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Key Largo Coral Reef National Marine Sanctuary Deep Water Resource Survey

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National Oceanic and Atmospheric Administration
Office of Coastal Zone Management

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Key Largo Coral Reef National Marine Sanctuary Deep Water Resource Survey

Edited by
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Office of Coastal Zone Management

in cooperation with
National Ocean Survey
Klein Associates, Inc.
Army Corps of Engineers
Harbor Branch Foundation, Incorporated
The Cousteau Society

Washington, D.C.
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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Office of Coastal Zone Management
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TABLE OF CONTENTS

Editor's Preface vii

Biological Zonation
S. Jameson, Office of Coastal Zone Management, NOAA 1

Stony Corals (Milleporina and Scleractinia)
W. C. Jaap, Florida Department of Natural Resources 7

Octocorals (Octocorallia: Gorgonacea)
J. Wheaton, Florida Department of Natural Resources 15

Fishes
R. Jones and M. Clark, Harbor Branch Foundation, Inc. 25

Algae
N. J. Eiseman, Harbor Branch Foundation, Inc. 31

Echinoderms
J. Miller, Harbor Branch Foundation, Inc. 37

Mollusks
P. Mikkelsen, Indian River Coastal Zone Museum and Smithsonian Institution, Fort Pierce Bureau 45

Decapod Crustaceans
R. H. Gore, Smithsonian Institution 49

Sponges
S. Pomponi, University of Maryland 55

Geology
E. A. Shinn, U.S. Geological Survey 59

Archaeology
S. Jameson, Office of Coastal Zone Management, NOAA 65

Biotic Comparison With Flower Gardens
T. Bright, Texas A & M University 69

Conclusion
S. Jameson, Office of Coastal Zone Management, NOAA 75

FIGURES

1. Del Norte navigation system 77

2. Del Norte towers 78

3. Side scan sonar survey tracklines 79

4. NOAA Ship PEIRCE 80

5. Klein Model 530 side scan sonar receiver 81

6. Klein Model 530 side scan sonar transducer 82

7. Hydrography 83

8. Shipwrecks, submersible tracklines 84

9. JOHNSON-SEA-LINK 85

10. R/V JOHNSON 86

11. Side scan sonar data showing coral reef 87

12. Fathometer record showing coral reef 88

13. French Reef biological zonation 89

14. The Elbow biological zonation 91

15. South Carysfort biological zonation 93

16. Diver lockout site, French Reef, about 36 m, Montastraea cavernosa, to left; Madracis mirabilis, dense cluster in center; Siderastrea siderea below M. mirabilis, obscured by Pseudopterogorgia octocorals; large sponges in background 95

17. French Reef lockout site, Agaricia lamarcki 96

18. Barrel sponge (Xestospongia muta) 97

19. Tropical fish (Haemulon) 98

20. Green turtle (Chelonia mydas) 99

21. Lithothamnion cobble zone 100

22. Sea bisquit (Meoma ventricosa) tracks in Lithothamnion cobble zone 101

23. Lithothamnion cobble zone beyond 52 meters with starfish Oreaster ... 102

24. Lockout diver 103

Figures (continued)

25. Coral disease 104

26. Abandoned lobster trap 105

27. Discarded line 106

28. French Reef lockout site; Eusmilia fastigiata, lower center, Agaricia lamarcki, left center 107

29. Coral mound, French Reef 108

30. Iciligorgia schrammi (in situ), French Reef 108

31. Pseudopterogorgia bipinnata (in situ, foreground), French Reef 109

32. Swiftia exserta (in situ), off French Reef 109

33. Swiftia exserta (in jaws of manipulator arm), French Reef 110

34. Coral mound, South Carysfort Reef 110

35. Millepora complanata zone (3-4.5 m depth), Carysfort Reef 111

36. Gorgonian zone (4.5-9 m depth), Carysfort Reef 111

37. Acropora cervicornis zone (11-14 m depth), Carysfort Reef 112

38. "Barren" zone (14-15 m depth), Carysfort Reef 112

39. Beginning of reef slope (16 m depth), Carysfort Reef 113

40. Edge of reef (21.3 m depth), Carysfort Reef 113

41. Bottom photograph of Lithothamnion nodules piled up by sand tile fish at a depth of 46 meters, off French Reef 114

42. Trails made by burrowing echinoids which have broken through a surficial algal scum at a depth of 56 meters, off French Reef 115

43. Carbonate sand which has been cemented to form rock under submarine conditions at a depth of 76 meters, off French Reef. The rock was thought to be part of a more extensive subsurface layer that was exposed by burrowing organisms. Three "big eye" fish (arrows) had taken residence in the rocks 116

44. Carysfort Reef lighthouse 117

45. East Flower Garden Bank 118

TABLES

1. Dive log.. 119

2. Stony corals from Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey in FDNR Marine Research Laboratory invertebrate reference collection.. 121

3. Stony corals from Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey.. 122

4. Comparative occurrence of stony corals at various South Florida and Bahamian reefs.. 124

5. Jaccard coefficient of association, faunal comparison of reefs.. 126

6. Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey. Octocoral observations and collections by site............... 127

7. Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey, 1979. Octocorallia observed and/or collected....................... 128

