwards & Haime	x	x^R		x	x	x
Family Pocilloporidae Gray						
Madracis myriaster M E & H	x^R					
M. decactis Lyman	x	x^A		x	x	x
M. formosa Wells						x
M. mirabilis (Duchassaing & Michelotti)	x^A			x	x	x
M. asperula M E & H	x	x			x	x
M. brueggemanni (Ridley)	x^R					
Family Acroporidae Verrill						
Acropora cervicornis Lamarck				x	x^A	x^A
A. palmata Lamarck				x^R	x^A	x^A
A. prolifera Lamarck					x	x
Suborder FUNGIINA Verrill						
Superfamily Agariciicae Gray						
Family Agariciidae Gray,						
Agaricia agaricites (Linne)	x	x		x	x	x

APPENDIX C: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol-ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
A. tenuifolia Dana					x	
A. lamarcki Milne Edwards & Haime				x^A	x	x
A. fragilis Dana	x	x^R			x	x
Helioseris cucullata Ellis & Solander	x	x			x	x
Family Siderastreidae Vaughan and Wells						
Siderastrea radians (Pallas)		x	x	x	x	x
S. siderea (Ellis & Solander)	x	x	x	x	x^A	x^A
Superfamily Poriticae Gray						
Family Poritidae Gray						
Porites astreoides Lamarck	x^A			x	x^A	x^A
P. branneri Rathbun		x^R		x	x^A	x
P. porites (Pallas)	x	x^A		x	x^A	x
Suborder FAVIINA Vaughan & Wells						
Superfamily Faviicae Gregory						
Family Faviidae Gregory						
Favia fragum (Esper)					x	x
F. gravida Verrill						x^R
Diploria labyrinthiformis (Linne)				x	x	x
D. clivosa Ellis & Solander				x	x	x
D. strigosa (Dana)	x^A			x	x	x
Manicina areolata (Linne)		x		x	x	x
Colpophyllia amaranthus (Muller)	x			x		
C. natans (Houttyn)	x^A			x	x	x
C. breviserialis Milne Edwards & Haime						x
Cladocora arbuscula (LeSueur		x	x	x	x	x
C. debilis M E & H		x			x	x
Montastrea cavernosa (Linne)	x^A			x^A	x^A	x^A
M. annularis (Ellis and Solander	x^A		x	x^A	x^A	x^A
Solenastrea hyades (Dana)		x	x^A	x	x	x
S. bournoni M E & H				x	x	x

APPENDIX C: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol-ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Family Rhizangiidae						
Astrangia astreiformis Vaughan			x			
A. danae Agassiz (= astreiformis M E & H)	x	x	x		x	x
A. solitaria (LeSueur)	x	x			x	x
Phyllangia americana M E & H	x	x	x	x	x	x
Family Oculinidae Gray						
Oculina arbuscula Verrill			x			
O. varicosa LeSueur	x		x[A]	x	x	
O. tenella Pourtales		x				x
O. diffusa Lamarck, 1816		x		x	x	x
O. robusta Pourtales		x				x
Family Meandrinidae Gray						
Meandrina meandrites (Linne)		x		x[A]	x	x
Dichocoenia stellaris Milne Edwards & Haime		x[A]			x	x
D. stokesi M E & H		x[A]		x	x	x
Dendrogyra cylindrus Ehrenberg					x	x
Family Mussidae Ortmann						
Mussa angulosa (Pallas)	x	x[R]		x	x	x
Scolymia lacera (Pallas)	x	x	x	x	x	x
S. cubensis (Milne Edwards and Haime)						x
Isophyllia multiflora Verrill				x	x	
I. sinuosa (Ellis and Solander)		x			x	x
Isophyllastrea rigida (Dana)				x	x	x
Myceotphyllia lamarckiana Milne Edwards & Halme				x	x	x
M. danaana M E & H					x	x
M. ferox Wells					x	x
M. aliciae Wells				x	x	x
Suborder CARYOPHYLLIINA Vaughan & Wells						
Superfamily Caryophylliicae						
Family Carophylliidae						
Eusmilia fastigiata (Pallas)				x	x	x

APPENDIX C: Cont.

	Northern & Western Gulf of Mexico (Tx. to Florida)	Eastern Gulf of Mexico (No. & W. Fla. Coast)	No. Carol-ina-So. Fla. (Palm Beach)	Palm Beach-Miami	Florida Keys	Dry Tortugas
Tubastrea coccinea Lesson				x	x	
Caryophyllia horologium Cairns	x	x		x		
Rhizosmilia maculata (Pourtales)		x			x	
Pourtalosmilia conferta Cairns	x		x		x	
Paracyathus pulchellas (Duchassaing & Michelotti)	x	x+	x		x	
Suborder DENDROPHYLLIINA						
Family Dendrophylliidae						
Balanophyllia floridana Pourtales	x	x	x		x	x
TOTALS	29	32	14	37	56	54

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APPENDIX D. CORALS IDENTIFIED AS HAVING POTENTIAL COMMERCIAL VALUE

1. Shallow-water Species

Plexaura homomalla (Esper)

Significance: Large amounts of this gorgonian species (and perhaps also *Plexaurella*) have in the past been harvested from Florida and the Caribbean, due to the presence in their tissues of a class of compounds known as prostaglandins (polyunsaturated fatty acids which affect mammalian physiology by variously regulating activity of smooth muscle, endocrine secretion, blood flow, and the like). More recently, synthetic prostaglandins have become available at lower costs, thereby reducing collections considerably. Current studies are underway on a birth control pill using prostaglandins instead of estrogens.

Preliminary assays of other gorgonian species as well as other types of coral indicate that prostaglandins may be more widely distributed than previously thought (Morse, et al., 1978). Recent laboratory synthesis of prostaglandins may minimize the potential use of this species as a natural source of the compound. Nonetheless, *Plexaura* and other gorgonians are processed by Mexican businesses in a plant at Campeche Bay (Jordan, 1979, personal communication).

Diagnosis: Two forms have been described (Bayer, 1961). Forma *homomalla* has bushy, flattened colonies, branched laterally and dichotomously. Polyps strongly armed with a crown resting upon a distinct transverse collaret. Cortex friable when dry, with granular surface and gaping calycular orifices, often with a raised rim. Colonies dry to a deep brown, blackish brown or nearly black; purplish brown in alcohol. Forma *kukenthali*: colonies with branches more slender than the *homomalla* form, about 15 cm (6 in) long and 2.5 cm (1 in) in diameter.

Distribution: Bermuda, Florida Keys, Dry Tortugas, the Bahamas and the Caribbean Islands. Depth range: <1-20 m. Occasionally as deep as 30 m (Kinzie, 1974).

Ecology: More information is available on the ecology of this species than for any other cor[illegible] (Kinzie, 1974; Theodor, 1977). Growth rates are variable (r = 0.1-4 cm or 0.05 or 1.6 in yr[illegible] mean increase in height of 2 cm or 1 in yr^{-1}. Kinzie (1974) has shown that colonial growth in terms of height may not be correlated with new growth of branch tips. Reproduction involves the formation of planula larvae within the polyp of female colonies. Development time of the larvae is unknown, but sexually mature colonies of both sexes are found only during the summer months (Goldberg and Hamilton, 1974). Presumably, planulation occurs during late summer. Theodor (1977) states that *P. homomalla* will not be found in either extreme turbulence or very calm water. Moderately turbulent areas appear most favorable to the development of this species. Other characteristics, such as temperature and salinity tolerances, nutrition, and mortality and natality rates, have not been specifically studied in this species.

Cirripathes lutkeni (Brook)

Significance: This species of black coral is subjected to collecting pressure in the southern Caribbean where basal portions of the skeleton are fashioned into bracelets, rings and earrings (Chalker, 1978, personal communication). Dimensions of the resource and its exploitation elsewhere are unknown.

Diagnosis: Flagelliform colonies up to 7 m (23 ft) in length and 0.8 cm (0.32 in) in diameter at base. Skeleton tapers slightly, lower portion is nearly straight, upper regions are often twisted into irregular spirals. Skeletal spines are distinctly papillose and tend to be arranged in irregular spirals and longitudinal rows (Brook, 1889).

Distribution: Throughout West Indies, especially on steeply sloping reef faces 20 to at least 174 m (66 to 535 ft) (upper range, from Goldberg, 1979, personal communication; lower range from Lang, 1974). Known from the northwest Gulf of Mexico and southeast Florida coast; apparently uncommon in Florida Keys.

Ecology: Specific data on temperature and salinity tolerances, natality, and mortality are unknown. Goldberg (1977) has estimated the growth rate from skeletal ring analysis and field data. This information indicates that Cirripathes adds 5 to 10 cm or 2 to 4 in yr^{-1} its length annually. Lewis (1978) has studied feeding behavior in this species, finding that zooplankton and suspended particulate matter constitute the most readily observable portion of its diet. Other aspects of nutrition are unknown.

Manicina areolata and F. areolata (Linnaeus)

Significance: Rose coral is used in the aquarium trade as food for butterfly fishes and other corallivores. Informal interviews with tropical fish collectors indicate that the species is collected illegally in very small quantities by a few individuals. Total value of the catch approaches $2,000 in the Florida Keys at $0.15 to $0.25 per piece. As shown in Table 8-4, a limited quantity is harvested via the Florida permit system. Catches were higher before the 1976 Florida coral law.

Diagnosis: Colonies small, rarely greater than 15 cm (6 in) long. Form of colony roughly oval with narrow ends, upper surface descending to a single meandering valley, about 2.5 cm (1 in) wide. Septa number about 18 cm (45 in); when seen under magnification have fine holes. Underside of colony shows growth rings which narrow to a single stalk at the base. Colonies are attached to the substrate only when young. Soft tissue is usually yellowish, sometimes deepening to brown; some colonies have a greenish tinge near oral regions. Tentacles are in two rows; transparent except for the white terminus.

Distribution: Known from shallow, protected areas of the Florida Keys such as Soldier Key, along with other hardy species (e.g., Porites porites, Siderastrea radians). Also found at the Dry Tortugas as well as the Bahamas, the Caribbean, and off Brazil. Apparently absent from Bermuda (Matthai, 1928).

Ecology: Manicina is found in waters usually less than 1 to 43 m (3 to 142 ft) deep, around turtle grass, hard bottom and coral reefs; it is not a reef-dwelling species. It tolerates silty conditions (Voss and Voss, 1955) and has a well developed capacity to clean its living surfaces. Non-nutrient particles are imbedded in mucus and swept away by ciliary currents (Vaughan, 1916). Rose coral survives 50 percent seawater for 24 hours, and indications are that this species is also relatively tolerant of temperature changes. Manicina can be a carnivore consuming zooplankton (Vaughan, 1919) or an autotroph deriving energy directly through its zooxanthellae (Goreau, 1959). Lewis and Price (1975) found that rose coral uses mucus nets in addition to tentacles in food capture, and is thus capable of feeding on particulate matter as well. Growth rates are apparently rapid during the first four years, while maximum size requires longer periods (Jaap, 1979, personal communication). Additional studies on developmental biology have been published by Wilson (1888), Boschma (1929), and Yonge (1935).

2. Deepwater Species

Distichopora foliacea Pourtales

Significance: This stylasterine hydrocoral has been used in the manufacture of jewelry in the Marathon area of the Florida Keys.

Diagnosis: Flabellate colonies, 4 to 5 cm (1.6 to 2 in) in height and width. Color white-pink to white. Colony forms dichotomous, flattened branches, finely striated and granulated. Gastropores

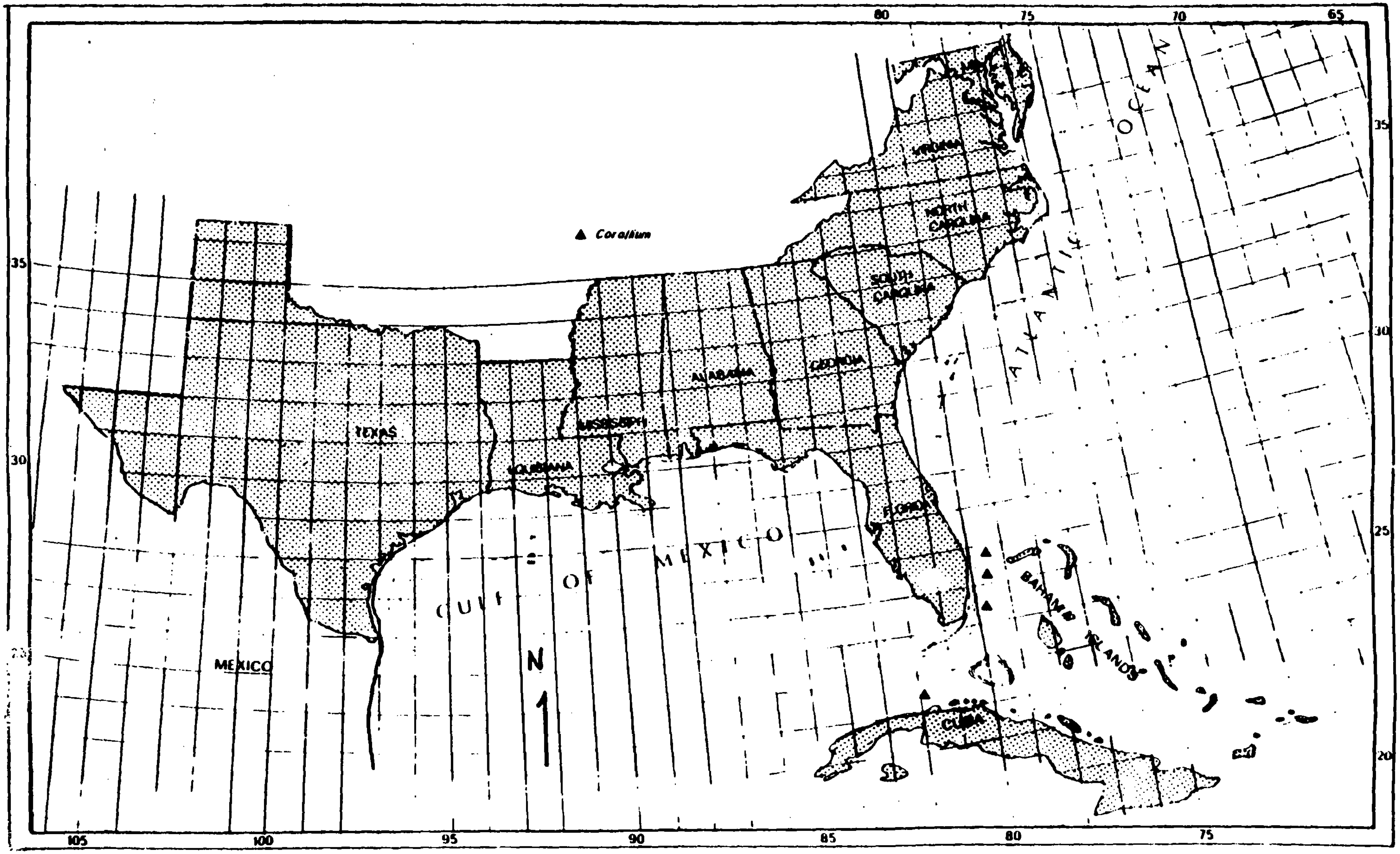

FIGURE D-1. Distribution of Corallium spp. in the vicinity of the management area.

occur on the thin edge of branches in a row; each gastropore has a gastrostyle in its center. Each side of the row of gastropores is flanked by a row of dactylopores. Small hemispherical swellings called ampullae occur over the gonopores on the broad side of the branches. Dioecious.

Distribution: Endemic to the continental shelf and slope from Key West to Savannah, Georgia, at depths of 152 to 479 m (500 to 1,580 ft). Occurs on hard surfaces. May occur on the Pourtales Terrace off the Florida Keys at 150 to 400 m (495 to 1,320 ft).

Ecology: Totally unknown. Collected only rarely. Systematics unrevised since the 1880's. Feeds via nematocysts on polyp tentacles.

Corallium medea Bayer and *Corallium niobe* Bayer

Significance: Relatives of these precious pink corals are carved and polished in Hawaii for use in the manufacture of jewelry (Grigg, 1977b). Larger pieces can be carved into statues and curios. Poh (1971) listed red coral prices as $16.50/kg ($7.50/lb) and harvests as 1,045 to 4,180 kg (2,300 to 9,200 lb) per year between 1963 and 1969 in Hawaii.

Diagnosis: Hard, unjointed axis formed of solidly fused sclerites; color white to pink. Colony uniplanar, dichotomously branched, approximately 0.5 m (1.6 ft) tall. Polyps occur on only one surface of the branches (probably away from the current). Cortical spicules of *C. medea* consist of 6, 7, and 8-radiates and double clubs; those of *C. niobe*: 6, 7, and 8-radiates.

Distribution: In the western Atlantic, known from only seven records in the Straits of Florida from off Palm Beach to off Key West (Figure D-1). Five of the seven records are reported here for the first time (Cairns, 1979, personal communication). The bathymetric range is 567 to 1,390 m (1,870 to 4,570 ft); however, it is most common between 600 to 700 m (1,970 to 2,300 ft). Its temperature range is approximately 3° to 8°C (37° to 46°F). The most important environmental factors that determine its distrbution are probably temperature, current (2 to 6 cm or 0.8 to 7.3 in sec^{-1}), and the presence of a hard substrate. A strong current is necessary to bring planktonic food to the coral and remove metabolic wastes and loose sediment. The structure of the corallum as uniplanar with directional polyps implies that it is in a constant unidirectional current. All corals require a hard substrate on which to initially settle, which could be provided by any number of benthic invertebrates found associated with deepwater banks. Species of *Corallium* were found both at recognized lithoherms on the Little Bahamas Banks and in other deepwater areas.

Ecology: Virtually nothing is known about *C. medea* and *C. niobe* beyond their brief original descriptions and remarks on several commensal organisms (Bayer, 1964). However, comparison to the much studied Hawaiian *Corrallium secundum* Dana, is probably acceptable (Grigg, 1976). *C. secundum* is dioecious and, despite its occurrence below the euphotic zone, maintains an annual reproductive cycle, spawning in the summer. Its growth rate is about 0.9 cm (0.36 in) yr^{-1} in length. It may live to be 50 years old but does not become sexually mature until about the twelfth or thirteenth year. The areal coverage, density, and therefore the standing crop of the western Atlantic *Corallium*, is unknown, the species having been collected only seven times. However, because of its association with deepwater banks and because very few of those banks have been biologically sampled, it is possible that its distribution and abundance may be far greater than these few records indicate. The corallia of six of the seven western Atlantic records are white, the seventh is light pink ("angel skin") and may represent a new species (Bayer, 1979, personal communication).

Like most other species of corals, it is assumed that *Corallium* feeds mainly on zooplankton, which is transported by moderate bottom currents. The predators of *Corallium*, if any, are unknown.

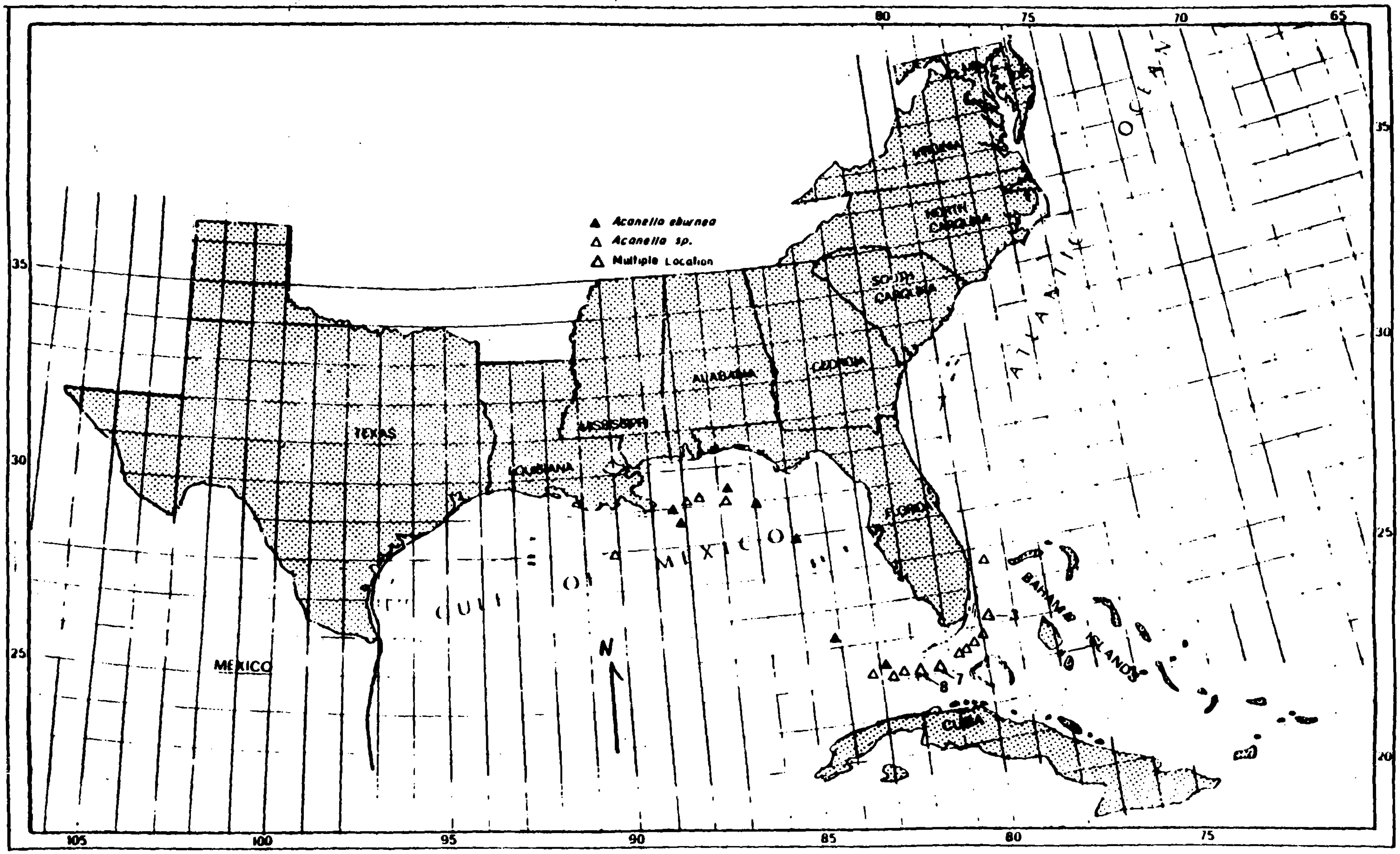

FIGURE D-2. Distributions of Acanella eburnea and Acanella sp. in the vicinity of the management area.

Corallium niobe usually supports a commensal polychaete worm, which induces abnormal growth of branchlets, forming a protective tunnel for the worm. Polychaetes of the genera Harmothoe and Polynoe are known to be commensal on Corallium (Bayer, 1956). C. niobe also contains parasitic copepods of the family Lamippidae in its gastrovascular cavities (Bayer, 1964).

Acanella eburnea (Pourtales), Keratoisis flexibilis (Pourtales), Keratoisis ornata Verrill, Lepidisis caryophyllia Verrill

Significance: The white, ivory-colored internodes of these bamboo corals can be polished and strung into necklaces. The various species of bamboo corals have different lengths and diameters of internodes (scale is 2.5 cm equal 1 in): Acanella eburnea - 1.5 cm long, 0.1 to 0.2 cm in diameter; Keratoisis flexibilis - 1 cm long, 0.1 to 0.7 cm in diameter; K. ornata - 5 to 6 cm long, 0.2 to 2.8 cm in diameter; Lepidisis caryophyllia - 4 to 50 cm long, 0.1 to 0.6 cm in diameter. Different sized nodes may have differing commerical uses. See Deichman (1936) for systematics.

Diagnosis: All bamboo corals possess an axis composed of alternating short, brown, purely horny nodes and longer, white, nonspicular, calcareous internodes. Their bases are usually modified into a root-like structure for anchoring. In Keratoisis branching occurs from the internodes; in Acanella and Lepidisis branching occurs at the nodes. K. flexibilis has short internodes (about 1 cm), whereas K. ornata has internodes of 5 to 7 cm (2 to 2.7 in). Acanella is distinguised from Lepidisis by its bushy colony with numerous branches originating at each node. Lepidisis is sparsely branched.

Distribution: Acanella eburnea is very common in the Straits of Florida off the Florida Keys and in the northern Gulf of Mexico off Louisiana, Mississippi, and Alabama (Figure D-2) at depths of 283 to 1,829 m or 931 to 6,017 ft (Giammona, 1978). Keratoisis is very common on the Blake Plateau of Georgia and throughout the Straits of Florida (Figure D-3) at depths of 183 to 965 m or 602 to 3,170 (about 6° to 12°C or 43° to 54°F). It is usually found on deepwater banks. Lepidisis caryophyllia is relatively rare, known only from the Straits of Florida off the Florida Keys (Figure D-4) at 733 to 1,003 m (2,400 to 3,300 ft). Acanella arbuscula (Johnson) has also been reported from one record in the northern Gulf of Mexico (Giammona, 1978). The key determinants of distribution for these species are probably optimum temperature, strong current, and hard substrate for attachment.

Ecology: Virtually nothing is known about the biolgy of the deepwater bamboo corals. Reproductive periodicity, growth rates, longevity, age at reproductive maturity, and symbionts are all unknown (Bayer, 1979, personal communication). Areal coverage and density are also unknown, but Acanella is probably very common within its range (represented by 49 records on Figure D-2) and Keratoisis (represented by 34 records on Figure D-3) is also probably very common on the Blake Plateau in association with deepwater banks. Lepidisis seems to be rarer than the others.