8. Geographical comparison of gorgonian distribution by reef zone.. 129

9. Carysfort transect studies, 1975. Octocorallia observed and/or collected.. 131

10. List of fishes recorded from the Key Largo deep reefs (26-38 m).. 132

11. Observation time, species observed and depth of observations of present study vs Jones and Thompson 1978........................... 140

12. Depth distribution of the marine algae of the Key Largo Coral Reef Marine Sanctuary.. 141

13. Comparison of sponges collected during Key Largo Coral Reef Marine Sanctuary Deep Water Survey with sponges observed during survey of Carysfort Reef.. 144

KEY LARGO CORAL REEF MARINE SANCTUARY DEEP WATER RESOURCE SURVEY

EDITOR'S PREFACE

The Key Largo Coral Reef Marine Sanctuary (Sanctuary) extends from the State's territorial sea off Key Largo, Florida, seaward to the 91 meter (300 foot) isobath. It is approximately 32.2 kilometers (20 miles) long, and 8.05 kilometers (5 miles) wide. About half of the Sanctuary lies in 30.4-91.4 meters (100-300 feet) of water. Little was known about the extent of natural and cultural resources in these deeper waters of the Sanctuary as exploration of such an extensive area at these depths without a submersible is somewhat hazardous and very time consuming because of short "bottom time" for SCUBA divers.

This survey was organized to fill some of the significant gaps in baseline data on the Sanctuary deep water resources thereby providing Sanctuary managers with scientitic information to make intelligent management decisions. It was designed as a two phased approach. Phase I was an extensive side scan sonar and bathymetric survey. Phase II was a qualitative submersible reconnaisance and resource inventory. A discussion of Phase I operations is included in the Biological Zonation section. Following the Biological Zonation section are descriptions of the major deep water communities.

The Deep Water Resource Survey was a cooperative effort, sponsored by the Office of Coastal Zone Management (OCZM), and required the donation of services and equipment by several organizations.

As project manager and coordinator, OCZM provided technical personnel responsible for designing and executing the project and contacting the necessary outside scientific experts. OCZM funded equipment shipping and personnel travel expenses, as well as land based logistical and ship to shore small boat support, during the project. In addition, OCZM contributed to shipboard logistical expenses for Phase II and served as editor for preliminary and final project reports.

The National Oceanic and Atmospheric Administration's, National Ocean Survey (NOS) is responsible for operating and maintaining a fleet of oceanographic and hydrographic survey vessels. NOS participated in Phase I by providing five days of the NOAA Ship PEIRCE's time as a work platform for the project and Del Norte navigation equipment.

Klein Associates, Inc., a leader in the field of developing and operating undersea search and survey equipment, provided side scan sonar equipment and a field engineer for resource mapping in Phase I.

The Army Corps of Engineers (COE), Environmental Analysis Branch, Savannah, Georgia, maintains side scan sonar, magnetometer and diver services in support of the COE mission to provide safe, navigable waters in the United States. This branch provided a field engineer during Phase I.

Harbor Branch Foundation, Inc. (HBF), is a not-for-profit organization established to conduct research in the marine sciences and to develop tools and systems for underwater oceanography. HBF provided technical and science personnel in Phases I and II, the JOHNSON-SEA-LINK research submersible and her support vessel, the R/V JOHNSON, plus other equipment to meet the operational requirements for Phase II of the survey.

The Cousteau Society is a non-profit, membership supported organization dedicated to the protection and improvement of life. They provided side scan sonar and diver support during the deep water archaeological investigations.

We wish to thank Captain Richard Holder, National Ocean Survey, for arranging the use of the NOAA Ship PEIRCE and the officers and crew of the PEIRCE for their outstanding contribution to the results of Phase I.

Our gratitude also goes to Marty Klein of Klein Associates, Inc., for contributing the side scan sonar system along with field engineer, Garry Kozak, whose dedication, enthusiasm and expertise resulted in superior side scan sonar records.

Thanks also go to Richard Anuskiewicz of the Army Corps of Engineers and to Lou Gilliland and Jim Schafer of Harbor Branch Foundation, Inc., for their help in monitoring the side scan recorder.

We wish to express our appreciation to Captain Jack Gillen, Florida Department of Natural Resources, Park Service, and his staff for providing exceptional shoreside logistical support.

Special thanks are due Lieutenant Ted Lillestolen for filling in for the project coordinator (Steve Jameson) aboard the NOAA Ship PEIRCE, thereby allowing him to get married, and for his help in erecting Del Norte towers during the Cousteau operations.

We wish to thank Dr. Robert Jones, Mr. Roger Cook, Mr. Joe Morgan, their crews and staff for outstanding support during submersible operations aboard R/V JOHNSON in PHASE II.

Considerable gratitude must be expressed to Mr. Ron Williams, National Hurricane Center for providing training in the operation of the Del Norte navigation system and in assisting the editor in erecting towers for Phase II operations.

Steve Viada's efforts are appreciated for the excellent job he did in drafting contour charts with submersible track lines as well as the three dimensional reef maps.

We wish to express our thanks to Captain Jacques Yves Cousteau and CALYPSO divers Albert Falco, Dominique Sumion, Bruno Capello, Marc Zonza, and Michelle Terboz for their help in searching for shipwrecks discovered in Phase I.

Mrs. Anner Y. Grantham is heartily thanked for her secretarial assistance in preparing this document.

Finally, we would like to thank all the authors, who contributed their professional services free of charge and helped make this expedition a success.

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BIOLOGICAL ZONATION

Lieutenant Stephen C. Jameson
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INTRODUCTION

Various investigators both scientific and recreational have made short dives in the deeper waters, beyond 30.4 meters (100 feet) in depth, within the Key Largo Coral Reef Marine Sanctuary (Sanctuary). However, no comprehensive scientific effort has been made to survey the extent of the natural resources or inventory and identify the marine life existing in this area. The large deep water area of 130 square kilometers (50 square miles) and the lack of appropriate technology have limited such biological surveys to depths usually less than 30.4 meters (100 feet). The technological development of side-scan sonar and manned research submersibles has opened a new dimension to resource investigation and management.

Previous scientific information on biological zonation beyond 30.4 meters (100 feet) in depth off Key Largo is limited primarily to the preliminary investigations by Harbor Branch Foundation, Inc. (HBF). Reports from HBF missions, May 30-June 5, 1973, indicated the existence of a deep water reef located in 40-50 meters (131.2-164.0 feet) of water off Molasses Reef. Photographs taken of this reef by HBF showed a well developed community of *Agaricia agaricites* and *Montastraea cavernosa* coral species.

The purpose of this work is to locate and accurately map deep water coral reefs, visually document their viability and qualitatively describe the biological zonation of this area in the Sanctuary.

METHODS

PHASE I

The first Phase in exploring the deep water resources of the Sanctuary was a side scan sonar and bathymetric survey conducted March 26-30, 1979.

A Del Norte navigation system (Figure 1) was established on Key Largo. This was an essential element of the project because weak signals made Loran C unreliable for accurate position fixing. Del Norte towers (Figure 2) of 6.1, 9.1 and 12.2 meters (20, 30 and 40 feet) were erected at Anglefish Creek, Upper Sound Point and Largo Lighthouse (Figure 3). This provided navigational control with an accuracy of ±3 meters (9.84 feet).

Survey lines (Figure 3) were run at a line spacing of 200 meters (656.1 feet) by the NOAA Ship PEIRCE (Figure 4) using a Klein Model 530 side scan sonar system (Figures 5 & 6). This line spacing provided 100% overlap of the side scan sonar data. The side scan sonar data was plotted to yield a map of possible coral reefs. Fathometer data was recorded and processed on a PDP-8 Hydro Plot System computer. Soundings were corrected for tides and smooth plotted (Figure 7) with contour lines.

PHASE II

Because time available was limited to seven days for submersible operations, a schedule was developed (Table 1) to incorporate submersible dives for general reconnaissance and site-specific inventory work (Figure 8). Based on the side scan sonar map developed in Phase I, three areas of particular interest were designated for inventory work at French Reef, the Elbow, and South of Carysfort Reef. Prior to beginning submersible work, the Del Norte navigation system was reestablished as described previously for navigational control.

The JOHNSON-SEA-LINK (J-S-L) (Figure 9), a sophisticated research submersible designed to operate in depths to 914 meters (3,000 feet) was used for all dives. The J-S-L has two manned pressure hulls: a two-man sphere constructed of four-inch thick acrylic and a separate dive compartment made of welded aluminum. The sphere provides the pilot and one observer with panoramic visibility and is maintained at one atmosphere. The dive compartment has two ports for scientific observation at one atmosphere and is designed for a diver lockout to 182.8 meters (600 feet) and mating to a deck decompression facility. The frame, ballast tanks, and electrical/electronic housings are all constructed from aluminum. It is equipped with SONAR, underwater communication, and diving equipment. Eight thruster units provide three dimensional mobility. An oil compensated battery and an inverter provides both DC and AC power.

The R/V JOHNSON (Figure 10), a converted 38 meter (125 foot) Coast Guard cutter, was used as support ship. It is designed specifically to support the lockout submersible, J-S-L. The ship and its deck decompression chamber (DDC) are integral parts of the submersible lockout system. The vessel provides a stable platform for the safe launch and retrieval in seas up to State 5, lock-on DDC with control console and a scientific lab and support facilities for 22 people.

Precise navigation control of the submersible was maintained using a Honeywell RS7 Tracker to position the R/V JOHNSON over the J-S-L. The Del Norte navigation system was used to precisely plot the position of the R/V JOHNSON. Depths were determined using an external pressure gauge.

Dives #674 on June 1 and #676 on June 2 (Table 1) were made for reconnaissance, biological zonation, and inventory site selection. During these dives pingers were placed at French Reef and South Carysfort which were designated areas of particular interest. This enabled the J-S-L to return scientists to the same area to complete biological inventory work. In addition to visual reconnaissance, photographs were taken during all dives to document the biological zonation of these areas.

RESULTS

PHASE I

Side scan sonar data revealed extensive deep reef formations (Figure 11). Fathometer records indicated formations up to 3.04 meters (10 feet) in height (Figure 12) which implied actively growing coral reefs. This relatively continuous reef system is approximately 25.9 kilometers (14 nautical miles) long and extends from the southern boundary of the Sanctuary to within about 7.4 kilometers (4 nautical miles) of the northern boundary. In general, the deep reef tract from Molasses Reef to a point about 2.8 kilometers (1.5 nautical miles) north of the Elbow extends as deep as 39.6 meters (130 feet) with the majority of the formation found at depths less than 36.6 meters (120 feet).