It is possible that some fish and molluscs (e.g., the aplacophoran solenogaster Chaetoderma) may browse the polyps of the bamboo corals.

Leiopathes glaberrima (Esper)

Significance: Carved and polished pieces of this black coral are used in the manufacture of jewelry (Grigg, 1977b); larger pieces can be carved into statues and curios (see, e.g., Poh, 1971). According to Opresko (1978, personal communication) the corallum of L. glaberrima is blacker, harder, less spinose and therefore takes a higher polish than all other western Atlantic antipatharians.

Diagnosis: Corallum black, irregularly branched, measuring up to 1.2 m tall with a basal diameter up to 4 cm. Branches usually crooked or bent, originating at right angles to the parent branch. Spines extremely small (20 to 50 per cm or 8 to 10 per in), occurring only on the smaller branches. Polyps and coenenchyme greyish-white. Polyps have six tentacles.

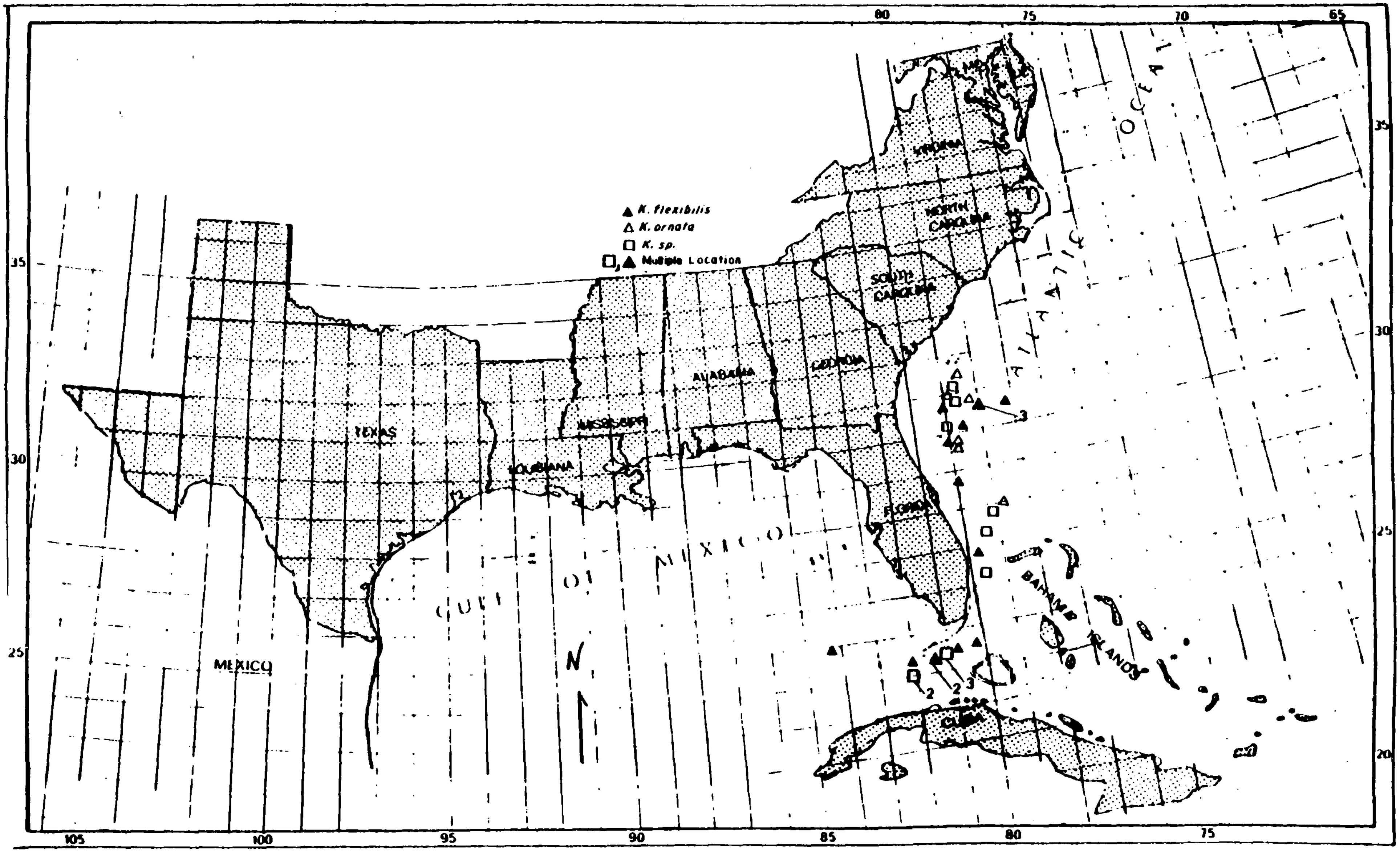

FIGURE D-3. Distributions of Keratoisis flexibilis, K. ornata, and Keratoisis sp. in the vicinity of the management area.

Distribution: Mediterranean, off Madeira, Hawaii, and the Bahamas. Within the management area: northern Gulf of Mexico, Straits of Florida, Blake Plateau off Georgia (Figure D-5). Bathymetric range is 176 to 549 cm (580 to 1,800 ft); temperature range about 8° to 12°C (46° to 54°F). The most important environmental factors controlling the distribution are probably on optimum temperature (below the thermocline and therefore stable) and a moderate current to replenish nutrients, carry away wastes, and remove sediment. Light may confine its bathymetric distribution to deep water because the larvae of some antipatharians are known to be negatively phototrophic (Grigg, 1965).

Ecology: Not much is known about the biology of L. glaberrima, but comparison with the Hawaiian Antipathes dichotoma Pallas is probably acceptable (Grigg, 1976). It should be remembered, however, that L. glaberrima lives in deeper water and probably does not grow quite as large. A. dichotoma is dioecious and probably reproduces in the summer. Its growth rate is about 6.4 cm per year in length and it may live to be 40 years old. It becomes sexually mature after 10 to 12.5 years. The areal coverage, density, and standing crop of L. glaberrima is unknown; however, most of the 18 known records of this species are concentrated on the edge of the shelf (200 to 300 m or 660 to 990 ft) off the Florida Keys. It is not associated with deepwater banks, being found in shallower waters.

The prey of Leiopathes is assumed to be plankton, and its predators, if any, are unknown. Commensals and parasites are also unknown.

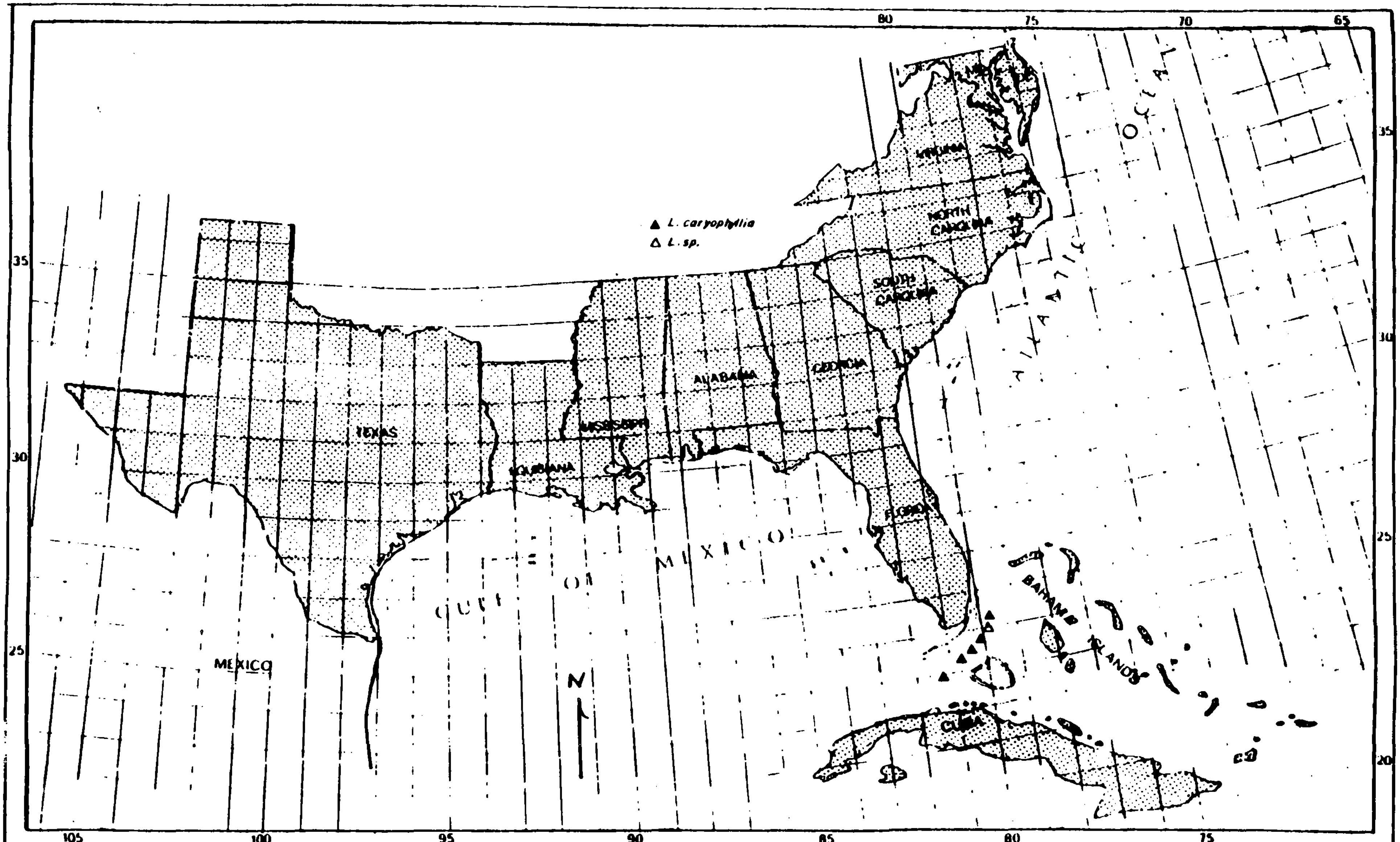

FIGURE D-4. Distributions of Lepidisis caryophyllia and Lepidisis sp. in the vicinity of the management area.

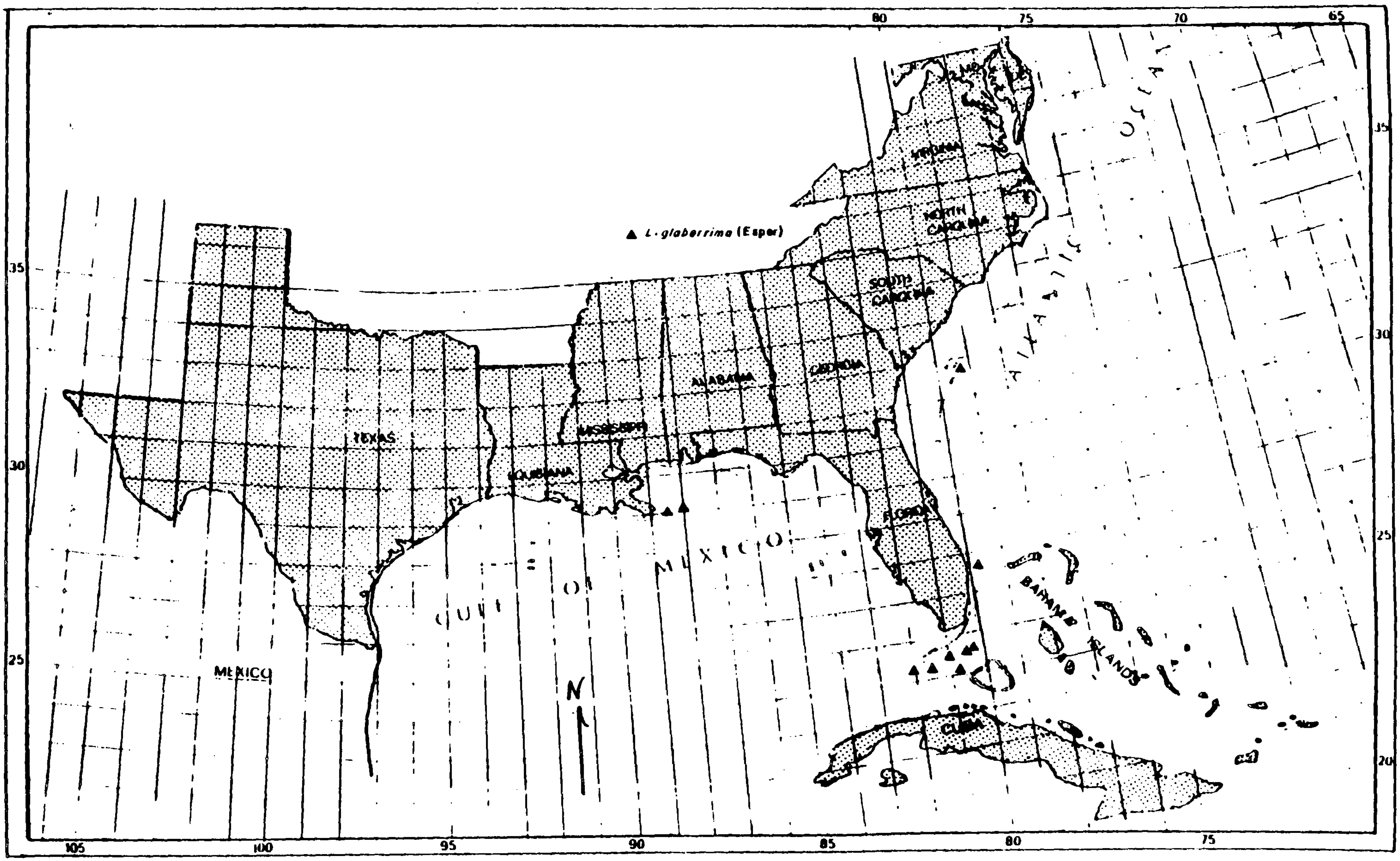

FIGURE D-5. Distribution of Leiopathes glaberrima in the vicinity of the management area.

APPENDIX E: Deep water (greater than 200m or 660 ft) corals in the management area. Symbols: X, present; *potential commercial importance (Cairns, 1979, personal communication).

	Gulf of Mexico	Straits of Florida	South Atlantic
Order STOLONIFERA			
Family Clavulariidae			
Clavularia modesta (Verrill)			X
Scleranthelia sp.		X	X
Order TELESTACEA			
Family Telestidae			
Telesto nelleae Bayer			X
Telestula sp.	X		X
Order ALCYONACEA			
Family Alcyoniidae			
Anthomastus agassizii Verrill			X
Anthomastus grandiflorus Verrill			X
Nidalia rigida Deichmann	X		
Bellonella sp.			X
Family Nephtheidae			
Pseudodrifa nigra Pourtales		X	X
Family Siponogorgiidae			
Siphonogorgia (=Neospongodes) agassizi (Deichmann)	X		
Order GORGONACEA			
Family Anthothelidae			
Anthothela grandiflora (Sars)			X
Anthothela tropicalis Bayer	X	X	X
Titanideum frauenfeldii (Kolliker)		X	X
Titanideum suberosum (E. & S.)			X
Family Paragorgiidae			
Paragorgia boschmai Bayer		X	
Paragorgia sp.		X	
Family Coralliidae			
*Corallium medea Bayer		X	
*Corallium niobe Bayer		X	
Family Acanthogorgiidae			
Acanthogorgia aspera Pourtales			X
Acanthogorgia schrammi (Duch. &			

	Gulf of Mexico	Straits of Florida	South Atlantic
Mich.)	X		
Family Paramuriceidae			
Paramuricea placomus (Linnaeus)			X
Paramuricea sp.	X	X	
Bebryce cinerea Deichmann		X	
Bebryce grandis Deichmann	X	X	
Bebryce parastellata Deichmann			X
Echinomuricea atlantica (Johnson)	X		
Muriceides sp.		X	
Placogorgia mirabilis Deichmann	X	X	
Placogorgia tenuis (Verrill)	X		
Placogorgia sp.		X	X
Caliacis nutans (Duch. & Mich.)	X	X	
Scleracis guadeloupensis (D. & M.)	X	X	
Swiftia casta (Verrill)	X	X	X
Swiftia koreni (Wright & Studer)		X	X
Swiftia pourtalesi Deichmann		X	
Swiftia exserta (E. & S.)			X
Thesea nivea Deichmann		X	X
Thesea rugosa Deichmann	X		
Thesea solitaria (Pourtales)		X	
Trachymuricea kukenthali (Broch)	X		
Trachymuricea hirta (Pourtales)		X	
Villogorgia nigrescens Duch. & Mich.	X		
Family Plexauridae			
Eunicella albatrossi Stiasny			X
Eunicella modesta Verrill		X	X
Muriceopsis petila Bayer			X
Family Gorgoniidae			
Lophogorgia cardinalis Bayer			X
?*Leptogorgia stheno* (Bayer)	X	X	X
Family Ellisellidae			
Ellisella barbadensis (D. & M.)			X
Ellisella elongata (Pallas)	X	X	
Nicella guadalupensis (D. & M.)	X	X	
Riisea paniculata D. & M.	X		
Family Chrysogorgiidae			
Radicipes gracilis (Verrill)	X	X	X
**Chrysogorgia desbonni* D. & M.		X	X
Chrysogorgia elegans Verrill	X		
Chrysogorgia fewkesi Verrill		X	X
Family Primnoidae			
**Callogorgia verticillata* (Pallas)	X	X	
Callogorgia grimaldii Studer	X		
Plumarella aurea (Deichmann)		X	X
Plumarella goesi Aurivillus	X		
Plumarella pourtalesi (Verrill)	X	X	X

	Gulf of Mexico	Straits of Florida	South Atlantic
Thouarella aurea Deichmann		X	
Thouarella sp.		X	X
Calyptrophora trilepis (Pourtales)			X
*Narella pauciflora Deichmann		X	
*Narella regularis (D. & M.)		X	
*Narella versluysi Hickson		X	
*Candidella imbricata (Johnson)			X
Family Isididae			
*Keratoisis flexibilis (Pourtales)	X	X	X
*Keratoisis ornata Verrill		X	X
Acanella arbuscula Verrill	X		
*Acanella eburnea (Pourtales)	X	X	X
*Lepidisis caryophyllia Verrill		X	
?Lepidisis longiflora Verrill	X		
Chelidonisis aurantiaca Studer	X		
Primnoisis humilis Deichmann	X		
Order PENNATULACEA			
Family Kophobelemnidae			
Kophobelemnon sp.		X	X
Sclerobelemnon sp.		X	X
Family Anthoptilidae			
Anthoptilum murrayi Kolliker			X
Anthoptilum sp.	X		
Family Funiculinidae			
Funiculina quadranularis (Pallas)	X	X	X
Family Protoptilidae			
Protoptilum thompsoni Kolliker	X		
Family Scleroptilidae			
Scleroptilum sp.	X		X
Family Umbellulidae			
Umbellula guntheri Kolliker	X		
Umbellula lindahlii Kolliker	X		X
Umbellula eloisa Nutting	X		
Umbellula sp. 1 (sensu Giammona)	X		
Umbellula sp. 2 (sensu Giammona)	X		
Umbellula sp. 3 (sensu Giammona)	X		
Family Virgulariidae			
Virgularia sp.		X	
Acanthoptilum sp.	X	X	
Scytalium sp.		X	
Stylatula elegans (Deichmann)		X	X
Stylatula sp.	X	X	X
Family Pennatulidae			
Pennatula grandis Ehrenberg			X

	Gulf of Mexico	Straits of Florida	South Atlantic
Order SCLERACTINIA			
Family Pocillopridae			
Madracis myriaster (ME & H)	X	X	
Family Fungiidae			
Fungiacyathus pusillus (Pourtales)		X	
Fungiacyathus symmetricus (Pourtales)		X	
Fungiacyathus crispus (Pourtales)	X	X	
Family Oculinidae			
Madrepora oculata Linnaeus	X	X	X
Madrepora carolina (Pourtales)	X	X	X
Family Anthemiphylliidae			
Anthemiphyllia patera Pourtales			X
Family Caryophylliidae			
Caryophyllia polygona Pourtales		X	
Caryophyllia berteriana Duchassaing	X	X	
Caryophyllia cornuformis Pourtales	X	X	X
Caryophyllia ambrosia caribbeana Cairns	X	X	X
Caryophyllia parvula Cairns	X		
Concentrotheca laevigata (Pourtales)	X	X	X
Cyathoceras squiresi Cairns		X	X
Labyrinthocyathus facetus Cairns		X	X
Labyrinthocyathus langi Cairns		X	X
Oxysmilia rotundifolia (ME & H)	X		X
Trochocyathus rawsonii Pourtales	X	X	X
Tethocyathus cylindraceus (Pourtales)		X	
Tethocyathus variabilis Cairns		X	
Paracyathus pulchullus	X	X	X
Deltocyathus moseleyi Cairns			X
Deltocyathus calcar Pourtales	X	X	X
Deltocyathus italicus Michelotti	X	X	
Deltocyathus eccentricus Cairns	X	X	X
Deltocyathus pourtalesi Cairns		X	X
Stephanocyathus (*S.*) *diadema* (Moseley)	X	X	X
Stephanocyathus (*S.*) *paliferus* Cairns	X	X	X
Stephanocyathus (*S.*) *laevifundus* Cairns		X	X
Stephanocyathus (*O.*) *coronatus* (Poutales)	X	X	
Peponocyathus folliculus (Pourtales)		X	
Peponocyathus stimpsonii			

	Gulf of Mexico	Straits of Florida	South Atlantic
(Pourtales)	X	X	X
Desmophyllum cristagalli ME & Haime		X	X
Thalamophyllia gombergi Cairns		X	
Lophelia prolifera (Pallas)	X	X	X
Anomocora fecunda (Pourtales)	X		
Coenosmilia arbuscula Pourtales	X		
Dasmosmilia lymani (Pourtales)	X	X	X
Dasmosmilia variegata (Pourtales)	X	X	
Solenosmilia variabilis Duncan		X	X
Asterosmilia prolifera (Pourtales)	X	X	
Asterosmilia marchadi (Chevalier)			X
Phacelocyathus flos (Pourtales)	X		
Family Flabellidae			
Flabellum moseleyi Pourtales	X	X	X
Flabellum fragile Cairns	X	X	
Javania cailleti (D. & M.)	X	X	X
Polymyces fragilis (Pourtales)	X	X	X
Gardineria paradoxa (Pourtales)		X	
Family Guyniidae			
Guynia annulata Duncan	X		
Schizocyathus fissilis Pourtales	X		
Stenocyathus vermiformis (Pourtales)	X	X	X
Pourtalocyathus hispidus (Pourtales)		X	X
Family Dendrophylliidae			
Balanophyllia palifera Pourtales	X		
Dendrophyllia cornucopia Pourtales	X	X	
Dendrophyllia gaditana (Duncan)			X
Dendrophyllia alternata Pourtales	X	X	
Enallopsammia profunda (Pourtales)	X	X	X
Enallopsammia rostrata (Pourtales)			X
Thecopsammia socialis Pourtales		X	X
Bathypsammia tintinnabulim (Pourtales)	X	X	X
Bathypsammia fallosocialis Squires		X	X
Rhizopsammia manuelensis Chevalier	X	X	
Trochopsammia infundibulum Pourtales		X	

	Gulf of Mexico	Straits of Florida	South Atlantic
Order STYLASTERINA.			
Family Stylasteridae			
Stylaster duchassaingi Pourtales		X	
Stylaster erubescens Pourtales	X	X	
**Stylaster filogranus* Pourtales	X	?	
Stylaster gemmascens (Esper)			X
Allopora miniata Pourtales		X	
Cryptohelia peircei Pourtales		X	X
Stenohelia sp.			X
**Distichopora foliacea* Pourtales		X	X
Distichopora sulcata Pourtales			X
Errina cochleata Pourtales		X	
Errina glabra Pourtales			X
Pliobothrus symmetricus Pourtales		X	
Order ANTIPATHARIA			
Antipathes americana D. & M.	X		
Antipathes hirta Gray		X	
Antipathes tanacetum (Pourtales)		X	X
Antipathes pennacea Pallas		X	
Antipathes tristis (Duchassaing)	X		
Antipathes picea Pourtales	X		
Parantipathes tetrasticha (Pourtales)		X	
Aphanipathes humilis (Pourtales)	X	X	
Aphanipathes thyroides (Pourtales)	X		
Aphanipathes felix (Pourtales)	X	X	
Aphanipathes abietina (Pourtales)	X		
**Leiopathes glaberrima* (Esper)	X	X	
Bathypathes patula Brook	X		

APPENDIX F: Fauna characteristic of deep-water banks in the western Atlantic. (Based on Smithsonian Institution collections CI-140, CI-246 in the south Atlantic; Cairns, 1979, personal communication).

I. Coelenterate species:

A. Octocorallia

- *Placogorgia* sp.
- *Swiftia* sp.
- *Paragorgia* sp.
- **Corallium medea*
- *Paramuricea* sp.
- *Muriceides* sp.
- *Eunicella modesta*
- *Pseudodrifa nigra*
- *Anthomastus* sp.
- *Plumarella* sp.
- *Trachymuricea* sp.
- **Narella versluysi*
- **Narella regularis*
- **Narella pauciflora*
- **Candidella* sp.
- **Keratoisis* sp.