Side scan data shows the northern third of the Sanctuary, extending from 3.7 kilometers (2 nautical miles) south of Carysfort Reef Lighthouse to the northern boundary, to be less well developed than the southern portion. Based on side scan data this northern area from 30.4-91.4 meters (100-300 feet) in depth appears to be predominately sand.

PHASE II

In the three main areas surveyed using the J-S-L submersible (French Reef, The Elbow and South Carysfort), the deep reef consisted of a series of mounds 3.28-6.56 feet (1-2 meters) high with scattered sand channels (Figures 13, 14, 15). The mounds were covered with a variety of corals. Platelike growth forms (Figure 16) of the star corals (*Montastraea cavernosa* and *M. annularis*) predominated. Also common was lettuce coral *Agaricia lamarcki* (Figure 17) and yellow pencil coral, *Madracis miribilis* (Figure 16). A complete listing of stony corals observed is included in Table 3. Associated with the deep reef were various common shallow reef sponges (Table 13) including the conspicuous barrel sponge, *Xestospongia muta* (Figure 18). Sea rods, sea fingers and other octocorals (complete listing in Table 7) were abundant. Most conspicuous of the algae were the leafy types but also present was a wide variety of green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta) algae in ligulate, and filimentous growth forms (complete listing in Table 12). A myriad of tropical reef fish (Figure 19) were present (complete listing in Table 10). The deep coral reef is also a habitat for the Green Turtle, *Chelonia mydas* (Figure 20).

At French Reef the deep reef is a continuous extension seaward of the shallow reef (Figure 13). The Elbow deep reef (Figure 14) is separated from the shallow water reef by a sand/soft coral zone that lies at the base of a 12.19 meter (40 foot) high shallow reef face. In both areas, the deep reef extends to 39.6 meters (130 feet) but the majority of the reef formation is found at depths less than 36.6 meters (120 feet). The deep reef south of Carysfort (Figure 15), in 26.8-27.1 meters (88-89 feet) of water, is completely isolated from any reef whatsoever. It is about 100 meters (328.1 feet) wide and 1,852 meters (1 nautical mile) long. This reef is also unique in that the common shallow reef staghorn coral, Acropora cervicornis is present.

Beyond the actively growing deep reef in all three areas is a Lithothamnion (a coralline red alga) cobble zone (Figure 21). This extends to a depth of about 55 meters (181 feet) and is characterized by an absence of reef building corals, however, rose coral Manicina areolata and finger coral, Porites exist here. Visually predominate are the leafy algae along with some octocorals, and antipatharians (Figure 21). Soft corals are found to depths of 48.8 meters (161 feet). Comprehensive lists of algae and soft corals found in this area are included in Tables 12 and 6. The Lithothamnion cobble substrate is tracked by the sea bisquit, Meoma ventricosa (Figure 22).

Beyond a depth of 55 meters (181 feet) the Lithothamnion disappears and one finds sand to at least 91.4 meters (300 feet) (Figure 23). Larger forms of algae diminish and the lack of any hard corals (except the rose coral, Manicina areolata) produce a very barren bottom. This zone however does provide a habitat for numerous inconspicuous algae (Table 12), the Tilefish Malacanthus plumieri, sea bisquits, sea urchins and the starfish Oreaster (Figure 23).

DISCUSSION

The use of side scan sonar to map biological resources was a unique approach that allowed OCZM to survey an extensive area with extreme accuracy and at relatively minimal cost.

The research submersible JOHNSON-SEA-LINK was indispensible for working at depths greater than 30.5 meters (100 feet). This research tool allowed extended excursions for area reconnaisance and provided lockout capability (Figure 24) for sample collection and up-close investigations. Without this submersible a survey of this nature using conventional diving techniques would have been prohibitively expensive and time consuming.

Time was limited for the survey to seven days. As a result, the entire deep water area of the Sanctuary was not visually reconnoitered. However, by using the complete side scan sonar record and correlating it with visual observations from the JOHNSON-SEA-LINK a general qualitative description of the area was possible.

The reefs in waters below 30.5 meters (100 feet) in depth appear to be flourishing and in a healthy condition. Little coral disease (Figure 25) was noticed. There were however, several abandoned lobster traps (Figure 26) observed on each dive containing lobsters, and discarded line (Figure 27). The only noticeable pollution in this area was oil in globular form trapped in floating algae (Sargassum). This undoubtedly originated from passing ships, which frequent this area.

Side scan sonar data shows the northern portion of the Sanctuary deep waters to be devoid of deep coral formations. This area appears to be mainly sand. The National Ocean Survey also indicates this area to be sand on nautical charts. The distribution and abundance of algae and soft corals is unknown. The species composition is presumed to be similar to what was found in the southern deep areas. The absence of coral formations in this area may be attributable to the breaks in the Key Largo land mass at Anglefish and Broad Creek which allows colder, turbid, less saline, Card Sound water into this northern area making conditions unconducive for coral proliferation.