B. Scleractinia

- *Cyathoceras squiresi*
- *Desmophyllum cristagalli*
- *Lophelia prolifera*
- *Solenosmilia variabilis*
- *Bathypsammia fallosocialis*
- *Bathypsammia tintinnabulum*
- *Enallopsammia profunda*

II. Other animal groups not identified to species:

- Porifera
- Hydroids
- *Stylasterina
- Actiniaria
- *Antipatharia
- Bryozoa
- Brachiopoda
- Gastropoda
- Octopoda
- Asteroidea
- Ophiuroidea
- Echinoidea
- Crinoidea
- Cirripedia
- Paguridae
- Galatheidae
- Polychaeta
- Benthic Fish
- Endolithic borers
  - Macroscopic (sponges)
  - Microscopic (sponges, fungi)

*Species of potential commercial value.

APPENDIX G. SUPPLEMENTAL INFORMATION ON SOURCES OF ENERGY IN CORALS

1.0 Scleractinia

1.1 Light

Fundamental to the flow of energy through the reef ecosystem is the symbiotic relationship with zooxanthellae characteristic of all shallow-water hermatypic corals. These algae are capable of producing more oxygen that is consumed by the algae and coral host combined (Yonge, et al., 1932; Odum and Odum, 1955; Kanwisher and Wainwright, 1967). But more important to corals, and the communities which they form, is the carbon fixed during the process of photosynthesis. Evidence that zooxanthellae can release photosynthetically fixed organic compounds to their hosts is well documented, as is the effect of zooxanthellae on nutrient recycling and enhancement of calcification (reviewed by Muscatine, 1973). The indispensability of the symbiosis, however, is one of the sources of controversy noted above.

While it appears that supplemental sources of nutrition are taken in addition to the amount supplied by zooxanthellae, the overall question of indispensability of such exogenous food to the existence of scleractinians is still debated. Yonge and Nicholls (1931) concluded that scleractinians can live for several months in complete darkness as long as food is provided. Conversely, Kawaguti (1964) observed that four genera of Pacific corals kept for more than 15 months in the light but without food appeared healthy and increased their numbers of polyps [note: although zooplankton were withheld as a food source, bacteria may have been present and consumed in Kawaguti's work]. Franzisket (1969; 1970) showed that Hawaiian corals performed in the same fashion and noted that corals kept in the dark for two months exhibited symptoms of atrophy. Connell (in Muscatine, 1973) excluded light from a section of the Great Barrier Reef using an opaque dome without affecting ambient currents and food supply. During three and one-half months in the shade, corals expelled their zooxanthellae and all colonies died. Control colonies under transparent domes survived. Lewis (1974) found that planulae of *Favia fragum* could not survive more than three months if not provided with both food (Artemia) and light (12h:12h, light:dark photoperiod).

1.2 Zooplankton

Opinions differ on the adequacy of zooplankton in satisfying the food requirements of coral and other benthic invertebrates on reefs (Lewis, 1977). Johannes (1974) has argued that the biomass of zooplankton over coral reefs is insufficient to supply energy needs although it may be important as a source of essential nutrients. In this view reef corals are "autotrophic" and depend extensively upon energy supplied by their zooxanthellae.

The early papers of Sargent and Austin (1949, 1954) indicated that the zooplankton biomass of surrounding waters at Rongelap in the Pacific were too small to support all the benthic invertebrates on the reef. Johannes, et al. (1970) calculated that zooplankton on a Bermuda reef were not sufficiently abundant to support the energy needs of the corals present as indicated by their rates of respiration. Johannes and Tepley (1974) found that the zooplankton biomass present could supply only 20 percent of the daily requirements for respiration in the Pacific coral, *Porites lobata*, and Porter (1974) estimated that during a two-hour feeding period at sunset, the small star coral (*Montastrea annularis*) could capture only between 0.2 percent and 11 percent of the total daily food required for energy used in respiration.

Although the supply of oceanic zooplankton appears to be inadequate to support reef secondary production, reefs undoubtedly produce their own zooplankton (Porter, et al., 1977; Porter and Porter, 1977). Sale, McWilliam and Anderson (1976) found that there was a resident plankton community at Heron Island, Australia, which was more abundant and richer in species than the offshore community.

They suggested that this plankton community was retained on the reef by local circulation or by behavioral responses and was a potential source of food for the sessile reef organisms. This aspect of reef zooplankton ecology may be of quantitative significance when its impact is more fully evaluated.

The view that reef corals are not wholly "autotrophic" in their nutrition has been summarized by Goreau, et al. (1971). They regard corals as specialized carnivores without structural modifications for an autotrophic existence depending primarily upon zooplankton for their food. The work of Coles (1969) supports this view. He found that reef corals were able to ingest more than sufficient numbers of brine shrimp to cover their energy expenditure in respiration with energy left for storage and growth. Furthermore, Goreau, et al. (1971) considered that reef corals may act as unspecialized detritus feeders upon a wide range of organic matter or may even utilize dissolved or colloidal organic matter. Lewis and Price (1975) discussed suspension feeding strategies in Atlantic reef corals.

The general conclusions regarding the importance of zooplankton to support reef production indicate that while there is a substantial removal of plankton by benthic organisms, zooplankton biomass from oceanic water flowing over reefs is too low even to supply the daily energy requirements of the corals present. Additional food must be suplied by resident plankton and other external sources.

1.3 Bacteria

It has been pointed out by DiSalvo (1973) and Sorokin (1973c) that there are very few quantitative data on the role of microbial populations in the productivity of coral reefs. One cannot conceive of such complex systems without micro-organisms functioning as organic decomposers, nitrogen fixers and in biogeochemical processes. Large number of bacteria on reef surfaces were reported by Odum and Odum (1955) and bacteria have been implicated in the high respiration rates of coral communities noted by Sargent and Austin (1949). The work of DiSalvo (1973, 1974) has been concerned with the diversity and abundance of bacteria on coral reefs while Sorokin (1973a, b; 1974) has emphasized the role of bacteria in secondary production in reef organisms, i.e., in transforming detritus to microbial biomass.

DiSalvo (1973, 1974) suggested that the finely divided sediments in reef spaces and cavities functioned as "regenerative surfaces" and that the rapid rates of oxygen consumption occurring in these cavities indicated rapid organic decomposition. Plate count of sediments at the bases of coral heads showed densities of 10^7 to 10^8 bacteria/g dry matter and among them were forms capable of digesting chitin and other organic compounds, reducing nitrates and digesting gelatin and agar.

The bacteria in reef sediments and in internal cavities are considered to have a role in nutrient regeneration (DiSalvo, 1974). Pools of dissolved nitrogen and amino nitrogen were found in sediments and in dead coral heads. Quantitative estimates gave value of 33 g-atoms of phosphorus and 30 moles of amino nitrogen/m^2 dead coral surfaces. His results show that bacteria may thus be important in cycling of nutrients in the reef system.

Sorokin (1973a, b, c; 1974) has stressed that the biomass of bacteria in reef sediments and in shallow coastal water corresponds with their importance in processes of mineralization and nutrient cycling on reefs. They are also considered important as food for secondary consumers. Results of feeding experiments (Sorokin, 1973a) showed that six species of reef corals could consume bacterioplankton. Other forms which were able to filter bacterioplankton from water were the tunicate Ascidia nigra, the sponge Toxadocea violacea, and the oyster Crassostrea gigas. Sorokin (1973a) regarded the bacterioplankton as being a high-quality food adequate in amount to supply a large percentage of the total energy needs of suspension feeders on the reef. A general scheme illustrating trophic relationships has been attempted by Sorokin (1973c) and is shown in Figure G-1. This study emphasized the importance of micro-organisms and the process of decomposition. It also suggested a shortage of phytoplankton as primary producers in the reef ecosystem and hence the minor importance of the phytoplankton/zooplankton trophic relationship.

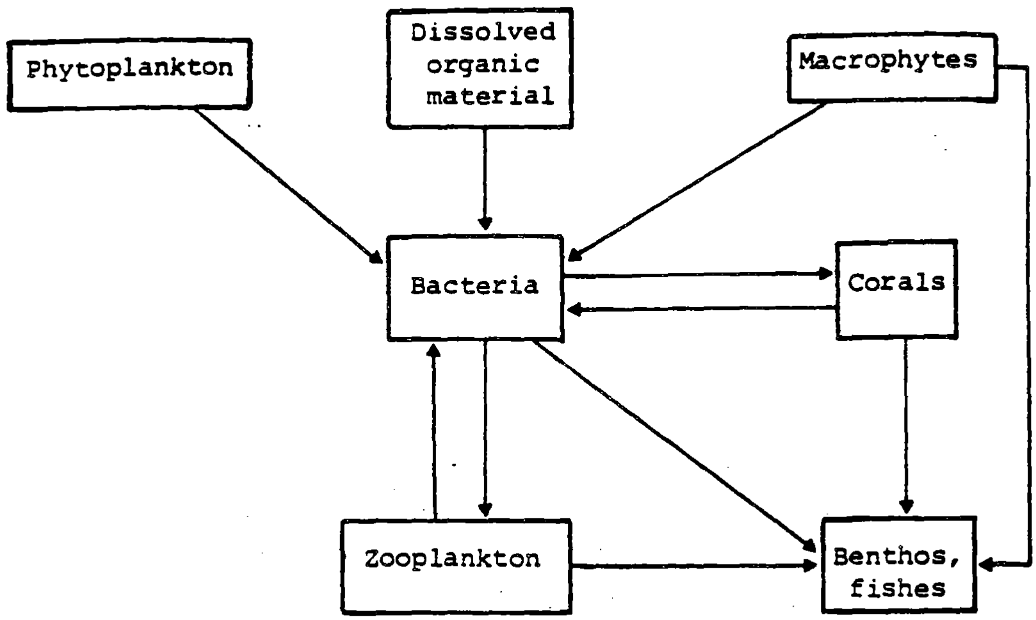

FIGURE G-1. Trophic relationships within a coral reef community, emphasizing the importance of bacteria (after Sorokin, 1973c).

1.4 Detritus

The quantitative significance of detritus as food for coral and other benthic organisms on the reef has not been evaluated. However, there is a good deal of evidence to indicate that suspended detritus is abundant in the water flowing over reefs.

Glynn (1973) found that dry biomass of suspended matter passing over a reef in Puerto Rico exceeded the dry biomass of net plankton by an order of magnitude or more. Evidence from examination of Millipore filters, plankton-pigment concentrations and productivity measurements indicated that the suspended matter was primarily detritus. The flux of suspended matter amounted to between 20 to 40g dry wt/m^2/day and there was no evidence of depletion of detrital material within the water mass flowing over the reef. In fact, there are a number of studies which show an increase in detritus available to suspension feeders after water has crossed a reef (Lewis, 1977).

Atlantic reef corals have been shown by Lewis and Price (1975, 1976) to behave as suspension feeders. By means of nets and strands of mucus they are able to capture a wide range of particulate material and larger plankton with their tentacles. Thus, when the biomass of zooplankton is too low to support the nutritional needs of corals (Johannes, 1974; Porter, 1974), other sources of food may be available to them. While those species with long active tentacles obtain food by means of tentacle capture and by mucus filaments, species with short tentacles such as the Agariciidae appear to feed entirely by suspension feeding. Lewis (1976, 1977) has shown experimentally that some Atlantic reef corals are able to clear the surrounding water of particulate material in amounts just enough to supply their daily maintenance requirements.

Some interest has been shown in the potential nutrient significance of the mucus which is produced in copious amounts by most reef corals. Johannes (1967) observed mucus released by corals and the subsequent formation of aggregates of mucus and entrapped particles. Marshall (1972) found considerable quantities of zooxanthellae in mucus discharged from coral heads. Suspended mucus strings were examined by Coles and Strathmann (1973) and found to have significantly higher organic carbon and nitrogen contents than suspended particles in the surrounding water. Benson and Muscatine (1974) found that the mucus from a variety of corals contained wax esters and they also observed that reef fish fed on the coral mucus. This is apparently one route by which energy-rich products of coral metabolism are transferred to higher trophic levels.

This raises the possibility of a detritus-based food chain such as exists in mangrove swamps (Odum and Heald, 1975). Feeding strategies for particulate food sources other than zooplankton are different from strategies in which zooplankton is the main food source (Jorgensen, 1966). Filter feeding, a type of suspension feeding, is one way of capturing particulate matter and Crisp (1975) has commented on the fact that suspension feeders require less energy for feeding than do zooplankton feeders. The proportion of ciliary-mucoid suspension feeders (including corals) and filter feeders on reefs has been estimated by Glynn (in Lewis, 1977). Glynn also found that the total biomass of the macrobiota at Panama was 441 g protein/m^2. Of this, 285.5 g consisted of corals and 14.6 g of other suspension feeders. If, as Crisp (1975) suggests, suspension feeders are intrinsically efficient converters of energy, then such a feeding strategy based on suspended detritus is particularly suitable for zooplankton-poor tropical waters. With this view in mind Lewis (1977) outlined trophic relationships within a coral reef community, incorporating detritus as a food source (Figure G-2).

1.5 Dissolved Organics

As yet there is no conclusive proof that corals use dissolved organic matter as food. Stephens and Schinske (1961) and Stephen (1962, 1968) discussed the problems that must be overcome in determining the extent of net utilization of a particular dissolved organic substance. As stated by Muscatine

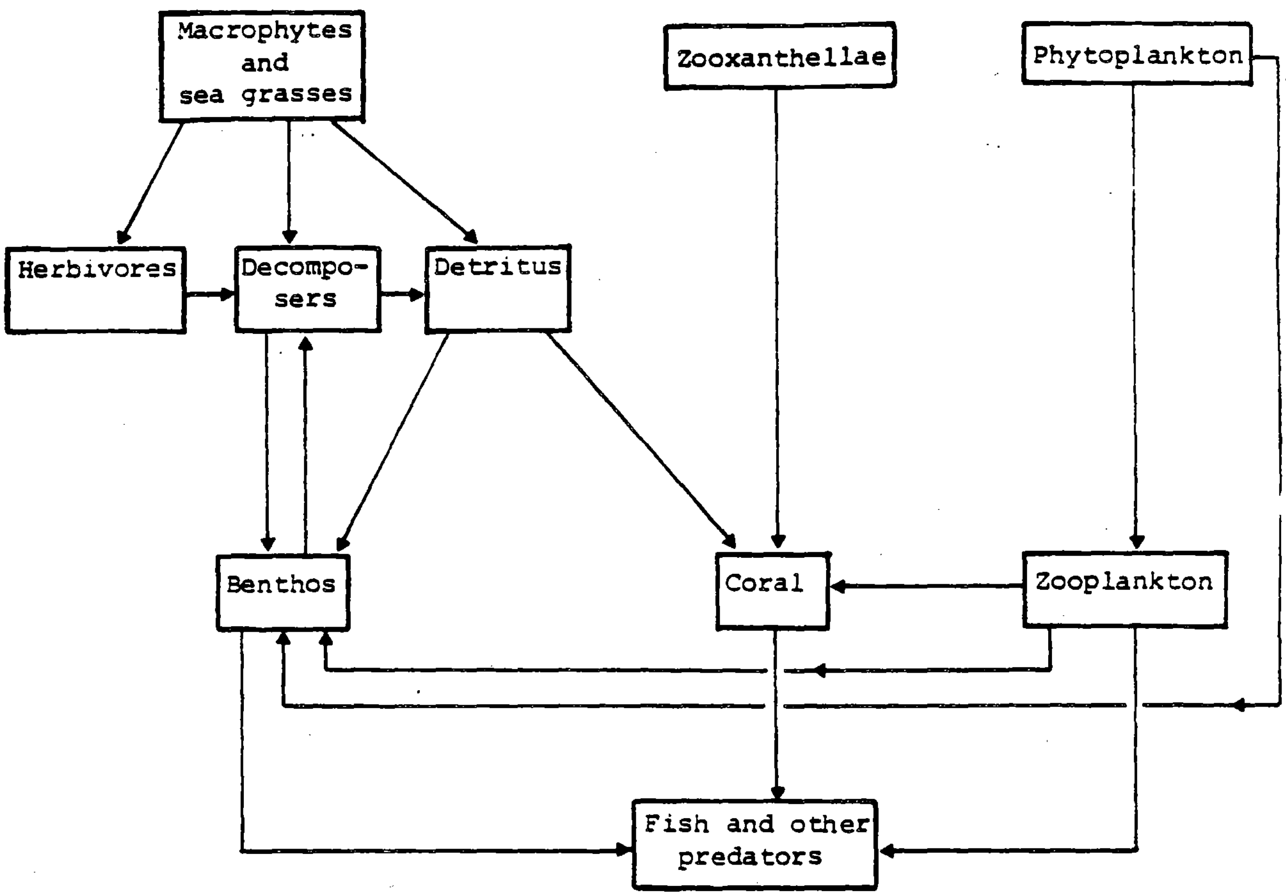

FIGURE G-2. Trophic relationships within a coral reef community, emphasizing the importance of detritus (after Lewis, 1977).

(1973), experiments have yet to be conducted with appropriate concentrations. Release as well as uptake of the material has not been determined, so that net gain, if any, is unknown. Finally, there is no documentation that absorbed organic material participates in the metabolism of the host.

2.0 Alcyonaria

Alcyonarian corals have been considered carnivorous along with the rest of the coelenterates (Hyman, 1940). There is evidence that at least in some species, this statement is valid. Both Bayer (1956) and Grigg (1970) reported that Leptogorgia virgulata and Muricea spp., respectively, prey extensively on shelled bivalve larvae. Grigg found through hypochlorite digests of polyps that this item constituted 90 percent of the diet of both M. californica and M. fruticosa but concluded that only one percent of metabolic needs were met in this fashion. Experimental work showed that microzooplankton and particulate organic matter were also consumed and probably represented the bulk of the diet of these species.

On the other hand, Pratt (1906) described the morphological "reduction" of the digestive areas in the alcyonacean octocorals Lobophytum, Sacrophyton, Alcyonium and Sclerophytum, correlating this in each species with an increase in numbers of zooxanthellae. Pratt conjectured that the needs of growing colonies of Sclerophytum could not be satisfied by the small amount of zooplankton actually captured and that nutrition of these species was supported by zooxanthellae. Gohar (1940, 1948) added members of the family Xeniidae to the species observed by Pratt as having a rich flora of zooxanthellae and also noted that xeniids lacked digestive zones of the mesenterial filaments. These animals were never observed to feed in the laboratory or in the field or to trap and paralyze zooplankters brought into contact with the surface of the animal. Since pulsating colonies ceased to move when placed in the dark but resumed movement when returned to the light, Gohar conjectured that "combustible energy-giving material" is normally supplied by zooxanthellae, rather than zooplankton. Wainwright (1967) reported the gorgonia expanded during the day when plankton was scarce but remained contracted at night showing little feeding activity when zooplankton was most abundant. This was considered to be an adaptation favoring photosynthesis by zooxanthellae during the day, implying a nutritional role for the algae. Similar to the case with scleractinian corals, Kinzie (1970, 1973) has shown that 73 percent of symbiotic gorgonians died after being placed in a light-tight aquarium with running seawater for 83 days. A non-symbiotic species (Diodogorgia) was alive and apparently healthy throughout the experiment. Bayer (1954) found evidence that the gorgonians Plexaura flexuosa and Psammogorgia antipathes, which have especially abundant zooxanthellae, have lost most, if not all of their nematocysts. In addition, they seem to show a reduction of gastrodermal gland cells, as in the case of the tropical alcynonaceans.

The data here are no less equivocal than in the stony corals. The arguments concerning the daylight expansion of the polyps in so-called "hermatypic gorgonians" (Wainwright, 1967) is countered by Theodor (1977) who found that members of the genus Pseudoterogorgia tend to be expanded at night and contracted during the day. The arguments for lack of feeding are often made with the assumption that only animal food is taken. However, Wilson (1884) and Roushdy and Hansen (1961) have both found evidence that octocorals are capable of feeding on phytoplankton. Diatom or detritus capture does not require nematocysts. This correlates well with electron-microscopic observations by Mariscal and Bigger (1977) who found that even asymbiotic octocorals have few nematocysts and no gastrodermal microvilli. In any case, no direct experimental approach has been employed in attempting to define the nutritional requirements in symbiotic Octocorallia.

3.0 Antipatharia

Inspection of the tentacular apparatus of Cirripathes or any other antipatharian in the study area will reveal large numbers of nematocyst batteries. Thus it is not surprising that Grigg (1965) was able to experimentally feed polyps of Antipathes grandis from Hawaii with various zooplankters.

However, Dantan (1921) reported that polyps of a *Leiopathes* contained large numbers of diatoms, often broken and apparently in a state of digestion, along with algal fragments. Although the data do not warrant antipatharians being considered herbivores, omnivorism cannot be ruled out, particularly in view of the recent studies by Lewis (1978) who notes that antipatharians are capable of feeding on fine suspended particulates by means of mucous strands and nets.

APPENDIX H. PREDATORS AND ASSOCIATIONS OF CORALS: GENERAL REVIEW

1.0 Scleractinian Predators and Their Effects

1.1 Fishes

Studies by Robertson (1970), Salvini-Plawen (1972) and Patton (1973), have shown that the number of animals specialized to feed on the Scleractinia has been underestimated (Wells, 1957; Yonge, 1963). Some of the observed effects also go far beyond the negligible damage claimed by Yonge (1968). Since many of the known coral predators have been described only relatively recently, it is likely that continued study will add to our knowledge of this feeding habit. The following review will no doubt soon be supplemented by new discoveries.

In Randall's (1967) survey of the food habits of reef fishes small volumes of coral were found in the alimentary tracts of four species: Scarus coelestinus Cuvier and Valenciennes and Sparisoma aurofrenatum (Cuvier and Valenciennes) (Scaridae), Chaetodipterus faber (Broussonet) (Ephippidae), and Microspathodon chrysurus (Cuvier and Valenciennes) (Pomacentridae). The only specific coral identifinoted was that of Oculina diffusa, a fragment consumed by C. faber. In some localities coral consumption by fishes appears greater than indicated by Randall's (1967) study. For example, in Panama (Bakus, 1969) and Bermuda (Gygi, 1969), the rasping of live corals by scarids is commonplace. Scarus guacamaia Cuvier rasps Siderastrea siderea with fair regularity along much of the north coast of Panama. The summits of large hemispherical colonies are commonly scraped to depths of 2-3 mm; such feeding is often performed by relatively small schools of S. guacamaia (five to 15 individuals) which appear to range over extensive areas. Microspathodon chrysurus, though predominantly herbivorous on epontic diatoms and filamentous algae, frequently feeds on S. siderea as well. Juveniles and adults of this fish bite the surface of the corallum vigorously, removing primarily the extended polyps. Corals preyed upon in this manner can be distinguished by the characteristic circular lesions left behind (Glynn, 1973). Juveniles and adults of Microspathodon commonly feed on the hydrocoral Millepora in Florida (Ciardelli, 1967), adults nest on it, and both juveniles and adults attack Millepora complanata in Panama. Other corals observed in Panama with deep rasping marks, similar to those produced by S. guacamaia, are Montastrea annularis, Acropora palmata, A. cervicornis, Agaricia agaricites, and Porites furcata. Mixed schools of Scarus croicensis, Acanthurus chirurgus (Bloch), Chaetodon capistratus Linnaeus, and other species occasionally feed on A. cervicornis. Such incidental feeding forays can lead to coral rasping by the scarid and selective removal of polyps by the latter two species (Glynn, 1973). On one occasion a scarid, possibly Scarus vetula Bloch and Schneider, was observed to bite off a terminal 2-cm tip of Porites porites. On some areas of the reef, Porites colonies commonly have many of their terminal branches broken off. This feeding habit was reported long ago in Haiti by Beebe (1928), who observed that scarids (most likely S. guacamaia) break off and ingest the terminal branches of corals. The effects of fish predators on Porites astreoides have not been reported in the Caribbean, but according to Gygi (1969) Sparisoma viride (Bonnaterre) commonly feeds on this coral at Bermuda, removing up to 200 mg with each bite. In addition to direct browsing, Glynn (1974) believes that indirect activity causes detachment of several coral species, notably Siderastrea radians and Favia fragum. This may be the cause of rounded, mobile coralliths often seen in lagoonal patch reef specimens.

As Yonge (1963) suggested, nematocysts must certainly deter some fishes from feeding on corals. That Microspathodon regularly consumes large amounts of the hydrocoral Millepora, however, indicates that certain fish species can cope with this potent means of defense. Possibly another effective deterrent that would tend to discourage fish predators is the presence of sharply projecting septa, often with serrated edges, on the corallites of Mussa, Scolymia, Isophyllastraea, Mycetophyllia, and Isophyllia. It may therefore be significant that the coral species most often consumed by large fishes have relatively smooth and unobtrusive surfaces. Reese (1977) has studied the relationship between feeding behavior, substrate type, and coral morphology in the Chaetodontidae fishes of three Pacific areas.

1.2 Invertebrates

Six invertebrate coral predators have been discovered in the Caribbean region since 1962. These include the amphinomid polychaete Hermodice carunculata (Pallas), the majid decapod Mithrax (Mithraculus) sculptus (Lamarck), the gastropod mollusks Coralliophila abbreviata Lamarck, C. caribea Abbott, and Calliostoma javanicum Lamarck, and the echinoid Diadema antillarum Philippi. Hermodice was first described by Marsden (1962, 1963) to be an habitual predator of Porites porites and P. astreoides. Subsequent work by Ott and Lewis (1972) and Shinn (1976) showed that several other coral species are preyed upon (although Hermodice was found most often on the colonial anemone Palythoa). Ebbs (1966) noted that coral browsing may occur in all Atlantic members of the Amphinomidae. Both P. furcata and P. porites are attacked by Mithrax, which severs the polyps with its chelae. This feeding habit, first observed in Puerto Rico (Glynn, 1962), was also seen in Panama, where Mithrax commonly preyed upon ramose species of Porites (Glynn, 1973). Ward (1965) believed that the mode of feeding of Coralliophila abbreviata, involving the dissolution and ingestion of soft tissues, can lead to the death of polyps and eventual destruction of the colony of Montastrea annularis (small star coral). On the other hand, Robertson (1970) maintains that this species is a well-adapted parasite, causing little damage to polyps. This conclusion is challenged by Ott and Lewis (1972) who documented some damage by C. abbreviata to several different corals, especially M. annularis. Miller in Glynn (1973) found Coralliophila abbreviata and C. caribea associated with 14 hermatypes at Discovery Bay, Jamaica, and suggested that the gastropods may feed on plankton ingested by the corals. Calliostoma javanicum feeds on Mussa angulosa in the laboratory and on Agaricia spp. (lettuce coral) in the laboratory and field (Lang, 1970), with a preference for the latter group. Small circular lesions are produced, but it is not yet known which of the soft parts of the coral are consumed. Diadema antillarum preys on coral at night (Bak and van Eys, 1975) at the same time that it preys on Thalassia producing the well-known halo effect around patch reefs. Like the scarids (parrot fish), Diadema inflict substantial mechanical damage to the corallum, but their impact is greater due to their slow movement and continual feeding pattern.

From the foregoing, it is obvious that several reef animals are adapted to feed on the Scleractinia. Though the actual quantities of coral consumed appear to be slight, there is good evidence that the damaged areas of the corallum that do not undergo regeneration are invaded by other organisms which may overgrow and eventually smother the entire colony. Continuing observations of the rasped surfaces of Siderastrea siderea have shown that, while repair normally takes place rapidly (two to three months), some areas suffer irreparable damage. The latter are often invaded initially by a variety of filamentous algae, including members of the Cyanophyceae, Chlorophyceae, Rhodophyceae, and Phaeophyceae, and epontic diatom growths. Large colonies of Montastrea annularis with their surfaces in various stages of invasion provide a concrete example of the course of destruction. Scarid nicks often contain mixed growths of filamentous algae and these can be traced through a successional continuum to surfaces highly eroded by boring clionid sponges (Glynn, 1973). Another type of algal invasion is induced by continuous attack on Acropora cervicornis (staghorn coral) and Montastrea annularis (small star coral) by the threespot damselfish, Eupomacentrus planifrons. As described by Kaufman (1977), the fish's continual attack on living and dead corals prevents regeneration of coral tissue and allows "algal lawns" to become established. Feddern (1979, personal communication) claims these "lawns" are cultivated year-round. These "lawns" in turn serve as a food source and egg cultivation space for the fish. Ott and Lewis (1972) find that the blue-green alga Lyngbia sp. invades regions of coralla which have been injured due to predation by the polychaete Hermodice (see Antonius, 1975). There is no evidence that the algae can expand past the site of injury; however, Antonius (1973, 1976) has described a blue-green alga, Oscillatoria submembranacea, which appears to be capable of rapid coenenchymal lysis, and spreading once a foothold on a corallum is gained.

2.0 Other Scleractinian Associations

There is a good deal of evidence from the field indicating that competition for living space is acute among the long-lived benthic populations of coral reefs. It appears that many groups of reef organisms have evolved body morphologies which tend to maximize the area of exposure to light and currents. Certain minimum levels of exposure are necessary for both photosynthetic and suspension feeding forms. Therefore, it is not surprising to find that a variety of strategies are employed to ensure the acquisition of space and access to the surrounding medium, and a subsequent hold on this resource once obtained.

2.1 Competition Among Scleractinian Species

To the rapid and spreading mode of growth employed by many corals as a means of reducing competition for space and light, must now be added the newly discovered adaptation of extra-coelenteric feeding (Lang, 1973). She has found that certain species will extend their mesenterial filaments and digest any living coral tissue from a colony of another species which they can touch, up to about 2 cm away. The species can be arranged in an aggressive hierarchy, each species attacking all others below it in the hierarchy and being attacked by all ranked higher. In general, the massive species of the families Mussidae, Meandrinidae, and Faviidae rank higher than those of other families. This agrees with Connell's (1973) findings that slow-growing massive colonies are not overgrown by the faster growing branching ones, and that in some instances, foliaceous species may inhibit massive ones.

While such competitive interactions can be observed among adult corals, they probably also play an important role among young growing forms. An active feeder, for example, would preclude the establishment of subordinate species within its feeding radius. Competitive exclusion by means of predatory interactions occurs most noticeably in the densely populated zones. *Montastrea annularis*, one of the principal reef-building species, is moderately active in extracoelenteric feeding and perhaps owes its presence in the buttress zone and along the seaward slope in part to its ability to compete successfully with more rapidly growing ramose and foliaceous forms (Glynn, 1973).

2.2 Boring Organisms

The importance of boring organisms in corals has been noted in reviews by Otter (1937), Yonge (1963), Goreau and Hartman (1963) and Lewis (1977). A wide variety of organisms including sponges, sipunculid and polychaete worms, molluscs, crustacea and algae are able to bore into corals, by either mechanical or chemical means (or both). Sponges are perhaps the most widespread borers on coral reefs. Rutzler (1971) has found that members of the adociid genus *Siphonodictyon* can excavate both into the living and nonliving portions of colonies of several coral genera. Pre-existing damage to the coral is apparently not a prerequisite for attack. Glynn (1973) noted that when a section of *Cliona* sp. was transplanted from an infected *Siderastrea* to the algal-covered scars of uninfected colonies, the sponge was able to expand over undamaged coral surfaces. The implanted sponge began to grow immediately and expanded 2 cm peripherally in a nine-month period, killing the underlying coral tissue. Neumann (1966) estimated that the sponge *Cliona lampa* can excavate carbonate at the rate of 1 to 1.4 cm yr^{-1}, Hein and Risk (1975) and MacGreachy (1975) estimate that three to 70 percent of the whole corallum may be reworked by clionids, while Hudson (1977) anticipates that a one-meter high coral head could be completely converted to sediment in 150 years or less based on scleroband measurements.

Rates of erosion of reef surfaces are difficult to estimate but Goreau and Hartman (1963) considered the activity of clionid sponges to be a widespread and significant force in the maintenance and formation of Jamaican deep reef communities. In shallow water, weakening of the bases of coral colonies by sponge excavation is perhaps counterbalanced by rapid calcification rates; in deeper water (>30 m or 100 ft), however, calcification is slow, corals become flattened and attached on an edge, the topography is steep, and there is a paucity of frame-cementing biota. All of these factors tend to magnify the effect of boring sponges in this environment.

2.3 Interactions between Corals and Other Sessile Organisms

Careful observation of benthic reef populations reveals frequent instances of unrelated organisms appoaching each other in growth and then one overgrowing and excluding its neighbor. While certain corals can coexist for long periods in close contact with alien species, for example, the beneficial association of Montastrea annularis with the sponge Mycale laevis (Carter) reported by Goreau and Hartman (1966), it appears that there is a tendency for some of the larger algae, sponges, octocorals, and zoanthideans to displace coral growth. This seems to take place in the absence of any detectable pre-existing damage to the coral as noted earlier for destruction initiated through the activities of predators. Some examples follow.

Among algae, Halimeda opuntia (Linnaeus) Lamouroux, Caulerpa racemosa var. macrophysa (Kutzing) Taylor, and Peyssonnelia rubra (Irgebille) J. Agardh are commonly found covering large areas of Porites furcata. The brown alga Lobophora variegata (Lamouroux) Womersley often proliferates over extensive populations. Chondrilla nucula, an encrusting sponge, and the colonial anemone Palythoa sp. can overgrow large tracts of Porites furcata and entire colonies of Siderastrea radians and Diploria clivosa. Porites is usually invaded from below, by way of the dead branches; massive corals are invaded from their periphery (Glynn, 1973). The scleraxonians Briareum asbestinum (Kinzie, 1970) and Erythropodium caribaeorum (Antonius, 1977) may function in the same manner, as may certain didemnid ascidians (Antonius, 1977).

3.0 Gorgonian Predators and Associates

The gorgonian octocorals are an important component of the reef and bank community in the study area. Their prominence has enabled them to provide shelter and food for a wide array of casual associates, epizoa and commensals and other symbionts, ranging from other coelenterates to fishes (Bayer, 1961; Salvini-Plawen, 1972). The associates of western Atlantic shallow-water gorgonians, particularly predators and parasites, are described below. The snail Neosimnia uniplicata and the shrimp Neopontonoides beaufortensis both feed on surface debris and material shed by the gorgonian Leptogorgia virgulata off North Carolina. The gastropod appears to incorporate spicular pigments into its own shell, thus acquiring concealing coloration. The nudibranch Tritonia wellsi probably feeds directly on Leptogorgia tissue (Patton, 1972). Cyclopoid copepods of the family Lamippidae are known to parasitize various octocorals (Zulueta, 1911) and have also been found in the polyps of Leptogorgia (Patton, 1972). Several species of Cyphoma, an ovulid gastropod, are conspicuous associates of Pseudopterogorgia, Plexaura, Plexaurella and related genera (Bayer, 1961). Kinzie (1970, 1974) has shown that Cyphoma is a predator which strips the coenenchyme, laying bare the axial skeleton. He has also described "herding" behavior, whereby cyphomas in groups of up to 24 individuals were capable of completely denuding several gorgonian colonies in a five-week period. Kinzie estimates that damage by Cyphoma may be less than the gorgonians' capacity for regeneration. Ott and Lewis (1972) and Birkland (1974) have also noted that the amphinomid worm Hermodice carunculata consumes gorgonians in addition to other corals. Morse, et al. (1977) describe algal tumors infesting Gorgonia ventalina in the Netherlands Antilles. Bagby (1978) reports considerable numbers of tumors from species of Pseudoplexaura, Pseudopterogorgia, Plexaurella, Plexaura and Muriceopsis from patch reefs off Key Largo, Florida. Randall (1967) found that the scrawled filefish Alutera scripta was the most prominent piscine gorgonian predator among 212 species examined. Ten other fish species had small amounts of gorgonian material in their stomachs but Randall concluded that gorgonians, in spite of their prominence, do not form a significant part of the diets of West Indian reef fishes.

The direct effect of predators and parasites is difficult to assess. However, mechanical damage to the coenenchyme by several sources appears to disrupt the antibiotic properties of the tissue (Burkholder, 1973), allowing the establishment of a variety of invading organisms, particularly Millepora alcicornis. Once established, Millepora spreads, killing the gorgonia before it. Kinzie

(1970) estimated the spreading rate at 244 $cm^2\ yr^{-1}$ on a colony of *Gorgonia ventalina* and 1.4 to 0.7 cm yr^{-1} on two tips of a *Plexaurella* species. He also noted that an unidentified keratosid sponge was capable of similar action on deep reef gorgonians in Jamaica. Whether any of these biological interactions is significant compared to periodic storm damage (Cary, 1914) or toppling due to the weakening of the substratum by boring organisms (Kinzie, 1970, 1974), remains to be determined.

4.0 Antipatharian Predators and Associates

Little is known of relationships between black corals and other organisms. Salvini-Plawen (1972) notes a nurse shark, *Nebrius concolor*, feeding on an unnamed antipatharian. Cyclopoid copepods of the family Vahiniidae appear to parasitize the polyps of antipatharians (Humes, 1967). A coralliophilid gastropod, *Rhizochilus antipathicus*, feeds on *Antipathes ericoidea* (Salvini-Plawen, 1972). Other symbionts involving various species and the antipatharian whip *Cirrhipathes* have been described (Davis and Cohen, 1968; Humes, 1973). None of these involve western Atlantic species, although further work on this neglected group will undoubtedly reveal a number of associations in this region. This expectation is heightened by the apparent absence of antibiotic activity in the tissues of a species of *Antipathes* sp. tested by Burkholder (1973).

APPENDIX I. NATURAL IMPACTS ON CORAL HEALTH

1.0 Hurricanes

Corals and associated resources are stressed by hurricanes in direct proportion to the depth of coral occurrence. Paralleling the discussion on wave energy above, hurricanes impose decreasing stresses as water depth increases. Observations at the Flower Garden Banks, however, indicate that storm surges associated with hurricanes can overturn head corals at depths in excess of 40 m (132 ft) (Continental Shelf Associates, 1978).

Although their frequency may be low in most areas, hurricanes do possess the power to be a most devastating stress on corals (Stoddart, 1969, 1970). In Florida waters, Ball, et al. (1967), Perkin and Enos (1968), and Shinn (1976), have reported damage from hurricanes, often resulting in fragmentation of sections of reefs. For example, a hurricane that struck the Key Largo Dry Rocks Reef inflicted heavy wave and storm-tide damage on living corals, increased the load of suspended sediments, enlarged the coral rubble pile on the leeward side of the reef, and left deposits of lime mud stranded when waters calmed; deeper water areas nearby seemed to escape the sediment accumulations (Ball, et al., 1967). Evidence presented by Stoddart (1969, 1974) suggested it may take many years for the reef to regenerate; no regrowth was apparent four years after a hurricane struck the barrier reef of British Hondorus.

The stresses exerted by hurricanes result from changes in water temperature, salinity, sedimentation, light penetration, and wave surge. The first four variables are discussed below in separate subsections. The potential damage from each of those factors is enhanced by strong wave and tide patterns. Waves may also topple corals regardless of the presence of a tropical storm (Tilmant, 197' personal communication).

1.1 Light, Depth, and Wave Energy

The influence of light on coral distribution and diversity has been elucidated. Generally, species diversity decreases rapidly as depth increases below the 10 m (33 ft) isobath (Wells, 1957), although Goreau and Wells (1967) indicate that coral reefs and corals may grow to 70 m and 90 m (230 and 330 ft), respectively. Similar trends with different depth ranges were observed by Porter (1972) in corals at San Blas on the Atlantic side of Panama. These patterns are dependent at least partially upon light intensity and algal symbiosis. Experimental work with different light intensities shows that the compensation point for Florida reef corals lies between 320 and 1,120 W/cm^2 (200 and 700 ft.c.), and that for most it is 480 and 800 W/cm^2 (300 and 500 ft.c.). This compares with a surface illumination in clear weather of 4,000 to 8,000 W/cm^2 (2,500 to 5,000 ft.c.) and a reading of 640 W/cm^2 (400 ft.c.) at 30 m (98 ft) (Kanwisher and Wainwright, 1967).

At the opposite extreme, low tide on rare occasions may expose some of the shallow water coral species found in the study area. Back reef species such as *Favia fragum*, *Siderastrea radians*, and *Manicina areolata* (rose coral) are the most resistant to emersion (Vaughan, 1919; Mayor, 1918), although *Montastrea annularis* (small star coral) is also known to survive exposure on Florida's reefs. The primary determinant of survival at extremely low tides is the degree of heat or cold coupled with the length of time of low water (see discussion of temperature in this subsection, 6.2.2.2)

The degree of turbulence and wave energy also acts as a depth-related limit to distribution. Scleractinian zonation in the surf zone of Caribbean reefs appears to depend to a large degree on this factor (Geister, 1977). Reef crests dominated by *Porites* spp. (finger coral) and *Montastrea annularis* (small star coral) are found in zones with weak wave action, while crustose coralline algae, *Palythoa* and *Millepora* (fire coral) are more often found in higher energy zones. Geister considers *Acropora-*

dominated crests as intermediate energy forms. It is conceivable that Geister's hypothesis could help explain local differences in reef crest zonation in the Florida reef tract such as the Elbow Reef dominated by Millepora and Acropora-dominated Carysfort Reef 10 km (5.4 nm) away.

Alcyonarians are affected by light in the same way that reef scleractinians are, and for the same reason (Bayer, 1961). Reef-dwelling corals are usually heavily infested with light-requiring symbiotic algae. On deeper (>20 m or 66 ft) reefs off south Florida, however, asymbiotic (i.e., lacking zooxanthella) species such as Iciligorgia schrammi and ellisellids become common; in the Gulf of Mexico, reefs may harbor asymbiotic Paramuriceids in addition to ellisellids. Depth limitation in such cases is not as distinct as in symbiotic species; the factors which prevent these groups from becoming successful on shallow reefs have not been investigated.

Unlike stony corals, the height of gorgonian whips does not appear to be strictly limited by low water. At Soldier Key, Florida, low tide frequently drops below the height of species in the "Alcyonarian Zone" (Voss and Voss, 1955). However, owing to the flexibility of the axial skeleton, the colonies simply drape across the water's surface much like kelp does in temperate regions. No study has been made of the degree of emersion tolerance in gorgonians. In high energy zones, shallow water exposes gorgonians to considerable stress. Among the few species capable of successful colonization are Gorgonia ventalina, Pterogorgia citrina, Plexaura flexuosa and Erythropodium caribaeorum (Wainwright and Dillon, 1969; Kinzie, 1973; Antonius, et al., 1978). Gorgonia ventalina appears to be the most consistent colonizer of surge zones, albeit with high mortality rates (Birkland, 1974).

Perhaps similar to the depth restriction of asymbiotic gorgonians is the case of the Antipatharia. Whether black corals lack zooxanthellae entirely is an open question since van Pesch (1914) found colorless cells which he consideredas symbiotic algae in several species. However, neither Pax (1914) nor Grigg (1965) found zooxanthellae in their investigations. Grigg found that Antipathes grandis Verrill are adversely affected by light intensities of >60 percent of surface, and by the abrasive effects of surge in waters <24 m (79 ft) deep in turbulent areas. He postulated that black coral larvae will not settle unless light penetration is less than 25 percent of surface, corresponding to a depth of about 35 m (114 ft) around Hawaii. Grigg found that only in turbid waters or in shaded areas are colonies found in shallower water. There have been no comparable studies on the ecological requirements of black corals in the western Atlantic.

Light, depth, and wave energy are each affected by other activities which may affect corals synergistically. Light penetration is dependent upon water clarity and activities that effect it, e.g., dredging, some polluting activities, algal blooms, and storms. Depth is more independent of other activities but remains correlated with such factors as light intensity and wave length, temperature profiles, and salinity gradients. Wave energy, a function of meteorological activity, may be altered by dredging activity, shoaling, and by the integrity of the reef which absorbs wave forces.

1.3 Temperature

The impact of temperature upon coral is species-specific. Some corals occurring throughout large sections of the management area (the starlet coral, Siderastrea radians and the stump coral, Solenastrea hyades, for example) are more eurythermal than corals found only in deeper waters (Lophelia and Enallopsammia, for example) (Macintyre and Pilkey, 1969; Voss, et al., 1969; Neumann, et al., 1977). The gorgonian Briareum asbestinum seems adapted to warmer waters (Cary, 1917, 1918). Many other species are more stenothermal in their temperature requirements. Nonreef gorgonians may be more tolerant then reef species (Bayer, 1961).

The impacts of water temperature may be accentuated when shallow-water corals are exposed to extended periods of calm seas. Shinn (1979, personal communication) observed loss of zooxanthellae and, in some cases, death of Acropora cervicornis at Grecian Rocks near Key Largo after 30 days of calm in August and September 1978.

The most poorly developed reefs are found astride the middle and northern Florida Keys. At the northern end, reef development appears limited by the lack of barriers between Biscayne Bay and the Ragged Keys. Here, both patch reefs and outer bank reefs are depauperate, but become better developed seaward of Elliott Key (Marszalek, et al., 1977). A similar situation exists south of Key Largo to Big Pine Key where Florida Bay waters are exchanged through numerous passes. Thus, no reefs or rocky shoals are known from Alligator Reef to Tennessee Reef, and from Tennessee Reef to Coffin's Patch (Ginsburg, 1956). The best known reef in this section, Alligator Light, is not especially diverse, being dominated in its shallows by Millepora (Starck, 1968).[1] Patch reef development is similarly affected with only 50 known to exist in the southern section of the tract, from Tavernier to Big Pine Key (Marszalek, et al., 1977). This region extends for 40 percent of the length of the outer reef arc from Fowey Rocks to Key West, but includes only about one percent of the number of patch reefs. Again, increased land mass from Big Pine Key to Key West, and protection from cold Gulf and Bay water have been cited as the principal reasons for increases in the number of patch reefs to seven percent of the reef tract total (Marszalek, et al., 1977).

The best available temperature data for the reef tract as a whole are still those of Vaughan (1918) who cited the following maxima and minima (in °C):

Sand Key (Key West)		Carysfort Reef		Fowey Rocks	
Min.	Max.	Min.	Max.	Min.	Max.
17.9	32.2	18.2	30.3	15.6	30.9

Note that temperature differences between reef areas along the reef tract are small. In fact, if all of Vaughan's December, January, and February minimum temperatures (32 years) at Fowey Rocks are taken into account, a mean of 19.8 ± 2.0°C (63 ± 3.8°F) is obtained, while those of Carysfort Reef (21 years) equals 20.9 ± 1.3°C (65 ± 2.5°F), and Key West's (12 years) are 19.6 ± 1.4°C (63 ± 2.6°F). While the significance of these differences is debatable, an alternative view is possible if one takes Vaughan's ten day means of 20°C (68°F) as a function of total observed winter days (December through February).

Carysfort Reef	40/1,620 = 2.5% of winter days <20°C
Fowey Rocks	160/2,610 = 6.1% of winter days <20°C
Key West	90/1,140 = 7.9% of winter days <20°C

It should be noted that 30 of the 40 days of <20°C temperature at Carysfort Reef occurred during January, 1893. At Fowey Rocks during this time, the minimum was 20.8°C (65°F), but mean temperatures below 20°C were recorded for at least a single ten day period during nine of the 21 years for which records were kept. The temperatures taken at Sand Key (Key West) indicate lows in six of the 13 years of data kept at that station. Thus, if the data depict the real differences between Carysfort Reef, and the relatively barren Fowey Rocks, it would seem that Florida's coral reef tract is indeed living a precarious thermal existence. Furthermore, minimum temperature records alone do not appear to explain why there are reefs at Sand Key, but not at Fowey Rocks.

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1 Although Millepora reefs may be considered as less prolific than those dominated by Acropora, it is worth noting that the atoll-like structures of the southwest Caribbean form a vigorous Millepora zone, analogous to Indo-Pacific algal ridges (Milliman, 1973). At Molasses Reef, Florida, spur and groove systems have formed from Acropora growth but have become capped with Millepora (Shinn, 1963). This does not necessarily mean that Molasses Reef is not prolific. In fact, comparative studies of calcification indicate that M. complanata may grow nearly as rapidly as A. palmata and A. cervicornis (Goreau and Goreau, 1959).

Goldberg (1973) determined temperature tolerances of gorgonians from south Florida. The observed ranges (15.9 ± 1.7°C to 32.2 ± 1.1°C or about 61 to 90°F) were not unlike those reported for scleractinians, although "indicator" species were not subjects of experiments. Cary (1917; 1918) found that Briareum asbestinum, an indicator of well-circulated environments was the most heat resistant species. This implies that circulation is more important in the distribution of species than temperature per se, since well-circulated environments rarely develop temperatures above 32°C.

Thermal tolerances of Muriceopsis flavida, characteristic of shallow, well-circulated reefs of the Florida Keys, and M. petila, characteristic of deep reefs, were tested in thermally controlled running seawater aquaria (flow rate = 48L hr^{-1}) by Goldberg (1979, personal communication). Colonies of both species exposed to 31°C (88°F) for 24 hours survived, but exposure to 32 to 33°C (90 to 92°F) for the same time period (different colonies) was lethal. Muriceopsis flavida withstood 24 hour exposure to 16°C (61°F) but at 15°C (60°F) recovery took 17 days; polyps were "bleached" from loss of zooxanthellae and colonies suffered partial necrosis. As expected, M. petila was more tolerant of low temperatures. Only one of six colonies died at 14°C (57°F), as did two of six colonies exposed to 12.5°C (54°F). This was the lowest temperature tested.

Like some of the scleractinians noted above, some gorgonian species occur in nonreef environments. Pterogorgia citrina, Plexaurella dichotoma, Plexaurella nutans and Eunicea knighti, for example, occur in Biscayne Bay (Bayer, 1961) and can be expected to be more tolerant than those species which have been tested to date.

Water temperature changes associated with winter weather patterns naturally stress corals throughout the management area. Apparently, coral atop some of the banks in the northwestern Gulf of Mexico (Flower Gardens, Stetson, Sonnier) are protected from cold water intrusion by the warm water masses flowing northward. Corals in the Florida Middle Grounds are shielded by their depths. The Florida Keys, however, are sufficiently shallow to expose corals to fluctuating temperatures which may approach the thermal extremes stated above. Occasionally, cold fronts will sweep over the Keys or drive cold Florida Bay waters south and east whereupon massive kills can occur. Davis (1979, personal communication) estimated that the extreme cold of January 1977 killed over 90 percent of the staghorn corals (Acropora cervicornis) at Dry Tortugas while most unbranched corals survived the 14°C (58°F) waters. Hudson, et al. (1976) recorded an 80 to 90 percent mortality of the Hen and Chicken patch reefs of the Florida Keys during the winter of 1969 to 1970 when air temperatures dropped to 13°C (57°F).

Goldberg (1973b) published data on temperature and salinity tolerances of reef-dwelling gorgonians off the coast of Florida. Gorgonians were found within a range of about 15.9°C to 32.2°C.