STONY CORALS (MILLEPORINA AND SCLERACTINIA)

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INTRODUCTION

Results of the stony coral [Milleporina (firecoral) and Scleractinia (true stony corals)] qualitative inventory are reported here. Temporal and geographic limitations of sampling make it probable that more intensive sampling would yield additional species.

Submersibles offer researchers a safe means of study remote deep reef environments. Lockout diving capability from the submersible allows scientists to selectively collect fragile organisms as well as conduct in situ experiments and make observations. Ginsburg and James (1973) used submersibles to study geological processes of the Belizian Barrier Reef to 190 m. Lang (1974) studied zonational patterns of deep reef communities to 306 m off Discovery Bay, Jamaica, utilizing submersibles. Both studies reported that scleractinian corals were replaced by sclerosponges as principal framework builders at or near 70 m.

Early coral reef research in Florida began with the Agassizs' (1852, 1869, 1880, 1882, 1885, 1888) descriptions of the reefs and keys and Pourtales's (1871) systematic account of reef scleractinia. In 1904, the Carnegie Institution established a research laboratory on Loggerhead Key, Dry Tortugas; in the years that followed a great deal of fundamental coral reef research was conducted at this facility. Some of the more significant work includes: Vaughan (1910), marine geology of southeast Florida, Vaughan (1911), cultured coral larvae and initiated life history studies on scleractinian corals; Vaughan (1912), growth rate of scleractinian corals; Vaughan (1913); Bahamian marine geology and scleractinian coral growth rates; Vaughan (1914), salinity at Tortugas and geological processes in the reef tract; Vaughan (1915), reef scleractinia tolerance to altered salinity and light exclusion; Vaughan (1916a), summary of scleractian life history studies; Vaughan (1916b), summary of the ecology of Floridian and Bahamian reef scleractinia; Vaughan (1919), summary of Tortugas studies; Mayer (1914, 1918), scleractinian thermal tolerances; Matthai (1916), comparative morphology of Tortugas scleractinia; Boschma (1925), digestion and postlarval development in Manicina areolata; Yonge (1935a), morphological variation in Siderastrea; Yonge (1935b), biology of M. areolata; Yonge (1937), effect of mucus on oxygen consumption in five scleractinian species; Wells (1932), scleractinian coral salinity tolerance; and Wells (1933, unpublished), ecological survey of the shallow Tortugas reefs.

METHODS AND MATERIALS

Areas seaward of French, Elbow, and Carysfort Reefs, Key Largo Coral Reef Marine Sanctuary (Sanctuary) (Figure 8) were qualitatively surveyed utilizing Harbor Branch Foundation's JOHNSON-SEA-LINK I (J-S-L) submersible on 6 June 1979. Survey areas were selected by Lt. Steve Jameson (NOAA) based on side scan sonar surveys and earlier submersible reconnaissances in the area. Data acquisition included visual observations, lockout diving (collections, 35 mm Nikonos (T. M.) photography, and field notes), specimens collected with the submersible's mechanical manipulator, and photographic documentation with the submersible's 35 mm camera-strobe system. Depths and duration of submersible excursions were as follows: J-S-L DNE #686 French Reef, 36-38 m, 2h:45min (lockout dive 36 m); J-S-L DNE #688 Elbow Reef, 38-55 m, 3h:30 min; J-S-L DNE #687 Carysfort Reef, 27-38 m, 2h (lockout dive 27 m). The Elbow Reef excursion encompassed a short examination of shallow reef structures and a long duration survey of non-reef, algal-covered sedimentary environments to seaward. French and Carysfort Reef surveys studied reef structures in the 27-38 m depth regime. Additional material and data collected during other phases of the survey were also studied. Collected specimens were analyzed and accessioned into the FDNR Marine Research Laboratory Invertebrate Reference Collection (Table 2).

RESULTS AND DISCUSSION

Twenty-six species of stony corals were collected or observed at the Sanctuary during 1979 (Table 3). In general, the three sites are similar in species composition to the bank reef fore-reef zone which is dominated by Montastraea cavernosa (star coral) (Figure 16) Agaricia lamarcki (lettuce coral) (Figure 17) and dense clusters of Madracis mirabilis (branching coral) (Figure 16). Observed explanate or flattened colonial morphology reflects the attenuation of light at depth; plate-like colonies develop to maximize interception of solar radiation. Only two ahermatypic (non-reef) scleractinia were collected (Madracis asperula and Paracyanthus pulchellus), supporting the contention that the faunal assemblage is an extension of the offshore bank reef fore-reef zones.

Submersible observations revealed that corals within the zone of interest are located on outcroppings or isolated carbonate structures surrounded by algal covered sediments. Outcrops in 30 m depths appear to be spurs from antecedent spur and groove tracts that developed when sea level was at a lower stand. Attached corals and epibenthos continue to add to the development of these structures. Reef formations appear to terminate at or near 37-40 m. Seaward of this depth, the bottom was dominated by algal covered sedimentary deposits with occasional large sponges (Xestospongia, Verongia, Spheciospongia and others) and tilefish burrows. Presumably, the nature of the continental shelf off Key Largo and Holocene sea level changes have limited active reef development to less than 40 m. Gradual shelf slope, wide shelf width, and associated algal covered sedimentary environments are unfavorable to active reef development in depths beyond 40 m. Climate also restricts coral reef development off Florida. In many parts of the Caribbean and western Atlantic, hermatypic scleractinia are found at 70-80 m depths. Marine geology, more favorable climate, and radical change in depth from less than 1 m to 300 m in less than 1 linear km are the major influences on the bathymetric distribution for hermatypic scleractinia in these geographic locations.