One of the diagnostic responses of corals to heat or cold is "bleaching", the expulsion of zooxanthellae. In laboratory studies, the reef species Muriceopsis flavida and M. petila became bleached upon exposure to temperatures of 32 to 33°C and 15°C for 24 hours (Goldberg, 1979, personal communication). Jaap (1979) observed zooxanthellae expulsion in response to high temperature shock in Millepora complanta (encrusting fire coral), Palythoa sp., Acropora palmata (elkhorn), and Montastrea annularis (small star coral) to varying extents. Goldberg and Jaap reported recovery (in varying degrees of tissue death or necrosis) in 17 days and about six weeks, respectively.

There are no data on thermal limits in the Antipatharia. However, their distribution would lead one to suspect that they are less tolerant of high temperatures and more tolerant of lower ones, compared with shallow, reef-dwelling scleractinians and gorgonians.

1.4 Salinity

The effects of salinity resemble those of temperature listed above; some corals may be expected to be euryhaline (e.g., Pterogorgia citrina, Plexaurella dichotoma, Plexaurella nutans, and Eunicea knighti as judged by their distribution in Biscayne Bay (Bayer, 1961)] while others, notably coral reef species, thrive only in environments with normal salinities. Work by Vaughan (1916) and Wells (1932) showed most corals to be stenohaline.

For most of the study area, salinity extremes are not important, although river outflow (e.g., portions of west and northwest Florida, the Mississippi Delta region and the capes of North Carolina) will certainly exclude most of the species which might otherwise occur. In Biscayne Bay, fresh water upwelling near shore apparently limits the distribution of several relatively tolerant corals such as Siderastrea and Solenastrea (Kohout and Kolipinski, 1967). The extraordinary salinity (and turbidity-temperature) extremes found in Laguna Madre, Texas (Moore, 1963) (sometimes exceeding 80 ppt) have also prevented coral development although serpulid (worm) reefs may be found in their place (Andrews, 1964).

The only study on salinity tolerances of octocorals is that of Goldberg (1973b) who concluded that gorgonians are somewhat more stenohaline than scleractinian corals. Conversely, Bayer (1961) noted that Leptogorgia setacea may inhabit both open ocean and estuarine areas where salinities of 17.2 parts per thousand are found. Leptogorgia virgulata is also known to be euryhaline, although probably not to the degree attained by L. setacea (Bayer, 1961).

The impacts of both hyper- and hypo-saline waters on corals is reviewed by Johannes (1975). Generally, waters which reach 150 percent of the normal salt content (such as desalination plant effluent) may be toxic to corals even with only short-term exposure (Edmondson, 1928). Responses to the stress are species-specific. The response of corals to desalination effluents must consider the presence of heavy metals such as nickel and copper in the effluent. Chesher (1975) reviewed the biological impact of a desalination plant in Key West, Florida.

Low salinity waters created by increased land run-off (via bad land management) or storms appears tolerable by most Atlantic corals at 50 percent of normal (Johannes, 1975). However, Johannes did cite several incidents of heavy rains destroying coral reefs. Usually, seawater diluted by heavy rainfall probably inflicts only short-term, nonlethal stress to submerged corals. Transported sediments, however, may bury the organisms.

Antipatharians appear to be strictly limited to open ocean conditions. Salinity tolerances of these animals probably vary accordingly although there has been no study of this to date.

1.5 Ecological Relationships

Predation is a natural component of coral systems. Species of fish such as trigger fish (Balistidae), filefish (Monocanthidae), puffers (Tetraodontidae), butterflyfish (Scaridae), and parrotfish (Chaetodontidae) feed directly upon coral polyps and, in doing so, damage the carbonate skeletons (Randall, 1974). Although the frequency of these attacks may be low, the resultant injury provides an entrance to disease and algal infestation. Fish may also graze upon algal zones on corals, e.g., the leafy algae zone atop East Flower Garden Bank, or other hard surfaces (Hiatt and Strasburg, 1960). Other coral reef predators include starfish, polychaetes, gastropods, crustacea, and sea urchins (see Appendix H).

Corals are also susceptible to "poisoning" by toxic plankton blooms. Shelf communities off the west central coast of Florida were devastated by a red tide of the dinoflagellate Gymnodinium breve (Bright and Jaap, in press). Smith (1975) stated that exposure to the toxicants of a red tide can cause extirpation of coral communities. In addition to the toxic substances in red tide organisms, an algal bloom also changes dissolved oxygen levels; waters may become anoxic at night or when the tide undergoes a natural decline.

2. Contamination of Ocean Waters

Any person who discharges organic matter including sewage and industrial wastes into the waters of the state which damage fish, shellfish and aquatic animals indigenous to or dependent on the receiving waters, shall be liable to the state for such damages as may be proved (48-1-13(b)). The pollution of water by oil and gas is specifically prohibited.

3. Use of Poison, Electricity or Explosives

The use of poisons, electrical currents, physical shocks, pressures, disturbances, dynamite, gun powder, lime or any other explosives to take fish is prohibited (50-13-1420 and 1440).

(c) Habitat Protection Programs

Heritage preserves may be established pursuant to the Heritage Trust Program for the protection of natural areas or features. Natural areas are defined to include areas of water which contain unique animal habitat. Natural features are defined to include "outstanding remnants or natural elements of surviving undisturbed natural ecosystems" (51-17-10).

(d) Coastal Zone Management Authorities

1. Activities Affecting Wildlife and Fisheries

A Coastal Zone Management Program has been adopted by the legislature and the Governor. According to the proposed program, activities occurring within the coastal zone which require a permit or a certification from the South Carolina Coastal Council, which are determined by the Council to have a significant negative impact on wildlife or fisheries resources, will not be approved unless overriding socioeconomic considerations are involved (Proposed South Carolina Coastal Management Program and Draft EIS, p. III-51).

2. Dredge and Fill Activities

A permit from the Council is required for all dredge or fill activities and for the erection of any structure on or which in any way alters any critical area (48-39-130(c)). Council rules provide that attention be given in the evaluation of potential sites for dredged material disposal to "possible adverse impacts on ... critical fish and wildlife areas" (R. 30-12(I)).

3. Geographic Areas of Particular Concern (GAPCs)

Several categories of GAPC's may be designated pursuant to the proposed South Carolina Coastal Management Program. Areas of unique natural resource value include scarce or vulnerable habitats and living marine resources. Priorities of uses are established for each area so designated. Management activities are conducted through several different programs, including: heritage preserves, wildlife preserves, state parks, marine and estuarine sanctuaries and shellfish areas.

Texas - (All citations to Vernon's Texas Code Annotated)

(a) Coral Protection - None

(b) Incidental Protection

1. Regulation of Fisheries

For the purpose of regulating shrimping activities in the waters of the state, a distinction is made between inside and outside waters. Inside waters include all bodies of water landward of the Gulf of Mexico. Outside waters are closed to shrimping (for a 45-day period), from June 1 to July 15, which may be extended by the Parks and Wildlife Commission to no more than 66 days (Parks and Wildlife (§77.061). The legal shrimp count for outside waters is not more than 65 headless or 39 heads-on shrimp per pound. There are no restrictions on the number or size of trawls used for shrimping in outside waters. Mesh size may not be smaller than five stretched meshes in eight and three-fourths inches of net and try nets may not exceed twelve feet in width (Parks and Wildlife Code §77.063).

2. Contamination of Ocean Waters

A permit issued by the Texas Water Commission is required before any discharge of waste, including oil, can be made into the Gulf of Mexico inside the territorial limits of the state (Water Code §26.121). Whenever it appears that a violation or a threat of violation of this provision has occurred that affects aquatic life or wildlife, the Parks and Wildlife Department may have a suit instituted for injunctive relief or civil penalty.

3. Use of Electroshock

The use of electroshock for the taking of fish is prohibited (Parks and Wildlife Code §66.004).

4. Dredge and Fill Activities

A permit must be obtained from the Parks and Wildlife Department to operate in or disturb any oyster bed or fishing water for any purpose other than that necessary or incidental to navigation or dreding permitted by the states (Parks and Wildlife Code §86.002). Any activity, including dredging and dredge material disposal, occurring on state public lands, including submerged lands, requires a permit from the General Land Office. Permits will be granted only if it is determined that all types of marine life and wildlife can be protected (Nat. Res. Code §33.001-.176).

(c) Habitat Protection Programs - None applicable

(d) Coastal Zone Management Authorities

A revised Hearing Draft of the Texas Coastal Management Program has been completed, but not yet submitted for approval. Pursuant to this Program, the Natural Resources Council will seek nominations for areas of particular concern (Texas Coastal Management Program, Revised Hearing Draft, p. 249). In addition, coastal public lands may be leased by the General Land Office to the Department of Parks and Wildlife as a means for these lands to be designated areas for preservation and restoration (Nat. Res. Code §33.105). In neither case is it clear whether submerged lands are eligible for designation.

As noted in the following discussion on gas seeps, filamentous algae may infest ulcers of corals subjected to natural gas (Bright, 1977). Other algae, notably the blue-green Oscillatoria submembranacea, have been associated with coral mortalities in Florida (Antonius, 1973, 1976). A "white death" pathogen (Dunstan, 1977) has been described in Florida but its significance or cause has not been elucidated (Bright and Jaap, in press). Algae may also cause tumors in the sea fans Gorgonia ventalina, Pseudoplexaura flagellosa, Plexaura homomalla, and related gorgonians (Morse, et al., 1977; Goldberg, 1979, personal communication).

Sedimentation

The effect of sedimentation as a control of coral growth, particularly after storms (see also man-induced sedimentation, discussed in Section 6.2.2), has been studied since the turn of the century (Stoddart, 1969). Certain corals may, however, grow even in muddy surroundings (Umbgrove, 1928; Shinn, 1979, personal communication). It is known that branching corals are better able to withstand sedimentation than hemispherical forms (Stoddart, 1969). Such corals of the genus Oculina are often found in turbid water conditions. Oculina diffusa (Atlantic cluster coral), for example, appears to survive on unconsolidated substrates adjacent to reef areas, rather than the reef itself. Oculina varicosa which inhabits the turbid continental shelf of central and northeast Florida, is often the only scleractinian to be found (Goldberg, 1979, personal communication). Branching gorgonian corals often dominate reef areas subject to heavy siltation (Courtenay, et al., 1974); Bright (1977) commented that members of the antipatharian zone are adapted to turbid water conditions on the south Texas fishing banks. Although these conditions cannot be thought of as an optimum for any species, coral dominance in certain areas can be at least partially explained by resistence to turbidity and sedimentation.

In portions of the management area, sabellariid worms form "worm reefs" that function as a turbid-water extension of coral reef ecosystems (Gore, et al., 1978).

Gas Seeps

Biogenic and petrogenic natural gas seeps of methane, ethane, and propane have been observed at many of the hard banks off the coast of Texas and Louisiana, e.g., Fishnet, 28 Fathom, East and West Flower Gardens, Southern, Hospital, and Baker Banks (see Figure 5-2) (Bright and Jaap, in press; Bright, 1977) and elsewhere in the Gulf of Mexico (Texas A&M University, no date). Ecological studies of corals near seeps appear to indicate that no large scale impacts are occurring, although one head of Montastrea annularis (small star coral) at 25 m (82 ft), on West Flower Garden Bank was discolored light brown, ulcerated, and ringed with a filamentous alga (Bright, 1977). In most cases, corals appear to live coincidentally with seeps.

Seeps of petrogenic gas and oil are common on hard banks because of the geological structure of the salt domes and their capability to trap petroleum reservoirs. Slow and constant releases from those underground pockets has been estimated by Abbott and Bright (1975) to contribute 200 to 600 million cubic meters of gas to the water column each year at East Flower Garden Bank alone. Oil seeps are also common but contribute far less volume of petroleum.

Despite the enormity of gas escapes, natural gases from petroleum or biogenic degradation have been considered nonpollutants. Corals and other hardbank biota may in fact be tolerant to the chronic exposure levels.

APPENDIX J. STATE LAWS, REGULATIONS, AND POLICIES INDIRECTLY RELATED TO CORAL RESOURCES

Alabama - (all citations to Code of Alabama)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

Licenses are required for the use of seines and trawls for the taking of shrimp (9-12-92). Fees for licenses according to the length of the net or seine (9-12-113). Permissable mesh size for seines, nets, or trawls are prescribed by the Department of Conservation and Natural Resources (9-12-110). Lead lines for seines, nets, and trawls may not exceed 500 fathoms (900 m or 3,000 ft). For shrimp trawls this measurement is taken along the cork line rather than the lead line (9-12-111). Shrimping is prohibited completely from Portersville and Heron Bays (Alabama Marine Resources Regs. §§3 and 4).

2. Contamination of Ocean Waters

The Alabama Water Quality Criteria include special water use classification for shellfish harvesting and fish and wildlife which require that higher standards of water quality, sufficient for those purposes, be met in areas so classified. The Water Pollution Control Act contains no special provisions for the prevention of discharges of oil into ocean waters.

(c) Habitat Management or Protection Programs - None applicable

(d) Coastal Zone Management Authorities

1. The Alabama Coastal Area Protection Act does not include dredge and fill activities in the coastal area as a permissable use (9-7-13). Therefore such activities are subject to the management authority of the Coastal Area Board. The final coastal plan as released in August, 1978.

2. The final draft for the Alabama Coastal Area Management Program (August 1979) lists all open Gulf waters and certain bays as Geographic Areas of Particular Concern. Uses given highest priority pursuant to this designation include those that preserve, protect, or enhance the coastal waters and those that are dependent upon coastal waters and do not degrade coastal waters beyond existing levels. Uses that degrade coastal water quality beyond existing levels are prohibited (p. 43).

Florida - (all citations to Florida Statutes Annotated)

(a) Direct Coral Protection - see text in Section 7.4.

(b) Indirect Protection

1. Regulation of Fisheries

Permits are required to fish for either commercial or bait shrimp. Due to the varied habitats and types of bottoms and hydrographic conditions found in open areas of coastal waters, the Division of Marine Resources reserves the authority to specify and regulate the types of gear that may be used in different sections of the open areas [§370.15(5)(a)]. With certain exceptions, these regulations are site-specific to such an extent that general statements concerning the type of gear that may be allowed in coral habitat are impossible. Breeding areas are provided special protection. Any area where the shrimp count reveals a predominance of "small shrimp or prawn," defined as 47 shrimps with the heads, or 70 with the heads off to make a pound, shall be designated a sanctuary area and closed to the taking of shrimp [§370.15(2) and (3)]. Special rules regarding gear and seasons have been instituted in certain areas which have been determined to contain particularly valuable resources. Of particular importance to the protection of coral are the Tortugas shrimp beds, which are closed to shrimping at all times.

2. Use of Explosives, Poisons, Drugs, or Chemicals

Throwing dynamite, lime, other explosives into the waters of Florida or use of any firearms whatsoever for the purpose of killing fish is prohibited. Poisons, drugs or other chemicals may not be placed in the marine waters of Florida for the purpose of capturing live marine specimens without a permit from the Division of Marine Resources [§370.08(5) and (10)].

3. Contamination of Ocean Waters

The discharge of any pollutant into the coastal waters of Florida is prohibited (§376.041). The discharge of oil into any saltwaters of the state from any source is specifically prohibited (§370.09).

Pursuant to Florida water quality standards, the highest protection is afforded to "outstanding Florida waters." It is not known at the present time exactly what standards will be applied to such areas. Waters in national parks, monuments, wildlife refuges and marine sanctuaries, state parks, recreation areas, and aquatic preserves, and special waters of ecological significance are considered outstanding waters. As mentioned in Section 6.4 several such areas have been established in Florida waters for the protection of coral (17 Florida Admin. Code §3.041).

4. Regulation of Dredge and Fill Activities

All persons engaging in dredge and fill activities in the bottom lands of Florida must obtain a certificate of registration from the Department of Natural Resources and keep accurate logs and records of all such activities so that the natural resources may be protected and conserved (§370.03).

(c) Habitat Protection Programs

1. Aquatic Preserves

As discussed in Section 6.4, the Florida Aquatic Preserves Act of 1975 authorizes the permanent preservation of submerged lands of exceptional biological, aesthetic or scientific value (§258.35). Regulations are developed for each preserve to protect water quality and aquatic resources. Three areas of the Florida Keys designated as aquatic preserves include important coral habitat: Biscayne Bay, Coupon Bight, and Lignumvitae Key. Regulations have been promulgated for one of these preserves, the Biscayne Bay Aquatic Preserve. Within the Biscayne Bay Aquatic Preserve dredging or filling is allowed only if certain stringent conditions are met and discharges of wastes are prohibited (§258.165).

2. Areas of Critical State Concern

The state planning agency may designate areas containing environmental or natural resources of regional or statewide importance as areas of critical state concern for which special protection will be provided (§380.05). As of the present no areas containing coral habitat have been so designated.

3. Environmentally Endangered Lands

The issuance of state lands for state capital projects for environmentally endangered lands is provided for by the Land Conservation Act of 1972 (§259). Such capital projects will have as their purpose the protection of environmentally unique and irreplaceable lands as valued ecological resources. Eligible types of lands include "areas of ecological significance the development of which would cause the deterioration of submerged lands."

4. John Pennekamp Coral Reef State Park - See Sections 6.4 and 7.4.2.

(d) Coastal Zone Management Authorities

Coral reefs are listed as a unique environmental feature and therefore classified as a potential area of particular concern by the Florida Coastal Management Program (Legislative Draft, 3/1/78, p. 43). Highest priority in this type of area of particular concern will be placed on non-intensive uses that are water dependent and maintain natural features. The Florida Coastal Management Program Hearing Draft of August 1980, identifies problems and issues related to the Florida reef tract. It recommends full utilization of the existing state Interagency Management Committee to examine coral reef management issues and to make recommendations for the resolution of those issues. It also recommends full utilization of CZM funding to assist the Florida Department of Natural Resources in improving state capability for developing specific cooperative management programs in the Florida reef tract.

Georgia - (all citations are to Georgia Code Annotated)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

Offshore areas maybe opened for shrimping by the Coastal Resources Division of the Department of Natural Resources from June 1 through December 31 of each year, provided that the shrimp count is 45 or less to the pound with heads on. If the shrimp count does not exceed 50 during the months of January and February, an additional open season may be declared. Offshore waters are permanently closed at other times. Power drawn nets used for commercial shrimping may not exceed 20 feet at the widest part of its mouth. No other restrictions on net length or mesh size appear in the Georgia code (45-902).

2. Use of Firearms, Electricity, Explosives, or Poisons

The use of firearms, batteries, generators or similar devices, or any dynamite, explosives or other destructive substances, including poisons, walnut hulls, and lime, for the purposes of catching, killing, taking, or harming fish is prohibited (45-711).

(d) Coastal Zone Management Authorities

Pursuant to the Coastal Wetlands Protection Law permits are required for the dredge and fill activities in the coastal zone (49-27-1). Performance standards for these activities will be developed as part of the coastal management plan currently being prepared.

North Carolina - (all citations to North Carolina General Statutes)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

Trawl nets generally may be used for taking shrimp in the Atlantic Ocean (15 North Carolina Admin. Code 3B/.0305). In certain areas of ocean waters the use of trawl nets is prohibited altogether and in others it is only permitted during certain times of the year (15 North Carolina Admin. Code 3B/.0402). In other areas the taking of shrimp by any method whatsoever is prohibited. Shrimp may be taken by the use of a butterfly net or float net only in areas designated by, and with a permit issued by, the Secretary of the Department of Natural Resources and Community Development. Dates for opening the season for the taking of shrimp through the use of nets are set by the Secretary (15 North Carolina Admin. Code 3B/.0701). Seasons will vary from year to year and place to place. If any shrimp count reveals a predominance of undersized shrimp or juveniles in particular populations, waters may be closed to shrimping and/or the use of trawls for as long as the Secretary deems advisable for the protection of such populations (15 North Carolina Admin. Code 313/.0702). It is unlawful to take shrimp by the use of a net with a mesh length less than one and one-half inches or to use a net which contains an inner or outer liner [15 North Carolina Admin. Code 313/.0701(c)].

2. Contamination of Ocean Waters

The discharge of wastes into the open waters of the Atlantic Ocean within the jurisdiction of the state, except pursuant to a permit issued by the Environmental Management Commission, is prohibited (143-214.2). The discharge of oil into the waters of the state is specifically prohibited (143-215.83). The person discharging the oil is responsible for conducting cleanup operations and liable for any damage caused by its discharge (143-215.84 and 215.90).

3. Dredge and Fill Activities

Applications for permits to dredge or fill in estuarine waters shall be denied if it is determined by the Department of Natural Resources and Community Development that there will be a significant adverse effect on wildlife ... or estuarine or marine fisheries [113-229(e)(5)].

4. Use of Poisons, Drugs, Explosives or Electricity

The use of poisons, drugs, explosives or electricity to take any fish is prohibited (113-262).

(c) Habitat Protection Programs

1. Research Sanctuaries

Coastal fishing waters may be closed by the Secretary of Natural Resources and Community Development, upon the advice of the Director of the Division of Marine Fisheries, with respect to taking any or all kinds of marine or estuarine resources and with respect to using any kind of equipment (15 North Carolina Admin. Code 3B/.0111). Such areas could be established for the conduct of coral research, and sanctuaries established for research concerning other resources could indirectly protect coral.

2. Nursery Areas

Nursery areas may be established to protect fragile estuarine areas which support juvenile populations of economically important seafood species. In order to protect the integrity of nursery areas, the use of bottom-disturbing fishing gears, trawls, and dredges is prohibited (15 North Carolina Admin. Code 3B/.1401).

3. Underwater State Parks

The Marine Fisheries Commission has passed a regulation endorsing the concept of underwater state parks. Removal and destruction of plants and animals would be prohibited in such parks. No action has been taken on this resolution on the departmental level as of the present time (Hall, 1978, personal communication).

(d) Coastal Zone Management Authorities

The North Carolina Coastal Management Program has been approved by the federal Office of Coastal Zone Management. With approval, North Carolina receives Section 306 funding for coastal programs.

The Coastal Areas Management Act provides for the designation of Areas of Environmental Concern. A permit must be issued by the Coastal Resources Commission before all but certain exempted activities can be conducted and appropriate standards must be complied with. Several different types of AEC's may be designated for which different standards of performance would be established (113A-113). The Marine Fisheries Commission has recommended that at least four underwater areas identified as containing significant coral and/or sponge resources be designated as "fragile coastal natural resource areas." The Coastal Resources Commission has yet to act on this recommendation (Hall, 1978, personal communication).

South Carolina - (all citations to South Carolina Code)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

It is unlawful to trawl for shrimp except in established legal trawling areas in the Atlantic and in certain sounds and bays (50-17-1610). Except for designated sounds and bays, trawling is prohibited in inside waters, including several estuarine areas where live bottoms are known to exist (Bearden, 1979, personal communication). Seasons for trawling for shrimp within the statutory areas may be set by the Division of Marine Resources (50-17-1510 and 1520). Seines and trawl nets used for shrimp or prawn may not have a mesh size of less than one-half inch nylon twine (square mesh) or nine-sixteenths inch cotton cord (square mesh) and may not exceed 40 feet in length (50-17-1020).

3. Contamination of Ocean Waters

The Georgia Water Quality Criteria include a water use classification for fish, shellfish, and aquatic life, which require that higher standards of water quality, sufficient for their survival, be met in areas so classified. There are no special provisions for the prevention of discharges of oil into ocean waters.

4. Dredge and Fill Activities

Dredge, fill, removal, or drainage or other alterations of marshlands within the estuarine area of Georgia without a permit from the Department of Natural Resources is prohibited (43-120). Permits are granted only after a determination that the proposed activity will not damage marshland and estuarine resources.

(c) Habitat Protection Programs

Pursuant to the Heritage Trust Act of 1975, areas of land, marsh, or water which have been identified by the Heritage Trust Board, as having significant historical, cultural, or natural values may be provided special protection as determined by the Heritage Trust Board. As of the present time no coral habitat areas in the coastal waters of Georgia have been provided such protection (43-2300).

(d) Coastal Zone Management Authorities

Areas of particular concern within the coastal zone whose environmental, economic, recreational or cultural characteristics are of statewide, areawide, or regional significance and therefore require special management, may be designated by the Coastal Management Board (43-26). No document presenting a Georgia Coastal Zone Management Program has yet been drafted. Georgia has disbanded its grant with the federal Office Of Coastal Zone Management but will continue its program on state funds.

Louisiana - (all citations to Louisiana Revised Statutes - Title 56)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

Louisiana fisheries laws make a distinction between inside and outside waters for the purpose of regulating shrimping activities; outside waters are all waters seaward of a line established by the Wildlife and Fisheries Commission. The state asserts no jurisdiction over outside waters for the purpose of regulating shrimping activities (§495). Within inside waters, no trawling is allowed during a closed season set by the Wildlife and Fisheries Commission. Closed seasons are based on the shrimp count and will vary from year to year. During the open season no vessel trawling for shrimp may pull more than two trawls and no trawl may be over 50 feet in length along the cork line (§495.1). Breeding areas are provided protection by a prohibition on the possession of shrimp which average more than 68 specimens to a pound, except during the spring open season (§498). Use of seines or trawls with mesh size less than three-fourths of an inch bar or one and one-half inches stretched or seines over three thousand feet in length is prohibited.

2. Contamination of Ocean Waters

Discharge of any wastes or pollutants into state waters which could tend to destroy fish or other aquatic life must comply with regulations promulgated by the Stream Control Commission (§1440).

(c) Habitat Protection Programs - None applicable

(d) Coastal Zone Management Authorities

The draft Coastal Resources Program was submitted to the federal office of Coastal Zone Management in September 1979.

Mississippi - (all citations to Mississippi Code Annotated)

(a) Direct Coral Protection - None

(b) Indirect Protection

1. Regulation of Fisheries

The Mississippi Marine Conservation Commission is authorized to establish open and closed seasons for shrimping in state waters north of the intercoastal waterway. State waters south of the intercoastal waterway may be closed to shrimping upon the appearance of excessive numbers of small juvenile brown shrimp. Certain areas are closed to shrimping at all times (49-15-6205). North of a line defined by a series of offshore islands (Cut, Ship, Horn, and Petit Bois) it is illegal to use more than one trawl net, other than a test or try trawl, which may not measure more than 50 feet along the cork line and not more than 60 feet along the lead line. No restrictions are placed on use of trawl nets south of this line. Trawls used to catch live bait shrimp may not exceed sixteen feet on the cork line and twenty feet on the lead line.

2. Contamination of Ocean Waters

The Marine Conservation Commission cooperates in the enforcement of water quality standards in the salt waters of the state. Shellfish harvesting has been established as a water use classification for the purpose of setting water quality standards (49-17-22).

(c) Habitat Protection Programs

1. Natural Heritage Areas

Land and water areas containing an element of the state's natural diversity may be listed on a Register of Natural Areas and held in trust for their protection (49-5-141). Since the Mississippi Heritage Trust was only recently established, it is too early to determine whether coral habitat will be eligible for protection.

2. Protection of Endangered Wildlife

Land on aquatic habitat may be acquired for the protection of endangered wildlife (49-5-111

APPENDIX K

REGULATORY IMPACT REVIEW (RIR)

OF THE

FISHERY MANAGEMENT PLAN

FOR

CORAL AND CORAL REEFS

IN

THE GULF OF MEXICO AND SOUTH ATLANTIC

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NATIONAL MARINE FISHERIES SERVICE
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9450 KOGER BOULEVARD
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Summary

The Coral and Coral Reef Fishery of the Gulf of Mexico and south Atlantic is of importance to both recreational and commercial fishermen. This fishery is unique in that its habitat and nonconsumptive value greatly exceed its value as a harvested product.

Evaluating the economic impact of proposed regulations in a quantitative manner is not possible and appears unnecessary. First, the unique character of the fishery makes it a crucial, if not major, part of the life cycle of several important species of fish and shellfish; the commercial and recreational value of these species would conservatively exceed $300 million annually. While there is no question of the habitat value of coral to marine life in general, there is little or no information available to estimate incremental decreases in value as coral may be destroyed gradually. Thus, only gross values and relationships can be used. Second, the Fishery Management Plan (FMP) and associated regulations would be classified as a minor rule under the criteria of Executive Order 12291 and the Interim Guidelines established by the Office of Associate Administrator for Fisheries.

The need for federal regulation through a FMP is critical because the traditional federal role of managing coral and coral reefs in the FCZ has been largely abrogated in the fishery conservation zone (FCZ) except as it applies to oil and gas exploration and development. Uncontrolled harvesting and subsequent damage to coral and coral reefs will threaten several major fish and shellfish fisheries as well as the nonconsumptive value derived from coral.

The management measures proposed by the Councils are responsive to the problems in the fishery and represent the most cost-effective approach to protect coral and coral reefs. Rejected management measures were generally more costly to implement, a greater regulatory burden on the public, and less responsive to the conservation of the resource.

Benefits that will accrue from implementation of the proposed measures are maintenance of the fishery's habitat and nonconsumptive values (cited above), as well as the harvest value of coral. Coral growth is so slow and miniscule that its harvest is analogous to a mining operation; however, its relationship to renewable marine resources is so vital that short-term increases in coral harvest would have far greater long term, adverse effects on those resources.

Annual cost for implementation of the plan are estimated at $224,563. The RIR indicates that the adopted measures minimize the burden on the public and address the problems in the fishery in a cost-effective manner. The proposed action is not a major rule requiring the preparation of a Regulatory Impact Analysis under Executive Order 12291, or under the Interim Guidelines established by the Office of the Assistant Administrator for Fisheries.

CONTENTS

I. INTRODUCTION

Executive Order 12291 "Federal Regulation" established guidelines for promulgating new regulations and reviewing existing regulations. Under these guidelines each agency, to the extent permitted by law, is expected to comply with the following requirements: (1) administrative decisions shall be based on adequate information concerning the need for and consequences of proposed government action; (2) regulatory action shall not be undertaken unless the potential benefit to society for the regulation outweigh the potential costs to society; (3) regulatory objectives shall be chosen to maximize the net benefits to society; (4) among alternative approaches to any given regulatory objective, the alternative involving the least net cost to society shall be chosen; and (5) agencies shall set priorities regularly with the aim of maximizing the aggregate net benefit to society, taking into account the condition of the particular industries affected by regulations, the condition of the national economy, and other regulatory actions contemplated for the future.

In compliance with Executive Order 12291, the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA) require the preparation of a Regulatory Impact Review (RIR) for all regulatory actions which either implement a new fishery management plan or significantly amend an existing plan, or may be significant in that they affect important DOC/NOAA policy concerns and are the object of public interest.

The RIR is part of the process of developing and reviewing fishery management plans and is prepared by the Regional Fishery Management Council's with the assistance of the National Marine Fisheries Service (NMFS), as necessary. The RIR provides a comprehensive review of the level and incidence of impacts associated with the proposed or final regulatory actions. The analysis also provides review of the problems and policy objectives prompting the regulatory proposals and an evaluation of the major alternatives that could be used to solve problems. The purpose of the analysis is to ensure that the regulatory agency or Council systematically and comprehensively considers all available alternatives so that the public welfare can be enhanced in the most efficient and cost effective way.

The RIR also will serve as the basis for determining whether the proposed regulations implementing the fishery management plan or amendment are major/nonmajor under Executive Order 12291, and whether or not the proposed regulations will have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (P.L. 96-354).

A. Background of RIR

This RIR is based on the most recent commercial and recreational information, as well as the most recent biological, economic, and legal information regarding coral and coral reefs. The proposed regulations, which this RIR evaluates, will be subject to public review during hearings to be held in early 1982.

B. Background of the Coral and Coral Reefs FMP

The Gulf of Mexico and South Atlantic Fishery Management Councils, established by the Magnuson Fishery Conservation and Management Act (MFCMA; 16 U.S.C. 1801 et seq.), are responsible for preparing management plans for mutual fishery resources in the FCZ of the Gulf of Mexico and south Atlantic. The Councils, recognizing that coral and coral reefs constitute a valuable fishery (see Section IV.C.1 below) and require management under MFCMA, developed a FMP to address and overcome problems in the fishery.

C. Problem Identification

1. The overall problem in the fishery is the degradation of the stocks through natural and man-made impacts. Coral and coral reefs in the management unit are frequently plagued by a wide variety

of adverse impacts, as detailed in FMP Section 6.2.2. The cumulative effect of these stresses has been a degradation of stock size, areal distribution, and coral health generally. This problem undermines the value of coral and coral reefs as habitat, in nonconsumptive as well as consumptive uses.

2. Limited scientific information on many species and many sections of the management unit, which includes the inability to assess the impact of coral harvest. The existing biological data presented in FMP Section 5.4 show that there is very little information on growth, mortality, abundance, and recruitment for the management unit. This information on catch/effort from a directed fishery is absolutely necessary to estimate MSY (and then OY) for each species. Without this information, estimated MSY's are uncalculable.

3. Susceptibility to stress because of corals being located at the northern limit of their distribution. Corals in the management unit are located at the northern end of their natural distributions. This means that they are subjected to water temperature extremes that stress them to the limit of their ability to survive. In fact, in some instances water temperature drops and/or other natural occurrences (such as hurricanes), have killed large segments of reefs in the management unit. These natural stresses are uncontrollable by man. However, because of these natural stresses, corals in the management unit are more susceptible to man-induced stresses.

4. Inability of corals to escape stress because of their sedentary nature. Corals, unlike finfish, crustaceans, and most mollusks, cannot move to escape stress. Instead, the polyps must retract. Resulting disruptions in energy flow may interfere with normal ecological functions such as reproduction and feeding.

5. Complexity and inconsistency of existing management regimes. As summarized by Shinn (1979b, and 1980), the management area is covered by numerous federal and state authorities with jurisdiction over coral and coral reef resources. This presents problems in overlapping regulations by federal and state agencies, differing regulations (e.g., concerning tropical fish collecting in Florida Keys parks, monuments, etc.), and more. The resulting regime is complex, burdensome, and inconsistent; a single coordinating authority such as National Oceanic and Atmospheric Administration (NOAA) may offer a solution via the FMP within the mandate of the MFCMA.

6. Lack of adequate public understanding of the importance of coral and coral reefs. Dead coral is sold extensively in the management area both for use as curio items and aquarium decorations. On the other hand, living coral is important both ecologically and economically to the management area. Living coral provides habitat for many species of finfish and shellfish. Many of these species are commercially valuable. Living coral also provides a major tourist attraction to south Florida and to a lesser extent in other states.

7. Present lack of jurisdiction over most coral and coral reefs by a federal agency which has traditionally executed authority and jurisdiction. In a recent decision (U.S. v. Alexander) the court ruled that the Bureau of Land Management only had authority to manage corals threatened by oil lease operations. This decision has left the majority of coral and coral reef resources in the FCZ unprotected and unmanaged.

D. Specific Objectives of the FMP

The specific objectives of the FMP are to:

1. Develop the scientific information necessary to determine the feasibility and advisability of harvest of coral.

2. Minimize, as appropriate, adverse human impacts on coral and coral reefs.

3. Provide, where appropriate, for special management for coral habitat areas of particular conc[illegible] (HAPC).

4. Increase public awareness of the importance and sensitivity of coral and coral reefs.

5. Provide a coordinated management regime for the conservation of coral and coral reefs.

E. Achievement of Stated Objectives

The Councils have recommended an OY for all corals as a level of harvest specified or as may be authorized pursuant to the permitting criteria established in the FMP. This OY is very different from those in other fisheries because the allowable level of harvest is very limited, MSY for coral and coral reefs is presently incalculable, and their importance to other fisheries cannot be overstated.

OY for stony corals is to be zero (0) except as may be authorized for scientific and educational purposes. The current and expected level of harvest for this purpose is estimated to be 140 kilograms per year.

OY for octocorals is the amount of harvest which is authorized pursuant to this plan. It is to be all octocorals (except sea fans) that are harvested by U.S. fishermen. Octocorals, except for sea fans, are identified as presently being harvested without apparent stock damage (Section 8.2.6). Present and expected level of harvest is estimated to be about 5,845 colonies, 1,463 of which come from the FCZ.

The U.S. harvesting industry has the capacity and intent to harvest the entire OY; therefore, there is no surplus available for foreign fishing. The U.S. processing industry also can process as much of the resource as becomes available to it.

Proposed Management Measures

1. Permits

Establish a permit system, with mandatory reporting, for:

A. the use of toxic chemicals in taking fish or other marine organisms which inhabit coral reefs,

B. for taking stony corals and sea fans and corals in prohibited areas for scientific and educational purposes.

2. Time and Area Restrictions

See FMP Section 13.5 for special regulations applicable in habitat areas of particular concern and Proposed Measure 5 below.

3. Catch Limitations

A. Total Allowable Level of Foreign Fishing - none. The expected domestic annual harvest will equal the optimum yield.

B. Types of Catch Limitations:

(1) Prohibit the taking of stony corals and sea fans (*Gorgonia flabellum* or *G. ventalina*) o[illegible] the destruction of these corals and coral reefs in the FCZ of the Gulf and South Atlanti[illegible] Fishery Management Councils' jurisdiction, excep[illegible] as provided for in this plan. (FMP Section 12.4).

(2) Stony corals and sea fans taken incidentally in other fisheries must be returned to the water in the general area of capture as soon as possible. An exception is provided for the groundfish, scallop, or other similar fisheries, where the entire unsorted catch is landed. In such instances the stony corals and sea fans may be landed but may not be sold. (FMP Section 12.4.)

(3) Should harvest of octocorals become accelerated which in the Councils' judgement is threatening the habitat in localized or widespread areas, the Councils may request the Secretary to take available measures designed to eliminate such threat of damage to the resource and fishery habitat. On the advice of its Scientific and Statistical Committee or other sources that one or more species of octocorals may be endangered from widespread or localized depletion from overharvest or threat of overharvest, the Councils may notify the Secretary of the threat and recommend that he take one or more of the following actions.

a. Restrict by regulation amendment or through promulgation of emergency regulations the harvest of one or more species of octocorals to a recommended level or amount.

b. Restrict by regulatory amendment or through promulgation of emergency regulations the area from which one or more species of octocorals may be taken.

c. Restrict by regulatory amendment or through promulgation of emergency regulatons the method of harvest by which one or more species of octocorals may be harvested.

d. Utilize any procedures other than regulatory amendment or promulgation of emergency regulations which may be within the realm of authority of the Secretary and which will achieve the results of action proposed in options (a) through (c) above.

4. Types of Vessel, Gear, and Enforcement Devices

Prohibit the use of toxic chemicals in taking fish and other marine organisms which inhabit coral reef areas except under permit as may be specified in this or any other fishery management plan. (FMP, Section 12.4.)

5. Habitat Preservation, Protection, and Restoration (FMP, Section 12.4)

Measures are proposed for the coral habitats of particular concern (HAPCs).

a. East and West Flower Garden Banks (nominated national marine sanctuary). Traditional, historical fishing methods are allowed but bottom longlines, traps and pots, and bottom trawls are prohibited in waters shallower than 50 fathoms. The taking or destruction of all corals is prohibited except as authorized by permit.

Anchoring shall be prohibited on the East and West Flower Garden Banks, on bottoms shallower than 50 fathoms in depth except for vessels less than 100 feet in registered length.

b. Florida Middle Grounds - the northernmost hermatypic (shallow reef-type) coral community in the Gulf of Mexico. Within the HAPC as defined in the plan, bottom longlines, traps and pots, and bottom trawls are prohibited to prevent damage to corals (see Section 6.2.1). The taking or destruction of all corals is prohibited except as authorized by permit.

c. *Oculina* Bank - In this four by 23 nm HAPC off Florida's central east coast the use of bottom trawls, bottom longlines, dredges, fish traps, and pots is prohibited in order to protect the coral from damage.

6. Other Measures to Achieve OY (FMP, Section 12-4)

A. Recommended that the Secretary establish a communication program to inform the public of the reasons for coral management and regulations which protect corals and coral reefs.

B. Recommended that the Secretary establish a procedure to coordinate coral management activities in the FCZ and territorial sea within the Councils' area of jurisdiction.

C. Recommended that the states and NMFS monitor at least at the present level of effort the condition of the octocorals and report damage or threat of damage to their habitat.

Alternative Management Measures

1. Establish regulations for coral fisheries on a species or group basis, including at a minimum, allocation of catch, possibly location or harvest area, use of the resources, and regulation of collection method.

2. Initiate a research and monitoring program of data gaps and ongoing activities to provide information necessary to fulfill management needs.

3. Develop a public information and awareness campaign to acquaint the public with the values of corals, the fragility of corals to human and natural stresses, problems with stock management, and ways in which the public may contribute to resource conservation and management.

4. Study effects of trial fisheries on selected species.

5. Provide for a fishery for rose coral.

6. No action. (No management or regulation.)

7. Include for special management purposes as habitat areas of particular concern the following:

   a. Sand Key and Sambo Reefs.

   b. Onslow Bay, North Carolina.

   c. A larger area for Oculina Reef System off central eastern Florida and the Florida Middle Grounds.

   d. Looe Key.

8. Permit system for harvest of octocorals.

II. ANALYSIS OF PREVIOUS YEAR'S FMP

Not applicable since no PMP or FMP is now in effect for coral and coral reefs.

III. METHODOLOGY

A. Procedural Framework

The procedure used in estimating the economic impacts will include a systematic discussion of both adopted and rejected management measures. Each management measure, to the extent possible, will be analyzed with regard to its effect on:

(1) Changes in price - price flexibilities will be used where appropriate.

(2) Changes in supply - effects on production and marketing costs and related changes throughout the distribution system.

(3) Changes in employment - total number of jobs affected.

(4) Distribution of income, benefits or costs - universe of affected fishermen, income distribution, reporting burden, and other effects on vessels, crewshares, processors, and user groups.

(5) Productivity - relative to altering output, investment, and technology.

(6) International implications - effect on foreign fishing or foreign markets.

(7) Market structure - changes in the size, number or locations of firms.

(8) Government - administration, data collection, and enforcement costs.

(9) Recreational participation.

After all measures are examined, impacts under the above categories will be summarized.

B. Data Base

Most data used in this RIR are contained in the FMP.

IV. REGULATORY IMPACTS

Management programs currently in effect in the Gulf states and South Atlantic states are reported in the FMP (Section 7.0), as well as present federal regulations. These present conditions, as well as no action where applicable, will serve as the basis for estimating the incremental economic impact of the proposed and alternative measures.

A. Proposed Management Measures

1. Permits

A. This measure is intended to protect corals from death or damage from toxic chemicals used in the collection of fishes and other marine organisms in coral reefs. Some tropical fish collectors utilize chemicals to remove specimens from within coral reefs. When used with care the chemicals can be used effectively with little effect on the corals. Improper use, however, can result in loss of corals. Restriction to permitted users would provide a degree of control to limit use to approved chemicals and individuals knowledegable in their use.

It is expected that the permit program developed through the office of the Regional Director of NMFS will utilize the permit information and procedures of the Florida Department of Natural Resources (FDNR). Fishermen with valid permits through FDNR to operate in state waters may operate in the FCZ with the same FDNR permit. Their permit information would be on file in the Regional Office. Federal expenditures and unnecessary duplication would therefore be at an absolute minimum. Practically all coral-related activity takes place off of Florida; the expected number of permit holders is estimated initially to be 40 to 50 (A. Huff, FDNR, 1981; personal communication).

This permit procedure will minimize any burden placed on fishermen and would allow easy ope tion between the waters of the FCZ and state without identification problems. The Regional Director can issue permits to fishermen operating in the FCZ only, or may designate FDNR, with its approval, as his designee to issue permits. The cost of these permits is expected to be zero as in the Gulf Reef Fish FMP, and of minimal cost ($10 each) to the government. Since practially all existing coral-related activity occurs in Florida, the additional cost to federal government will be zero in the short-term.

B. Permits for only the scientific and educational taking of stony corals, sea fans, and other protected corals in HAPCs will neither create an economic burden on researchers and commercial collectors, nor create unnecessarily large federal government expenditures. While the collection of corals, including stony corals and sea fans, in the FCZ is presently unregulated, the collection of stony corals and sea fans is believed to be nonexistent. Most commercial collection occurs off of Florida where there is a permit system and possession of stony corals and sea fans is prohibited. The cost of these permits to the research and educational community is expected to be zero and of minimal cost ($10 each) to the federal government.

Initially the number of permits under this submeasure is not expected to exceed 18. The Regional Director will in all likelihood issue the permits because research and educational activity occurs throughout the Gulf and south Atlantic FCZ. Other federal agencies with jurisdiction over specific HAPCs, i.e., Fort Jefferson, Looe Key, etc., may devise their own permit system or may utilize the offices of NMFS.

The mandatory reporting required of all permit holders, estimated to very between 58 to 68, will be obtained through a survey form designed by the Southeast Fisheries Center, NMFS. Forms will be mailed periodically to NMFS or collected by NMFS agents. Costs for mailing, printing, data processing, editing, verification, and publication should not exceed $25 annually per permit holder, or a total of $1,450 to $1,700 to the federal government. The reporting burden to respondents should be no more than one hour per year. Information required will include:

1) catch by weight (or colonies) and species;
2) catch by location and depth;
3) date of catch(es);
4) intended use of catch;
5) type of chemicals used, if any, and
6) other perfunctory information as listed in FMP Section 14.2.

2. Time and area restrictions apply specifically to HAPCs which are discussed below under item 5.

3. <u>Catch Limitations</u>

A. A zero harvest level for foreign fishing will cause no economic burden on foreign fishermen since there is no present or past foreign fishing activities in the Gulf and south Atlantic FCZ. Expenditures by the federal government will be at an absolute minimum.

B. Type of catch limitations:

(a) The impact of prohibiting the taking of stony corals and sea fans, or the destruction of these coral reefs, is described above in Management Measure 1.B, and in general terms in the Summary section.

(b) The economic impact of this submeasure is minor on the fishing industry, and in most cases on coral and coral reefs. First, the exemption to groundfish, scallop, and other similar fisheries does not impose any unnecessary regulation on these fisheries; also, corals will not be threatened because these fisheries operate in low density coral areas either normally or by preference to minimize gear damage and loss. Second, fisheries which may land stony corals or sea fans, but are prohibited from selling them, will experience very little, if any, decrease in revenue. Any coral incidentally taken would have been so fragmented by bottom trawling as to make them worthless. Enforcement efforts by federal and state agencies need not be increased for a very low potential of this activity.

(c) The economic impact of this submeasure, which sets up a framework for future regulations if necessary, is uncertain until regulations are proposed. Under the current FMP, the harvest of octocorals is unregulated (except in two HAPCs where a permit is required). Recent information (J. W. Lowry, FDNR, 1981; personal communication) document the importance of octocoral habitat to other corals, coral reefs, and marine life. This measure allows the Councils to request the Secretary to take available measures (Sec. 305(e) of MFCMA) to protect octocorals.

4. Types of Vessel, Gear, and Enforcement Devices

The economic and regulatory impact of prohibiting the use of toxic chemicals except under permit is described in Management Measure I.A.

5. Habitat Preservation, Protection, and Restoration

A. The economic impact of prohibiting the use of bottom longlines, traps and pots, and bottom trawls, and prohibiting anchoring by vessels greater than 100 feet in length, will be very small, if any. While the use of this gear is presently unregulated throughout the whole Gulf and south Atlantic FCZ, and in the Flower Garden Banks, the gear is not used presently. Anchoring of vessels, and associated coral damage, has been observed (T. Bright, Texas A&M University, 1981; personal communication) in the Flower Garden Banks. Vessel operators, unaware of coral's importance or presence in the area, may anchor occasionally. After implementation of the FMP, the Flower Garden Banks will be marked on standard nautical charts as being off-limits to anchoring; vessels may easily anchor in other locations in the same general area.

B. The economic impact of prohibiting the use of bottom longlines, traps and pots, and bottom trawls is zero. The use of this gear in the three regulated HAPCs is very limited or nonexistent presently. Fishermen may use this gear in other areas of the FCZ consistent with regulations in other FMPs, e.g., Reef Fish, etc. The fish resource remains available to all fishermen by use of other, nonrestricted gear.

6. Other Measures to Achieve OY

A. The long-term economic impact of this recommendation to the Secretary would be maintenance of coral and coral reef as habitat and for nonconsumptive uses. An approximate economic value for all these uses is provided in Section IV.C, below and includes the $300 million in value of coral associated marine life cited above in the Summary section. Another benefit is the long-term reduction in effort required to enforce regulations associated with the plan. Cost to the federal government from this recommendation depend on the availability of budget funds and the extent of the educational program supported by the Department of Commerce.

B. The long-term economic impact of this recommendation to the Secretary would be a reduction of duplicative and overlapping regulations on industry enforced by several state and federal agencies. Industry productivity may increase, as well as revenue, and cost may decrease. Costs to the federal government from this recommendation may decrease from present levels depending on the extent that duplication and overlapping regulations, and their enforcement, is eliminated.

C. The long-term economic impact of this recommendation to the Secretary would be maintenance of the octocorals and their contribution to overall marine life productivity and value. Present data are inadequate to determine the exact contribution octocorals provide, but it is believed to be major since as a group octocorals are one of the most common species of coral. Costs to the federal government from this recommendation to the Secretary should be zero in the short term because of the adequate capacity of the existing monitoring programs of several state and federal agencies.

B. Alternative Management Measures

1. The economic impact of this measure would be the imposition of unnecessary regulations on industry and the public, as well as increased costs to the federal government for enforcement. Industry (see FMP Section 9.0) would be burdened with regulation which is presently unsupportable with the best available scientific data (except for stony corals and sea fans). Furthermore, the measure implies some level of harvest for coral species, which is contrary to the OY for coral and coral reefs. Enforcement costs for this measure and other alternative measures are discussed below in Section IV. C.

2. This measure was rejected because its implementation would have been a recommendation for resear to the Secretary. This measure is covered in Proposed Management Measure 6. C.

3. This measure was rejected because its implementation by the Councils is not consistent with their authority. The measure is a recommendation to the Secretary and is covered in Proposed Management Measure 6. A.

4. This measure would have resulted in unknown and possibly adverse effects on coral and coral reef productivity. Data is not adequate to identify particular species, excepting octocorals, for a trial fishery. The restrictions of a trial fishery, including some form of limited entry and/or an overall allocation, may discourage industry participation. Costs to the federal government may be substantial for enforcing the restrictions of a trial fishery depending on the range of the fishery, number of participants, the threat to the resource from overfishing, and the duration of a trial fishery.

5. The impact of this measure would be the exploitation of a type of stony coral, a species with a zero harvest level. Although the harvest of rose coral is presently unregulated in the FCZ, in 1976 Florida prohibited harvest in its territorial waters and possession of rose coral. Since almost all the rose coral is located off of Florida, for all practical purposes there is no fishery at present. Adoption of this measure would create enforcement difficulties for the state and an inconsistency with the OY specification for stony corals.

6. The impact of the No Action alternative would be potential loss in coral and coral reef productivity and destruction of the resource through avoidable man-made and natural causes. Loss of the resources' productivity would jeopardize at least a part of the $300 million in annual benefits to important marine fisheries and several million dollars in economic activity to nonconsumptive activities, i.e., diving and sightseeing.