Comparison of Sanctuary fauna with several other Florida reef surveys and a site off Grand Bahama Island revealed similarities (Table 4). Carysfort Reef fauna was censused in 1973 (Jaap). Long Key Reef, Dry Tortugas information is from a quantitative community structure investigation and was collected during 1975 and 1976 (Jaap). Grand Bahama information is from a community study of escarpment reefs off Lucaya, Grand Bahama (Jaap and D.A. Olsen). All data are previously unpublished. Pourtales (1871) listed corals found in the Florida reef tract. Collections were made with dredge and trawl and supplemented by hand collections in shallow water. Pourtales's report is a general survey, hence species richness is somewhat higher (33, Table 4). The report includes species from the high energy, shallow zones as well as those from intermediate and deeper depths [in this report, shallow is defined <15 m, intermediate is 15-25 m, and deep is >25 m]. Carysfort fauna represents the high energy, shallow reef zone, characterized by large stands of *Acropora palmata* (elkhorn coral). Long Key Reef, Dry Tortugas, supports an intermediate-depth fauna. Hydro-Lab, Grand Bahama fauna is comparable in depth to that at the Sanctuary, but is from an escarpment or wall habitat providing greater niche diversification. Comparisons of fauna (Table 5) imply that Sanctuary "deep reef" fauna is more similar to that at Grand Bahama than to the nearby shallow water fauna at Carysfort Reef.

The major influence separating shallow and deep reef corals is the physical environment. Shallow reef zones are characteristically unpredictable and physically severe; stresses include fluctuation in temperature, salinity, wave surge, and tidal phenomena. Loya (1972) classified Red Sea reef flat communities as physically controlled species. Diversity was low, an indication that few species could tolerate the extreme meterological and oceanographic conditions of the environment. Deep reef zones are more biologically accommodated (Loya, 1972) in that environmental factors are less important than species interactions in determining community structure.

The major barrier preventing shallow species from immigrating into deeper zones appears to be attenuation of light and reduced water movement. Shallow water stony coral species rely on autotrophic energetics and wave-induced flushing to remove sediments; so reduced light and water movement prohibit establishment of *A. palmata* and other shallow water species in deeper zones. Conversely, deep reef species accommodated to reduced light intensities and water movement are unsuccessful in shallower zones.

Shallow, high energy zones in well-developed Florida Keys reefs are dominated by *Acropora palmata*, *Millepora complanata* and *Palythoa mammillosum*, on spurs and seaward platform margins, usually limited to depths of 5 m or less. On the reef flat, (1-2 m deep) *Diploria clivosa* and *Porites astreoides* form low encrusting colonies that exist in the heavy wave surge zone. In deeper reef zones (25 m), explanate colonies of *M. cavernosa*, *A. lamarcki* (Figure 16, 17, 28), *A. fragilis*, *A. undata*, *H. cucullata*, and densely branching *M. mirabilis* (Figure 16) are characteristic species.

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OCTOCORALS (OCTOCORALLIA: GORGONACEA)

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INTRODUCTION

This report provides information on the octocoral fauna of the Key Largo Coral Reef Marine Sanctuary (Sanctuary) (Figure 8) and compares it with published reports of others in similar reef zones off Palm Beach County, Florida, and Jamaica. Information for the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey (Sanctuary Survey) was gained by utilizing submersible observations and collections. Although observations of and collections from deep water structures within the Sanctuary were conducted for only one day, use of the JOHNSON-SEA-LINK (JSL) submersible allowed observation of reefs from the northern, middle, and southern portions of the Sanctuary from about 27 to 57 m depths. Structure of the JSL's acrylic sphere allowed almost panoramic viewing and, with mobility of the submersible, provided for examination of selected areas. Visibility enabled some quantitative assessment of the fauna. Qualitative samples were procured by lockout divers from the JSL and with its mechanical arm and with SCUBA. Studies at Carysfort Reef, conducted in 1975 for Harbor Branch Foundation (HBF) Florida Keys Coral Reef Project (Keys Reef Project), Key Largo, provided additional data.

Study of shallow water gorgonians off Miami by Opresko (1973) and work on coral-octocoral communities off Palm Beach County by Goldberg (1973) have made important contributions to the ecology of Florida's octocoral fauna. Ecological studies of Caribbean reef gorgonians include work at Jamaica by Kinzie (1973) and Puerto Rico by Preston and Preston (1975). Only Goldberg's and Kinzie's studies encompassed depths sampled during the Sanctuary Survey, thus allowing comparison of their results with those on the present study.

Collection of octocorals (particularly gorgonians) by classical dredge and tangle gear is both destructive and inefficient. More selective means of obtaining samples have been desirable, with increased commitment to protection and preservation of habitat (particularly coral reefs). Use of SCUBA is now a commonplace selective method; however, its expediency and safety becomes unsatisfactory beyond depths of about 30 m. Submersibles are relatively new tools being used to extend this working range. Biologists and geologists have used submersibles to over 1000 m depths.

Submersible use for collection of octocorals has been most extensive in the Pacific. Those used in a study of new technology for Hawaii's precious coral industry worked at depths to 380 m. Grigg et al. (1973) found that precious coral [Gorgonacea: Scleraxonia: Corallium] collected by submersible was qualitatively better and quantitatively superior to those collected by dredge hauls. Besides being more efficient, collection by submersible allows selective harvest at a rate predetermined not to exceed natural replacement rates.

METHODS

Octocoral observations and collections were made at each of three selected sites on 6 June 1979. French and The Elbow Reef observations were made from the sphere of the JSL submersible J-S-L Dive #686 (Table 1) from 33.5 to 38.1 m at French Reef, lasted 2 h 30 min and included collections at 36.6 and 37.2 m supplemented by lockout collections at 35.4 m. J-S-L Dive #688 (Table 1) from 38.1 to 56.4 m at The Elbow lasted 3 h 30 min and included collections at 38.1, 40.5 and 48.8 m. Observations and collections at Carysfort Reef were made during a 30 min SCUBA dive at 27.4 m. Incidental collections of octocorals made by other investigators are included.

Photographs were taken from within the sphere using 35 mm camera and ambient light. In situ photographs were taken with the JSL camera system and by lockout diver with a Nikonos and strobe.

Octocoral faunal observations and collections were also made in shallower water at Carysfort Reef in September 1975 as part of the Keys Reef Project. A traverse across Carysfort seaward to 21.3 m depth provided reference for transects established perpendicular to the main traverse. Ten 25 m transects were selected as representative of biotic zones of the reef. Qualitative and quantitative octocoral observations were made within a 0.25 m square advanced along each transect. Identifications were made in situ, then confirmed with microscopic examination of voucher specimens. Photographs were taken with a Nikonos camera and flash.

RESULTS

The dive at French reef commenced on a relatively flat rubble plain at about 33.5 m interrupted by discontinuous coral mounds (Fig. 29). These mounds and low relief, coral-covered "islands" were separated by sand channels. *Iciligorgia schrammi*, a scleraxonian gorgonian, was conspicuous both in abundance and uniform orientation of its large colonies (Fig. 30). *Pseudopterogorgia* spp. were also common; most appeared to be *P. bipinnata* (Fig. 31). Colonies of *Briareum asbestinum* and *Plexaura flexuosa*, were also observed. Collections from the lockout site at 35.4 m (Table 6) included *I. schrammi*, *Eunicea pinta*, *Muriceopsis petila*, *Plexaurella nutans*, *Muricea laxa*, and *P. bipinnata*.

Large coral mounds were absent below about 36 m; however, low relief outcrops persisted to about 40 m. Flabellate colonies of *Swiftia exserta*, a paramuriceid, were the most conspicuous benthic invertebrates of the algalcovered expanses between outcrops in depths of 36-38 m (Figs. 32, 33). Colonies of an unidentified nicellid (presumably *N. schmitti*) were observed at the edges of outcrops and on the plain with S. exserta (Fig. 32). Flagelliform colonies of the ellisellid, Ellisella barbadensis, were observed and collected within these depths (Table 6). Numerous other octocorals colonizing outcrops included I. schrammi and species of the holaxonian general Eunicea, Muricea and Pseudopterogorgia (species unidentifiable from within the JSL sphere). Sampling of lower relief outcrops in 36-38 m was insufficient to provide more specific information as dive time was limited.

Observations at The Elbow began at about 38 m. Rocky outcrops were colonized by I. schrammi (abundant), slender euniceids, Pseudopterogorgia (likely P. bipinnata) and branched ellisellids. Swiftia exserta and Nicella schmitti colonized the interstices; the former was most abundant. Collections from outcrops in 38.1 m were made with the JSL manipulator arm and included I. schrammi, E. pinta, Eunicea ?succinea f. plantaginea, P. bipinnata and Ellisella elongata (Table 6). Specimens of P. bipinnata and E. elongata were collected from rocky patches at 40.5 m. The deepest octocoral collection from The Elbow was S. exserta from 48.8 m (Table 6).

Low relief outcrops were virtually absent below about 45 m, where after an algal community dominated the flat rubble plain. Incidental octocoral collections from The Elbow included Eunicea tourneforti, Eunicea clavigera and Pseudopterogorgia acerosa taken at 18.3 m by other observers.

At Carysfort (27.4 m), coral mounds were in closer proximity, and had moderate relief (Fig. 34). The most abundant octocorals appeared to be I. schrammi and Pseudopterogorgia ssp. (apparently mostly P. bipinnata). Thirteen species (the above, Plexaura flexuosa, Pseudoplexaura porosa, Eunicea pinta, E. calyculata, P. nutans, M. laxa, Pseudopterogorgia americana, Gorgonia ventalina, Pterogorgia citrina, Pterogorgia guadalupensis and N. schmitti (Table 6) were collected at Carysfort (27.4 m).

Twenty-three octocoral species were recorded during the Sanctuary Survey (Table 7). Nineteen species occurred within the depths surveyed (27.4 - 56.4 m) (Table 7). Four were collected by other observers in adjacent depths. Six were encountered only at 27.4 m and were representative of more typically shallow water species. Nine species were represented below 36 m, whereas only four species were collected below 40 m.