With the possibility of unregulated harvests in the FCZ, the resource appears to be under an unacceptable biological risk. The No Action alternative does not comply with the intent of MFCMA and National Standard one because it would allow an activity which would result in overfishing.

Incremental costs to industry (marine fisheries), the public, and government would mean the gradual loss in revenue, recreational participation, and taxes from decreased coral and coral reef productivity.

7. A. The impact of this measure would be an unnecessary regulation and an increase in costs to the federal government for enforcement. Sand Key and Sambo Reefs are not included as HAPCs because of their similarity and proximity to other HAPCs in the Florida Reef tract and because they are located in the territorial sea.

   B. The impact of this measure would be an unnecessary regulation and an increase in costs to the federal government for enforcement. Available data are insufficient to make a recommendation at this time for inclusion as an HAPC.

   C. The impact of this measure would be an unnecessary restriction of gear where it might be used without significant damage to coral. Only major, representative areas of the coral are included in the restricted areas designated as the HAPCs.

   D. Special measures were rejected after Looe Key was designated as a National Marine Sanctuary under NOAA's CZM program.

8. The impacts of this measure would be an unnecessary regulation by the federal government, a regulatory burden on industry, and an increase in costs to the federal government for enforcement. Enforcement itself may be difficult since the State of Florida has no regulations covering the harvest of octocorals.[1] The available data do not support restrictions on user groups presently (except in HAPCs), and Proposed Management Measure 3. B.(c) covers the potential for excessive local harvests. Under this measure permit holders, estimated at 40 to 50, would be subject to mandatory statistical reporting; at $25 annually per respondent, cost to the federal government would be $1,000 to $1,250. Processing of permits would cost $10 each.

C. Comparison of the Impacts of the Proposed and Alternate Measures

Among three management regimes evaluated, i.e., the preferred, the alternative, and No Action, the preferred management regime protects the resource and maintains its productivity best of all, minimizes the regulatory burden on the industry and public, and minimizes costs to the industry, public, and government.

1. Proposed Measures

The Proposed Measures are the Councils' approach to achieving the FMPs objectives, and to be consistent with MFCMA, the National Standards, and other applicable law and policies (such as E. O. 12291). The proposed management measures will help to maintain coral and coral reef productivity for nonconsumptive as well as consumptive uses. In addition to a large but unquantifiable esthetic value to coral, it serves as a vital habitat area to several commercially- and recreationally-important marine species; without the coral habitat, the continuation of fisheries for these species would be in jeopardy. These fisheries and associated annual economic values are listed directly below.

Fisheries Dependent on Coral Habitat

Fishery	Area	Sector	Annual Value[2]
Spiny lobster	Gulf and South Atlantic	Commercial Recreational	$ 16 million
Pink and rock shrimp	Gulf and South Atlantic	Commercial	$ 25 million
Reef Fish	Gulf	Commercial	$ 15 million
Reef Fish	Gulf	Recreational	$100 million
Reef Fish	South Atlantic	Commercial	$ 4 million (1977)
Reef Fish	South Atlantic	Recreational	$135 million (1975)
		TOTAL	$295 million

Source: Respective FMPs.

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[1] The exception is that the state prohibits harvest and possession of sea fans, as the FMP proposes (except for research and education).

[2] Commercial values are at exvessel level only.

While the total value of these species cannot be attributed to the presence of coral and coral reefs the reefs do serve as important sources of habitat for these species.

In addition to the nonconsumptive values, there is also the economic activity generated through diving (SCUBA and snorkeling) throughout the management area and through sightseeing (e.g., glass-bottom boats). Although it is difficult to estimate precise dollar amounts attributable to coral and coral reefs, almost half of all divers surveyed (Skin Diver Survey, 1977) do so for reef exploration; Florida is one of the top two states with the most number of divers; the average total investment and average annual trip expenditures by a diver was $942 and $646, respectively (Skin Diver Survey, 1977). Charter-boat activities are also important economically and are described in detail in FMP Section 9.1.2.1. Finally, the value of harvested octocorals is believed to range between $15,000 and $25,000 annually (FMP Section 9.1.1.2).

Cost of the preferred management measures include a maximum of $1,700 and $180 for statistical reporting and processing of permits, respectively; in addition, there is a potential cost of $222,683 for enforcement, to be conducted by NMFS, U.S. Coast Guard, and state agencies where cooperative agreements already exist. This is the estimated cost of full scale enforcement if a sufficient level of funding and enforcement vessels were available. Whichever management regime is selected, development costs for this FMP have already occurred. These costs are approximately $300,000 by both Councils.

The impacts of the proposed measures, according to the criteria listed above in Section III. A, are indicated in Table 1.

2. Alternate Measures

The alternate measures, including No Action, do not protect the resource and the habitat value it provides to important marine fisheries. Existing scientific information would not support unregulated

Figure 1. Option I - Proposed shelf-edge *Oculina* Coral Reef Habitat Area of Particular Concern (HAPC) off central eastern Florida. (Triangle = *Oculina* coral reef bank, 17-25 m relief; x = coral thicket; dot = colonies of live coral).

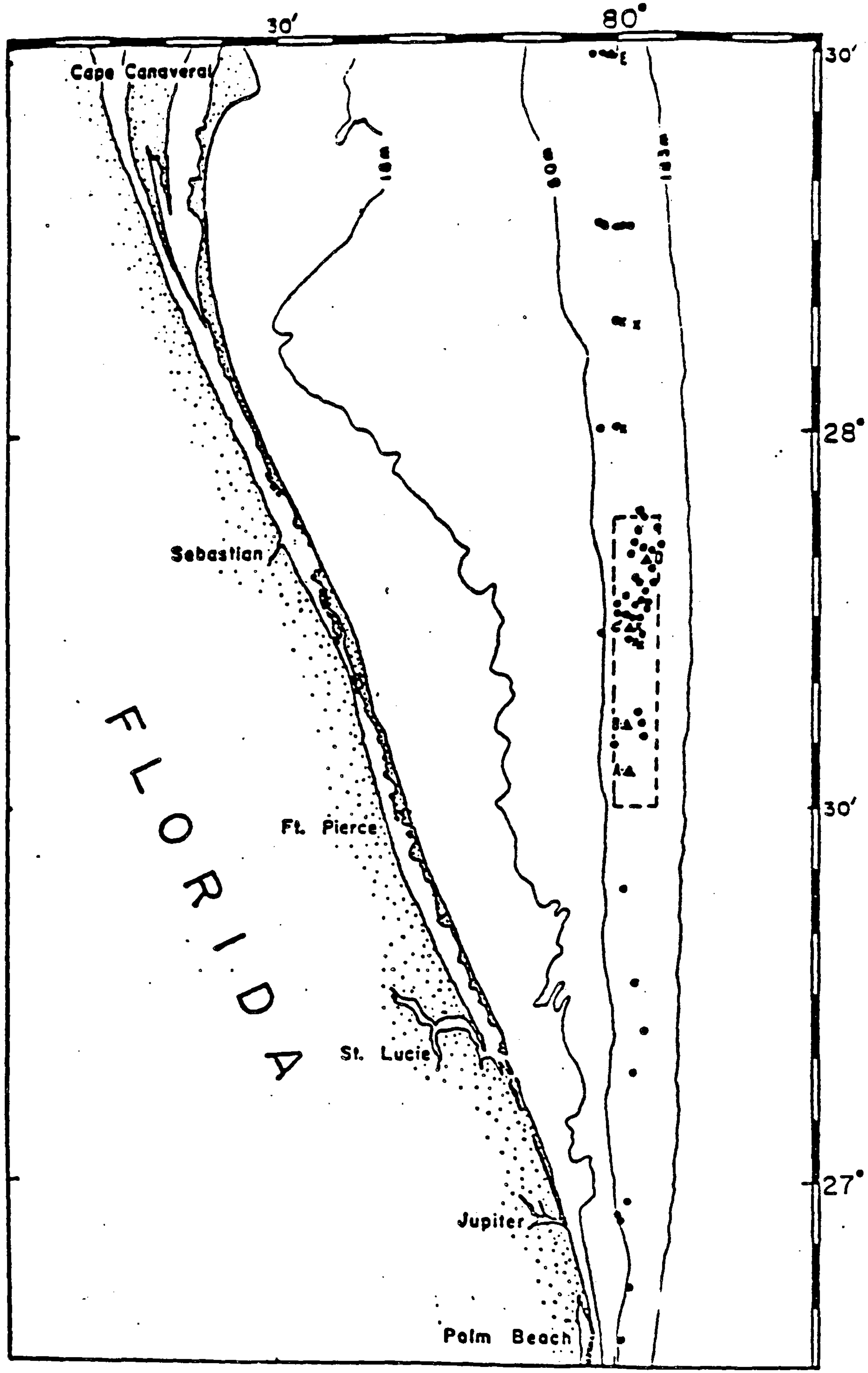
30'
80°
30'
28°
30'
27°
Cape Canaveral
Sebastian
Ft. Pierce
St. Lucie
Jupiter
Palm Beach
FLORIDA

Table 1. Summary of Economic Impacts of the Proposed Management Measures

Proposed Management Measure	Price	Supply	Employment	Revenues	Productivity	International Impact	Market Structure	Government Costs	Recreational Participation
1. A.	0	0	maintain	maintain	40 - 50 hours reporting	0	0	0[1]	maintain
B.	0	0	0	0	18 hours reporting	0	0	$180	0
Statistical Reporting								$1,450 - $1,700	
2. See Measure 5 below									
3. A.	0	0	0	0	0	0	0	0	0
B.(a)	0	0	0	0	maintain	0	0	See 4	maintain
(b)	0	0	0	0	slight increase in sorting time	0	0	See 4	0
(c)	may decrease	may increase	may increase	may increase	uncertain	0	0	See 4	0
4.	0	0	maintain	maintain	maintain	0	0	$116,500[2]	maintain
5. A.	0	0	maintain	maintain	maintain; large vessels must use other sites for anchoring	0	0	See 5.b	maintain

Table I (contd.) Summary of Economic Impacts of the Proposed Management Measures

Proposed Management Measure	Price	Supply	Employment	Revenues	Productivity	International Impact	Market Structure	Government Costs	Recreational Participation
5. B.	0	0	maintain	maintain	maintain	0	0	$65,268[2]	maintain
C.	0	0	maintain	maintain	maintain	0	0	$ 25,165[2]	
6. A.	0	0	maintain	maintain	maintain	0	0	-[3]	maintain
B.	0	0	0	0	possible reduction of regulations	0	0	possibly reduce	0
C.	0	0	maintain	maintain	maintain	0	0	0	maintain
Summary				maintain annual revenues of over $300 million	58 - 68 hours reporting			$180 permit costs $1,450 - $1,700 statistical reporting $222,683 enforcement[2] $224,313 - $224,563	

[1] Assumes dual-permit system with FDNR as Regional Director's designee.

[2] Federal government enforcement; source: C. Fuss, Law Enforcement Division, NMFS, St. Petersburg, Florida, March 31, 1982. Estimates above under separate measures are for Coast Guard only. NMFS estimate is $15,750.

[3] Depends on the availability of funds and scope of program.

Table 2. Summary of Economic Impacts of the Alternative Management Measures

Management Measure	Price	Supply	Employment	Revenues	Productivity	International Impact	Market Structure	Government Costs	Recreational Participation
1.	possibly increase	possibly decrease	possibly decrease	possibly decrease	decrease; more regulation	uncertain	tend to concentrate	-[1]	uncertain
2.	0	0	0	0	possibly maintain	0	0	-[2]	uncertain
3.	0	0	maintain	maintain	maintain	0	0	-[2]	maintain
4.	uncertain	uncertain	uncertain	uncertain	uncertain; more regulation	0	uncertain	-[1]	uncertain
5.	possibly decrease	possibly increase	possibly increase	possibly increase	short-term increase; long-term negative	0	0	-[1]	uncertain
6.	possibly decrease	possibly increase	uncertain	risk losing revenue from dependent marine fisheries, $300 million annually	risk of over-harvest	uncertain	uncertain	-[1]	decrease
7. A.	uncertain	uncertain	uncertain	uncertain	possibly main-tain; more regulation	0	uncertain	-[1]	uncertain

Table 2 (contd.) Summary of Economic Impacts of the Alternative Management Measures

Management Measure	Price	Supply	Employment	Revenues	Productivity	International Impact	Market Structure	Government Costs	Recreational Participation
7. B.	uncertain	uncertain	uncertain	uncertain	possibly maintain; more regulation	0	uncertain	-[1]	uncertain
C.	uncertain	uncertain	uncertain	uncertain	possibly maintain; more regulation	0	uncertain	-[1]	uncertain
D.	uncertain	uncertain	uncertain	uncertain	possibly maintain; more regulation	0	uncertain	-[1]	uncertain
8.	0	0	0	0	more regulation; 40 - 50 hours reporting	0	uncertain	$1,000 - $1,125 reporting costs; $400 - $500 for permits; plus enforcement	uncertain
Summary				risk of losing value of related marine fisheries; $300 million per year	40 - 50 hours reporting burden; more regulation			$301,013 maximum in costs to federal government	

[1] Enforcement cost of $299,388. Source: C. Fuss, NMFS, April, 1982.

[2] Dependent on level and availability of funding.

fishing or even trial fisheries for an indeterminate number of species. Any short-term benefits from increased harvest to coral would be greatly exceeded by declines in landings and value of coral-dependent marine fisheries. The No Action alternative in particular would expose coral and coral reefs to indiscriminate destruction by commercial and amateur collectors.

The costs of the alternative measures are greater than those of the preferred measures. The cost of the No Action alternative in particular is the risk of losing the value of coral-dependent marine fisheries and other activities, upwards of $300 million annually. This loss would be felt by the industry and public. Costs of the alternate measures, excluding No Action, include up to $500 for processing of permits, up to $1,250 for statistical reporting, and $299,388 for enforcement; the enforcement estimate is the best estimate since the alternative measures are generally more restrictive and require more regulations than the proposed measures. Alternative FMP development costs of $300,000 would still be applicable in the No Action alternative.

The impact of the alternative measures, according to the criteria listed above in Section III. A, are indicated in Table 2.

D. Paperwork Reduction Act (44 U.S.C. 350 et seq.)

The proposed management measures will not increase the reporting burden for commercial, scientific, and educational users significantly, or over present amounts (Florida requires reporting of its permit holders, and FDNR may be the Regional Director's designee). The major change will be a shift from voluntary to mandatory reporting and the addition of needed information. Actual costs and reporting burdens are indicated in Measure 1, Section IV, A.

E. Regulatory Flexibility Act (5 U.S.C. 601 et seq.)

A review of this FMP indicates that there will be no significant economic impacts from its implementation on small business entities in the coral and coral reef fishery, or other related fisheries. The statistical reporting and permit requirements are not major impediments to business activity and, in almost all cases, the requirements are already in place through State of Florida regulations.

The proposed rule was published in the Federal Register (48 FR 39255) for a period from August 30, 1983, through October 14, 1983. No comments were received from small businesses objecting to this proposed rule. Due to the absence of negative comments from small businesses, NOAA concludes that this rule will not have an adverse impact on small businesses.

F. Determination of Major/Minor Rule

This FMP is a minor rule under the interim guidelines established on June 17, 1981, by the Office of the Assistant Administrator for Fisheries. This determination of a minor rule for this FMP is based on the insignificant impacts as a result of this FMP on the following criteria:

1) increase in the total cc.* or price of goods of $5 million per year;
2) increase in cost or prices of ten percent or more;
3) adverse impact on competition;
4) adverse impact on employment;
5) adverse impact on investment;
6) adverse impact on productivity;
7) adverse impact on exports.

REFERENCES

Shinn, E.A. 1979. Collecting biologic and geologic specimens in south Florida. Atlantic Reef Committee, Information Circular No. 1. 4 pp.

1980. Scientific Collecting in South Florida: Problems With Permits. Coastal Zone '80, Vol. III:2017-2026.

Skin Diver. 1977. Reader Survey '77; Petersen Publishing Company, Los Angeles, California.

APPENDIX L. SUMMARY OF PUBLIC COMMENT

This appendix summarizes testimony on the draft FMP/EIS at five public hearings or submitted by letter to the Councils and the National Marine Fisheries Service. Some letters from associations and agencies are included in this appendix.

Appropriate responses to the comments have been provided herein by the Councils.

Oculina Bank HAPC

(1) Comment: A portion of the Oculina coral bank off Florida's central east coast should be included as a HAPC with special regulations to protect the coral from damage from fishing gear.

(2) Comment: The boundary lines should exclude adjacent scallop fishing grounds which extend to about 39 fathoms.

(3) Comment: Bottom longlines and fish traps are not set on coral where there is danger of gear loss but are set in close proximity.

(4) Comment: A proposed area of 390 nautical square miles is too large because in much of the area prohibited gear can be used without damage to coral.

(5) Comment: Boundary of HAPC should be extended northward to off Daytona Beach where rough bottom may contain Oculina coral.

(6) Comment: Roller trawl fishermen avoid trawling over coral banks because of possibility of gear loss.

(7) Comment: Gear should not be prohibited without documentation that it causes damage in use.

(8) Comment: Establishment of a 390 square mile area in which fish traps are prohibited is discriminatory against commercial fishing and thus violates National Standard 4.

Response to Comments 1 through 8: The Councils have included as an HAPC only a representative portion of the Oculina Banks containing the highest known density of these coral thickets. Only gear types which are destructive of coral are prohibited in the four by 23 mile area. Fishermen may use other gear for commercial or recreational fishing.

Florida Middle Grounds HAPC

(9) Comment: The boundary of the HAPC is too large and includes substantial area where prohibited gear may be used without damage to coral.

(10) Comment: Anchor damage may have more impact than damage inflicted by bottom longlines.

(11) Comment: The prohibition of bottom longlines and fish traps should be extended to all areas inside of 20 fathoms and to the "elbow" area off Tarpon Springs.

Response to Comments 9 through 11: The Councils have adjusted the boundaries of the HAPC to include the high relief area containing coral and exclude areas where prohibited gear may be used without damaging corals. Anchor damage by small vessels at this time appears to be within an acceptable level, and anchoring is almost essential in some fishing activities and for safe diving practices. Restriction of bottom fishing gear in high use areas is more appropriately addressed in the reef fish plan.

Flower Garden Banks HAPC

(12) Comment: Concern that anchoring by vessels under 100 feet in length can damage coral.

Response: See response to Comment 10.

(13) Comment: The boundary of the HAPC would be better defined by using geographic coordinates or a depth contour as shown on navigational charts.

Response: The boundary has been changed accordingly to follow the 50 fathom contour.

(14) Comment: The plan and DEIS do not adequately address possible coral damage from oil and gas development and exploration activities.

Response: Lease agreements for oil and gas exploration and production issued by BLM stipulate measures and practices for the protection of corals. Additionally, the Environmental Protection Agency regulates discharge of materials that may be harmful to corals. While this plan proposes regulations to prohibit destruction of stony corals, these agencies have more effective control with authority to regulate nonfishing activities that may pose a threat to the coral.

(15) Comment: Consider the use of mooring buoys to minimize anchor damage to corals.

Response: Mooring buoys were considered; however, the size and cost at the Flower Garden Banks plus damage potential from tether chains far outweighed any benefit to be obtained. Restriction to anchoring by smaller vessels was a more practical alternative.

(16) Comment: There should be no fishing on the Flower Garden Banks.

Response: The Councils found no indication of overfishing of fishes and thus do not restrict fishing except gear detrimental to coral.

(17) Comment: The lower portions of the Flower Garden Banks (below 100 meters) should be included in the HAPC because of the presence of crinoids.

Response: There may well be other fragile ecosystems in need of some type of management; however, the objectives of this FMP are necessarily restricted to the management of corals.

(18) Comment: Include additional coral areas as HAPCs.

Response: The FMP prohibits the taking or destruction of all stony corals and sea fans in the management area. Additional special restrictions may apply in HAPCs. Areas which meet the criteria set forth in the FMP (Section 6.3) may be nominated for inclusion as HAPCs by plan amendment.

(19) Comment: HAPCs could be better managed as National Marine Sanctuaries.

(20) Comment: The designation of HAPCs is a duplication of effort and thus violates National Standard 7.

Response to Comments 19 and 20: The FMP identifies coral habitats in the management area which meet the criteria set forth. Where management is provided by other agencies, no regulation is proposed through the FMP. In fact the Councils were in coordination with the Office of Coastal Zone Management during the development of Looe Key and Gray's Reef as National Marine Sanctuaries. This action assured that any management regime proposed to the Secretary would address the concerns of the Councils and OCZM.

Permits

(21) Comment: Would tropical fish collectors need both Florida and NMFS permits to use chemicals to collect fish?

Response: Management Measure 4 in Section 12.4 has been modified to recommend that a compatible permit arrangement be established with the Florida Department of Natural Resources.

(22) Comment: Would permits be issued to allow removal of stranded vessels on coral reefs?

Response: Management Measure 1, Section 12.4, prohibits the destruction of coral and coral reefs. Indeed U.S. v. Alexander was brought about by the destruction of a portion of Looe Key during the salvage of a grounded vessel. While no permit arrangement is provided, prosecutorial discretion would be warranted in such instances of unavoidable loss of coral.

(23) Comment: The issuance of permits for scientific and educational collection of stony corals and sea fans could result in a limited entry program.

Response: The Councils have clarified intent in guidelines for issuing permits (Section 12.4, Measure 2).

(24) Comment: Mandatory reporting should be required of permit holders.

Response: Section 12.4, Measure 2, provides for this.

(25) Comment: The FMP is unnecessary, all HAPCs are either established or nominated National Marine Sanctuaries.

(26) Comment: The states can better manage coral; federal management is unnecessary.

Response to Comments 23 and 24: Section 4.0 has been revised to provide the Councils' rationale in determining that management is needed and justified.

(27) Comment: There is no evidence to show that fishing gear prohibited in the HAPCs destroys or damages coral.

Response: The scientific literature contains little documentation on the impact of fishing gear on coral, probably because it is a basic assumption. Section 6.2.1 (fishing) does cite some instances of damage, however. Because the Councils do not wish to restrict gear use unnecessarily, they have confined such restriction to three HAPCs. The boundaries have been reduced to include a minimum of bottom fishable by the prohibited gear.

(28) Comment: BLM and OZCM are not protective in the Gulf of Mexico.

Response: Each agency has its own authority and responsibility. Section 12.4, Measure 7, addresses coordination among the various agencies.

(29) Comment: Inadvertent harvest of coral should be reported.

Response: Section 12.4, Measure 3, requires the return to the water of stony coral and sea fans taken incidentally in other fisheries. Exception is provided for unsorted catches where no significant amount is expected to be taken.

(30) Comment: How many enforcement overflights are included in cost estimates?

<u>Response:</u> Cost estimates were based on 38 hours of flying time, some of which may be in multipurpose patrols, i.e., closed shrimp season, drug patrol, etc.

(31) Comment: Fines for violation should be substantial enough to cover expensive enforcement costs.

<u>Response:</u> The MFCMA provides for civil penalties not to exceed $25,000 for each offense.

(32) Comment: All ages of corals and each reefal ecosystem should be protected.

<u>Response:</u> Section 12.4, Measure 1, prohibits the taking or destruction of stony corals and sea fans and coral reefs.

JAN 29 1982

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1201 ELM STREET
DALLAS, TEXAS 75270

January 26, 1982

Mr. Wayne E. Swingle
Executive Director
Gulf of Mexico Fishery Management Council
Lincoln Center, Suite 881
5401 West Kennedy Boulevard
Tampa, Florida 33609

Dear Mr. Swingle:

We have completed our review of your Draft Environmental Impact Statement (EIS) for the Fishery Management Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic. Generally, the material reviewed was thorough and well prepared; however, the effects of oil and gas exploration on reef banks was discussed too briefly (see page 6-12). Additional information can be found in the "Preliminary Report: An Environmental Assessment of Drilling Fluids and Cutting Released onto the Outer Continental Shelf" prepared in 1981 by the Industrial Permits Branch and the Ocean Programs Branch of EPA in Washington, D.C.

We classify your Draft EIS as LO-1. Specifically, we have no objections to the project as it relates to Environmental Protection Agency's (EPA) legislative mandates. The Statement contained sufficient information to adequately evaluate the possible environmental impact which could result from project implementation. Our classification will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions under Section 309 of the Clean Air Act.

Definitions of the categories are provided on the enclosure. Our procedure is to categorize the EIS on both the environmental consequences of the proposed action and on the adequacy of the EIS at the draft stage, whenever possible.

We appreciated the opportunity to review the Draft EIS. Please send our office five (5) copies of the Final EIS at the same time it is sent to the Office of Federal Activities, U.S. Environmental Protection Agency, Washington, D.C.

Sincerely yours,

Frances E. Phillips

for Dick Whittington, P.E.
Regional Administrator

Enclosure

ENVIRONMENTAL IMPACT OF THE ACTION

LO - Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER - Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to re-assess these aspects.

EU - Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

ADEQUACY OF THE IMPACT STATEMENT

Category 1 - Adequate

The draft impact statement adequately sets forth the environmental impa of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 - Insufficient Information

EPA believes the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3 - Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement. If a draft statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make a determination.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
OFFICE OF COASTAL ZONE MANAGEMENT
Washington, D.C. 20235

CZ/SP/CC

February 1, 1982

FEB
TAMPA, FLORIDA 33609

Mr. Wayne E. Swingle
Executive Director
Gulf of Mexico Fishery Management Council
Lincoln Center, Suite 881
5401 West Kennedy Boulevard
Tampa, Florida 33609

Dear ~~Mr. Swingle~~ Wayne:

We have reviewed the draft Fishery Management Plan (FMP) for Coral Reef Resources (December 1981) and, in accordance with our established Memorandum of Understanding which provides for exchange of information and advice, we offer the following comments.

We are pleased that our previous comments on the FMP (February 2, 1981) were incorporated into this draft. For the most part, the FMP adequately and accurately describes the Office of Coastal Zone Management's (OCZM) role in managing national marine sanctuaries which complement the protection objectives of the FMP; however, a few sections could be improved as follows:

o page 2-4, section 2.7.5.b.d. To be consistent with descriptions of the other national marine sanctuaries, the description of Key Largo Coral Reef National Marine Sanctuary should be expanded to include location, area, and special management measures. I suggest the following:

> Key Largo Coral Reef National Marine Sanctuary. Designated in 1975, this sanctuary consists of a one hundred square nautical mile section of the upper Florida reef tract. Regulations prohibit, among other activities, removal or destruction of hard and soft corals within the boundaries of the sanctuary.

o page 6-28, section 6.3. The description of Looe Key National Marine Sanctuary should include reference to sanctuary regulations to be consistent with descriptions of the other national marine sanctuaries. I suggest that the following sentence be inserted after (Antonius et al., 1978) in the second paragraph:

> In order to protect the reef's resources the following activities are prohibited: taking or damage to sanctuary resources, including tropical fish and corals; spearfishing; using wire fish traps, poisons, or electric charges; littering; and lobster trapping within the forereef area of the Sanctuary.

o <u>page 7-1, section 7.1.2.</u> Reference to Gray's Reef National Marine Sanctuary is not included.

We appreciate the opportunity to comment on the coral FMP. We feel sure this cooperative exchange of ideas can only lead to more effective implementation of both our programs.

Sincerely,

Nancy

Nancy Foster
Deputy Director
Sanctuary Programs Office

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS: (G-OI
U.S. COAST GUARD
WASHINGTON, D.C. 20593
PHONE: (202) 755-115

A4:A-26
16214

FEB 11 1982

Mr. O. B. Lee, Chairman
Gulf of Mexico Fishery Management Council
Lincoln Center, Suite 881
5401 W. Kennedy Boulevard
Tampa, Florida 33609

Dear Mr. Lee:

The Draft Fishery Management Plan/Environmental Impact Statement (DFMP/EIS) for Coral and Coral Reefs dated November 1981 has been reviewed. The management measures are straightforwarded and generally should offer no problems to enforcement. The measures outlined should not require extensive additional Coast Guard enforcement effort.

It is understood that the general prohibition on taking coral will be enforced primarily at dockside by the NMFS and the Florida Department of Fish and Wildlife. Coast Guard enforcement will center around protection of the Flower Garden Banks and Florida Middle Grounds, habitats of particular concern. Enforcement in other areas will be incidental to enforcement of other FMPs and other laws. This will provide an efficient enforcement method at a moderate cost.

The East and West Flower Garden Banks first described on pages 6-22 would be best described by geographic coordinates such as described below:

> The East and West Flower Garden Banks habitat of particular concern is that area described by rhumb lines connecting the following points:
>
> C_1 27°46.5´N latitude, 93°57.0´W longitude;
> C_2 27°56.0´N latitude, 93°57.0´W longitude;
> C_3 28°04.0´N latitude, 93°32.0´W longitude;
> C_4 27°51.0´N latitude, 93°28.0´w longitude;
> C_5 27°47.0´N latitude, 93°45.5´W longitude;
> C_1 27°46.5´N latitude, 93°57.0´W longitude.

This will enable aircraft (the primary enforcement platform) to easily determine whether or not vessels are inside the area. It will also simplify the navigation problem of vessels in the area.

Since aircraft cannot determine the depth of water a vessel is actually in, it is recommended that water depth as a criteria for fishing and anchoring restrictions not be used. A depth contour such as the 50 fathom (91.5 m) contour as shown on navigational charts would be an appropriate limit.

Subj: Comments on the Draft Fishery Management Plan/Environmental Impact Statement for Coral and Coral Reefs dated November 1981

In Section 13.10 the costs of Coast Guard enforcement have increased. Paragraph 1.6 Cost of Patrols, is now $4440 per day using an average of 95 foot and 82 foot class patrol boats for a total of $106,500 for 24 patrol days. Paragraph 2.b. Cost of patrols is now $1813 per hour using an average cost of HC-130, HC-131 and HH-3F helicopters for a total of $65,268 for 36 patrol hours. This total cost of enforcement of $171,828 reflects current fiscal year 1982 estimates of Coast Guard costs.

The opportunity to comment on this DFMP/EIS is greatly appreciated. If you have any questions regarding this matter please contact LT Bill CHAPPELL of my staff at (202) 755-1155 commerical or FTS.

Sincerely,

B. F. THOMSON, III
Commander, U.S. Coast Guard
Chief, Fisheries Law Enforcement Branch
By direction of the Commandant

Copies to:

SAFMC
CCGD7 (oil)
CCGD8 (oil)
COMLANTAREA (Aol)
NMFS, F/CM5
NMFS, F/CM6
NMFS SER
COMDT, G-WS-1

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAR 1 1982

In Reply Refer to ER 81/2660

Wayne E. Swingle, Executive Director
Gulf of Mexico Fishery Management Council
Lincoln Center, Suite 881
5401 West Kennedy Boulevard
Tampa, Florida 33609

Dear Mr. Swingle:

This is in response to the request for the Department of the Interior's comments on the draft Fishery Management Plan/ Environmental Impact Statement for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic. We find the Management Plan/Impact Statement to be thorough and complete. With few exceptions, it takes a reasonable view of offshore oil and gas activities and does not propose unnecessarily strict prohibitions, even within designated Habitat Areas of Particular Concern (HAPC).

We believe that under some circumstances the prohibitions are not strict enough. Since anchoring is the single most important cause of damage to coral areas, we recommend that anchoring from any size vessel be prohibited within the Flower Garden HAPC and within those portions of the Florida Middle Ground HAPC that our Bureau of Land Management (BLM) has designated as "No Activity Zones" (map enclosed). Other HAPC's might benefit from such a prohibition as well. This Department has commented several times during the development of the Flower Garden Banks sanctuary proposal that anchoring damage from boats is our greatest concern. Our comments have stated that we believe the 100-foot vessel length restriction is too high and should be substantially lowered. We reiterate this concern and the concern that a mooring bouy system be required in the area.

The discussion of BLM's and Interior's roles in protecting and managing coral resources recognizes the pioneering efforts we have made in funding studies and managing coral areas in the Gulf of Mexico. Since the court decision in U.S. v. Alexander, which held that BLM authority to protect coral was restricted to activities connected to the administration of mineral leases, most coral and coral reefs are without management or protection. In general, because of the Alexander decision, BLM authority in this area has been negated. To the degree there is a need for management action, we support efforts through the Fishery Management Councils' plan to protect coral.

Specific Comments

Section 5.1. Information on, and classifications of, northern and northwestern Gulf of Mexico hard-bank communities could be enhanced considerably by using Texas A&M's five-volume report published in March 1981. It covers topographic highs from the Florida Middle Grounds to the Texas Hard Grounds. This is a continuation of BLM's study entitled "Northern Gulf of Mexico Topographic Features Study," Technical Report No. 81-2-T.

Pages 6-19 and 6-20. Continental Shelf Associates, Inc., could be added to the tables on these pages for mapping topographic highs and "live bottoms" in the Gulf of Mexico and South Atlantic. This is a BLM-funded study, August 1980, entitled, "Video and Photographic Reconnaissance of Phleger and Sweet Banks, Northern Gulf of Mexico."

Pages 6-23 and 6-24. A discussion should be included to describe how designation of the Flower Garden Banks as an HAPC and the protective measures proposed for them would change if the area is actually designated a National Marine Sanctuary.

Again, we reiterate our concern that the 100-foot vessel length anchoring restriction is too high.

Page 6-28 The area for Fort Jefferson National Mouument should be corrected to read 64,657 acres.

Page 6-32 to 6-35. The size of the Florida Middle Ground area (748 sq. miles) as deserving special management seems questionable. No justification is apparent as to why the entire area is critical or whether some smaller unit might be more deserving of special management protection. Also, the descriptions of the Florida Middle Grounds should be cited and listed in the "Literature Cited."

Page 6-36. Depiction of the Key West National Wildlife Refuge in Figure 6-11 is inaccurate. The Refuge includes all except one island west of Key West to the Marquesas Keys (see enclosed map). Fish and Wildlife Service jurisdiction, however, includes only upland, not marine habitat.

Page 6-39. The statement in the third paragraph that "...recent OCS Sale No. 48 in the Gulf of Mexico..." is in error; Sale 48 was a Pacific sale. Also, the reference cited (Bureau of Land Management, 1978) is not in Section 17.0, "Literature Cited."

Page 6-40. The National Natural Landmarks Program is listed as being administered by the Heritage Conservation and Recreation Service. The Heritage Conservation and Recreation Service has been abolished and most of its programs have been transferred to the National Park Service, including the National Natural Landmarks Programs.

Page 7-2. The second paragraph under Fish and Wildlife Service (FWS), DOI, should read "The FWS, under Department Manual 655-1, is also involved ..." The Secretarial Order was a temporary measure, and the coordination procedure is now included in the DOI Manual.

Page 7-9, 7.4.2. Flordia's CZM plan has been approved.

Page 12-9. We enthusiastically support Measure 7. Because of the extensive nature of overlapping jurisdiction among agencies that have roles in protecting coral, a system of coordination such as Memoranda of Understanding could serve a useful purpose.

Page 17.1. Adams is listed incorrectly. He was with BLM before coming to Fish and Wildlife Service (FWS) over 2 years ago. Likewise, Table 6-4 (page 6-19) should be changed to show that Adams is now with the FWS.

Page 17-6. The citation is incomplete for Davidson 1979.

In summary, we support the Fishery Management Councils' and National Marine Fisheries Service's proposal for management of coral and coral reef resources and thank you for the opportunity to review the EIS and Plan.

Sincerely,

Bruce Blanchard, Director
Environmental Project Review

Enclosure

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553

REPLY TO
ATTENTION OF:

SWGED-E

8 March 1982

Mr. Wayne E. Swingle
Executive Director
Gulf of Mexico Fishery Management
Council
Lincoln Center, Suite 881
5401 West Kennedy Boulevard
Tampa, FL 33609

Dear Mr. Swingle:

This is in response to letter from Ms. Joyce M. T. Wood dated 11 December 1981, which provided a copy of a Draft Environmental Impact Statement/Fishery Management Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic, for review and comments.

We have no comments on the document. The opportunity to review the document is appreciated.

Sincerely,

JOSEPH C. TRAHAN
Chief, Engineering Division

Copy furnished:
Ms. Joyce M. T. Wood
Director
Office of Ecology and
Conservation
U.S. Department of Commerce
Room 5813
Washington, D.C. 20230

DEPARTMENT OF THE AIR FORCE
REGIONAL CIVIL ENGINEER, EASTERN REGION (HQ AFESC)
526 TITLE BUILDING, 30 PRYOR STREET, S.W.
ATLANTA, GEORGIA 30303

RECEIVED
MAR 1 1982
GULF OF MEXICO FISHERY MANAGEMENT C.
5401 W. KENNEDY BLVD., SUITE 881
TAMPA, FLORIDA 33609

REPLY TO ATTN OF: ROV2

24 February 1982

SUBJECT: Review of the Draft Fishery Management Plan Environmental Impact Statement (EIS) for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic

TO: Gulf of Mexico Fishery Management Council
Attn: Mr. Wayne E. Swingle
Executive Director
Lincoln Center
5401 West Kennedy Boulevard
Suite 881
Tampa, Florida 33609

1. We have reviewed the subject EIS and have the following comments:

a. Development of a fishery management plan for the area described in the memorandum attached to the subject EIS will not adversely affect normal Air Force operations in the Florida area.

b. Should it become necessary to search for and retrieve downed aircraft or other Air Force equipment in the described area we reserve the right to carry out any necessary underwater search and salvage operations in the interests of national defense.

2. Thank you for the opportunity to review this EIS. Our point of contact is Mr. Winfred G. Dodson, commercial telephone (404) 221-6821/6776 or FTS: 242-6821/6776.

Thomas D. Sims

THOMAS D. SIMS
Chief
Environmental Planning Division

Cy to: USAF/LEEV
6550 ABW/DEEV
US DOC/Ms. Wood
South Atlantic Fishery Council/Mr. Gould

HARBOR BRANCH FOUNDATION, INC.

LINK PORT • RR 1, BOX 196 • FORT PIERCE, FLORIDA 33450, U.S.A. • 305/465-240C

January 8, 1982

Mr. Wayne E. Swingle
Executive Director
Gulf of Mexico Fishery Management Council
Lincoln Center, Suite 881
5401 West Kennedy Blvd.
Tampa, Florida 33609

Dear Mr. Swingle:

Once again I urge the Gulf of Mexico and South Atlantic Fishery Management Councils to accept the shelf-edge Oculina coral reefs off central eastern Florida as a Habitat Area of Particular Concern (HAPC) in their Coral and Coral Reef Fishery Management Plan. This reef system is a major coral habitat, satisfying nearly all criteria for the identification of a HAPC, and its inclusion is necessary if all major coral community types are to be represented as HAPCs within the management area. I respectfully resubmit the nomination of the shelf-edge Oculina coral reefs as a HAPC. This nomination is enclosed as a separate report.

In accordance with the National Environmental Policy Act of 1969, I have reviewed the Draft Environmental Impact Statement/Fishery Management Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic (December, 1981 draft) and offer the following comments:

1) page 5-9, Table 5-3: Oculina varicosa Lesueur - known as far north as Cape Hatteras, North Carolina from subtidal to 152 m (Reed, 1980b). Known from West Indies and St. Thomas, Virgin Islands (Verrill, 1901; Quelch, 1886).

2) page 5-16, Fig. 5-4: Include shelf-edge Oculina banks as a prominent feature from Fort Pierce to Cape Canaveral, Florida along the 80° longitude (see attached Fig.).

3) page 5-17, 2nd paragraph: Oculina specimens collected from Gray's Reef have been identified as O. varicosa (specimen on loan from Ms. A. Edwards, Skidaway Institute Oceanography, GA, identified by J.K. Reed, Harbor Branch Foundation).

First of all, the denial based on the large area of the banks is inconsistent with the presently accepted HAPCs. Three options of an Oculina HAPC were proposed in my letter of November 18, 1980, to the Gulf of Mexico and South Atlantic Fishery Management Councils and consisted of areas covering 576, 366, and 92 n mi^2. This third option is well within the size limits of the HAPCs which include the Middle Grounds covering 748 n mi^2 and the Key Largo Coral Reef covering 100 n mi^2.

Secondly, the denial stating that the only potential threat is from roller trawls is incorrect. Other potential impacts include OCS oil and gas exploration and development, bottom longlines, traps, the discharge of substances (since the banks are along major shipping routes), anchors (lost anchor lines have been observed from submersibles on these banks), and other types of unregulated dredge and trawl gear.

11) page 17-19: add -

Reed, J.K. 1981. In situ growth rates of scleractinian coral Oculina varicosa occurring with zooxanthellae on 6-m reefs and without on 80-m banks. Proceedings Fourth Inter. Coral Reef Symposium, Manila Philippines, May, 1981.

Reed, J.K., R.H. Gore, L.E. Scotto, and K.A. Wilson. 1982. (In press). Community composition, structure, areal and trophic relationships of decapods associated with shallow- and deep-water Oculina varicosa coral reefs. Bulletin Marine Science 32(3).

12) page C-3, Appendix C: "A. danae Agassiz" should read "A. danae Agassiz".

13) page H-1, 2nd paragraph, 9th line: "scraped to depths of 203 mm" is incorrect, possibly should read "2-3 mm".

14) page I-2, section 1.3, 1st paragraph, 3rd line: "deeeer waters" should read "deeper waters".

Sincerely,

John K. Reed

John K. Reed

/sc

cc: Terrance Leary
Robert Mahood
David Gould
Joyce M.T. Wood

NOMINATION OF A HABITAT AREA OF PARTICULAR CONCERN (HAPC)

NOMINATED BY:

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SITE NOMINATED:

Shelf-edge Oculina coral reefs off central eastern Florida. This includes banks, thickets and rubble zones of the scleractinian Oculina varicosa. The banks consist of Oculina colonies growing up to 1.5 m high, hundreds of feet long, and capping pinnacles up to 25 m in relief at depths of 70-100 m.

GEOGRAPHIC LOCATION:

One of the following options is suggested:

1) Option I - 27°30'N to 28°35'N and 79°56'W to 80°02'W; 65 x 6 n mi; 390 n mi^2 (see Fig. 1). This area contains all the presently mapped shelf-edge Oculina banks (17-25 m relief), major Oculina thickets and coral rubble pinnacles (up to 25 m relief).

2) Option II - 27°30'N to 27°53'N and 79°56'W to 80°00'W; 23 x 4 n mi; 92 n mi^2 (see Fig. 2). This area contains four (presently known) Oculina banks, several thickets, and coral rubble pinnacles. The area off Sebastian has very irregular topography of high relief.

In addition, the longitudinal boundaries of either Options I or II could be based on bathymetric contours which would more precisely define the limits of the Oculina banks'

The greatest relief and densest coverage of Oculina coral, however, is in the area of the proposed HAPC off central eastern Florida.

1.b. Oculina varicosa is endemic to the management area (Table 5-3, Draft FMP/EIS for Coral and Coral Reefs, 1981). The banks of Oculina, however, occur exclusively in the region off eastern Florida although thickets and isolated colonies occur elsewhere.

The precious black coral Cirrhipathes (C. lütkeni, C. desbonii) are abundant within the proposed HAPC.

1.c. The shelf-edge Oculina reefs are a unique ecosystem. They are monospecific, comprised of a single species of colonial coral, and form delicately branched bushes 1.5 m in height, hundreds of feet long, and covering hills and pinnacles with 25 m relief. These are the only known banks comprised of monospecific colonial coral that occur on the continental shelf (< 200 m depth) anywhere in the U.S.A. The deep-water ahermatypic coral Lophelia prolifera forms banks at much greater depths of 420 to 869 m on the Blake Plateau and in the Gulf of Mexico (Stetson et al., 1962; Moore and Bullis, 1960).

The shelf-edge Oculina reefs are part of a system of topographical highs (discontinuous hills, pinnacles, and ridges) which stretches from Florida to North Carolina, but greatest relief and densest coral coverage is off Florida. Surrounding the coral capped pinnacles, the bottom is following scientific studies are completed or presently underway: Ecosystem research - The macroinvertebrates that are directly associated with Oculina were sampled quantitatively every 2-3 months for one year. Hundreds of species (see above) occur in dense populations on and among the coral branches. Over 2000 individual invertebrates were found on a single, 27 cm diameter colony. The community structure, areal and trophic relationships are being analyzed in addition to the effects of various environmental parameters on the community (see Reed et al., in press).

Species specific research - Studies are continuing on the growth rates of Oculina and the effects of various environmental parameters (Reed, 1981). Basically the coral is extremely slow growing at an average 1.6 cm/year. Studies are underway on breeding behavior and feeding habits of several of the grouper species including gag and scamp which depend on this coral habitat (R. Jones, G. Gilmore, HBF). Several papers have worked up the larval life histories of various species of decapod crustacea collected from the Oculina (see Scotto and Gore, in press; Gore, 1979; Gore et al., 1981; Wilson, 1980; Andryszak and Gore, in press). The larval history of a sipunculid worm, Golfingia misakiana, associated with the coral was described by Rice (1981). Miller and Pawson (1979) described a new subspecies of holothurian found on these reefs.

shelf; 6) the reasons the coral has faster linear growth rates in cooler, deeper water where it lacks zooxanthellae than it does in shallow water where it possesses zooxanthellae; 7) the accretion rate of the reefs; 8) the health of the reefs, are they dying and what caused the extensive areas of dead coral rubble. There are also questions as to the impact of offshore oil and gas development as well as the effects of trawlers and other fishing methods.

2.b. The shelf-edge monospecific banks of *Oculina* coral are unlike any other reef system on the continental shelf in the U.S.A. They demonstrate the building of deep-water pinnacles under cool and turbid conditions by a single species of coral which lacks zooxanthellae. (In shallow-water, however, *O. varicosa* possesss zooxanthellae but only forms small, < 30 cm diameter colonies and does not form thickets). From submersible observations it is postulated that individual hemispherical colonies coalesce to form long linear rows which grow into thickets and banks. Low relief hillocks may represent young bank formation. One 16 m high bank was probed with a rod to a depth of 3.7 m without hitting rock substrate. Only coral debris and mud was encountered.

The proposed sanctuary site is a unique region of topographical highs and apparently is a drowned reef and coastal region that was exposed during the last low sea level stand (10,000 - 14,000 B.P.) when the sea level was approximately 80 m lower than present. The eastern most

(Draft FMP/EIS for Coral and Coral Reefs, 1981). The fauna associated with Oculina have both temperate and tropical affinities. Many of the decapod crustaceans and fishes are eurythermic tropical species which can endure cold water (pers. comm., Dr. R.H. Gore, Smithsonian Inst.; G. Gilmore, HBF, respectively).

3. Exploitation

a. The black coral Cirripathes lütkeni (and C. desbonii) which has potential commercial value (Appendix D, Draft FMP/EIS Coral and Coral Reefs, 1981) is abundant in the proposed HAPC.

Specimens of Oculina spp. are also known to be sold in the marketplace such as shell shops for prices ranging from $1-3 for a 15 cm piece (Table 9-7, Draft FMP/EIS Coral and Coral Reefs, 1981) (It should be noted that Oculina arbuscula, O. diffusa and O. varicosa are all quite similar in morphology and could be easily confused by wholesalers). Large pieces of O. varicosa are occasionally for sale in dive and bait shops along the east Florida coast.

3.b. OCS oil and gas exploration and development have potential impacts on the proposed HAPC. The Secretary of the Interior is now considering opening up the entire OCS area from Virginia to the Florida Keys for oil and gas leasing (pers. comm., M. Rinkle, OCS Representative to Governor of Florida and Chairman of BLM Technical Group for South Atlantic).

4. Recreation

a. Grouper and snapper commercial fishing off Florida is dependent on the shelf-edge reef system as fishing, feeding, breeding and nursery grounds. Commercial finfish include scamp grouper, gag grouper, black sea bass, snowy grouper, red grouper, speckled hind, along with warsaw grouper, amberjack, red porgy, and red snapper (see Appendix 1 for scientific names).

Possible commercially important invertebrates include the delicate ivory tree coral, Oculina varicosa; black coral, Cirripathes lütkeni; and squid, Illex oxygonius. Illex sp. was seen to spawn on these reefs; previously its breeding grounds were unknown. Illex sp. is known to form an important portion of the diet of sailfish (pers. comm., Dr. B. Voss, Univ. Miami).

Recreational finfish which utilize these shelf-edge reefs either as feeding and breeding grounds or migration pathways include snapper, grouper, king mackeral, amberjack, little tunny, sailfish, wahoo, tiger shark and hammerhead (see Appendix 1).

Charter and private boats commonly fish this region and sailfish tournaments are well known here. Actual catch statistics have not been compiled.

4.b. The shelf-edge Oculina banks are a submerged scenic area. The sight of pure white bushes of delicate coral growing in steep terraces on 25 m high hills with a

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Appendix 1

Species list of fishes observed or collected on shelf-edge *Oculina* reefs off central eastern Florida.

Species	Common Name
MURAENIDE	Morays
Gymnothorax nigromarginatus	
Muraena miliaris	
CLUPEIDAE	Herrings
Sardinella anchovia	Spanish sardine
BATRACHOIDIDAE	Toadfishes
Opsanus pardus	
HOLOCENTRIDAE	Squirrelfishes
Corniger spinosus	
Holocentrus ascensionis	
SERRANIDAE	Seabasses
Centropristis ocyurus	Bank seabass
C. philadelphica	Rock seabass
C. striata	Black seabass
Diplectrum formosum	Sand perch
Epinephelus adscensionis	Rock hind
E. drummondhayi	Speckled hind
E. itajara	Jew fish
E. morio	Red grouper
E. nigritus	Warsaw grouper
E. niveatus	Snowy grouper
Hemanthias vivanus	Red barber
Holoanthias martinicensis	
Liopropoma eukrines	Wrasse basslet
Mycteroperca bonaci	Black grouper
M. microlepis	Gag grouper
M. phenax	Scamp grouper
Plectranthias garrupellus	
Serranus phoebe	Tattler
S. subligarius	Belted sandfish
GRAMMISTIDAE	Soapfishes
Rypticus maculatus	
R. saponaceus	
PRIACANTHIDAE	Bigeyes
Priacanthus arenatus	
Pristigenys alta	
APOGONIDAE	Cardinalfishes
Apogon pseudomaculatus	

Species	Common Name
SCOMBRIDAE	Mackerals and Tunas
Acanthocymbium solandri	Wahoo
Euthynnus alletteratus	Little tunny
Scomberomorus cavalla	King mackeral
Scomberomorus maculatus	Spanish mackeral
SCORPAENIDAE	Scorpionfishes
Neomerinthe hemingwayi	
Scorpaena brasiliensis	
S. dispar	
MOLIDAE	Molas
Mola mola	Ocean sunfish
MOBULIDAE	Mantas
Manta birostris	Atlantic manta
CARCHARHINIDAE	Requiem sharks
Galeocerdo cuvieri	Tiger shark
SPHYRNIDAE	Hammerhead sharks
Sphyrna lewini	Scalloped hammerhead