Throughout the West Indies, different reef environments or types are defined by characteristic zonational patterns. In particular, fringing reefs such as those described by Goreau (1959) begin just offshore, grade through a number of subzones and descend into deeper water. Kinzie (1973), in his study of Discovery Bay gorgonians, defined ten main fringing reef zones within SCUBA diving range: shore zone (0-3 m); lagoon zone (1-3 m), rear zone (0.3-2 m), reef flat (0-0.5 m), Acropora palmata zone (4-6 m), barren zone (5-8 m), mixed zone (6-15 m), Acropora cervicornis zone (10-25 m), fore reef slope and pinnacles (20-60 m) and deep fore reef slope (50-75 m).

Outer reefs within the Sanctuary are basically related to the bank-barrier reef but are not continuous or adjacent to land. Most of these outer reefs consist of a back reef, reef flat, Acropora palmata zone, Millepora alcicornis zone, Montastraea annularis zone and an outer edge rubble zone (fore reef) (Hoffmeister et al., 1964). In particular, Carysfort, the best developed reef in the upper Florida Keys (Dustan, 1977) exhibits many of the zonational patterns described by Kinzie. Transects sampled at Carysfort in 1975 traversed the following zones within given depths: back reef (0.9 m) primarily of Acropora palmata rubble; reef flat (0-0.5 m); live Acropora palmata zone (1-3 m); Millepora complanata zone (3-4.5 m) (Fig. 35); gorgonian zone (4.5-9 m) (Fig. 36); Acropora cervicornis zone (11-14 m) (Fig. 37); barren zone (14-15 m) (Fig. 38); and reef slope (15+ m) (Figs. 39, 40).

Goldberg discussed the octocoral fauna of outer reefs off Palm Beach County in terms of ledge habitat, outer reef platform (16-20 m), outer reef slope [shallow (20-25 m); deep (25-30 m) and fore reef (30+ m)]. Areas observed during the Sanctuary survey encompassed depths described by Goldberg as outer reef slope and fore reef and by Kinzie as fore reef slope and pinnacles, and deep fore reef slope. The following species distribution patterns were analyzed by reef zone.

OUTER REEF SLOPE (SHALLOW)

The reef slope in all three sampling locations was characterized by knolls or pinnacles of relief and dominance of the stony coral fauna by the genus Montastraea. Kinzie reported the outer (fore) reef slope at Discovery Bay, Jamaica, began as a somewhat narrow zone of sand deepening from 20 to about 50 m (the "drop off"). This zone was characterized by high relief pinnacles (to 25 m tall) composed mostly of shingled Montastraea annularis. The bulk of substrate available to gorgonians was present on these pinnacles. From 24-33 m depth, he recorded 30 species of gorgonians (Table 8), only ten of which (Plexaura homomalla f. kukenthali, P. porosa, Eunicea clavigera, Plexaurella dichotoma, P. nutans, M. laxa, P. bipinnata, P. acerosa, P. americana and Gorgonia mariae) commonly occupied these depths as part of their typical range. The gorgoniid P. bipinnata dominated 50% of the fauna within these depths (Kinzie, 1973).

Within the Sanctuary, karst topography began at about 15-16 m depth off Carysfort, and Montastraea assumed dominance of the scleractinian fauna. Gorgonians were represented by Briareum asbestinum, E. calyculata, P. americana, Pseudopterogorgia navia and P. bipinnata between 16-21 m, (Table 9). P. bipinnata was dominant (about 70%). Collections by other investigators during the Sanctuary Survey included E. tourneforti, E. clavigera and P. acerosa from within these depths at The Elbow (Table 6).

Goldberg (1973) stated that the outer reef slope off Palm Beach County, Florida began at about 20 m and was characterized by rocky knolls of moderate relief where Montastraea cavernosa was the dominant scleractinian. Gorgonian diversity was greater at the upper limits of the slope (20-25 m) there than at Discovery Bay or Carysfort reefs. Nineteen species were represented (Table 8); most abundant were I. schrammi, Plexaurella fusifera, E. calyculata and E. tourneforti. Both Discovery Bay and Carysfort gorgonian faunas were dominated by P. bipinnata. Pseudopterogorgia bipinnata was not recorded by Goldberg, although several other species of Pseudopterogorgia were represented. This gorgoniid was the most dominant species at a patch reef near Miami, Florida (Opresko, 1973). It's range may therefore end somewhere between Miami and lower Palm Beach County.

OUTER REEF SLOPE (DEEP)

At Discovery Bay, the slope descends steeply to the drop off. Kinzie reported 20 gorgonian species from 33 to 50 m, (Table 8), ten of which (Diodogorgia nodulifera, P. homomalla f. kukenthali, E. clavigera, M. laxa, Pseudoptogorgia elisabethae, G. mariae and E. barbadensi) commonly occupied these depths as part of their typical range; decreasing to five species (D. nodulifera, E. clavigera, M. laxa, P. elisabethae and E. barbadensis) at about 40-45 m depths.

Pseudopterogorgia elisabethae replaced P. bipinnata as dominant, and E. barbadensis and D. nodulifera (on edges of sand channels) became prominent at about 45 m.

Observations at the deep outer reef slope during the Sanctuary Survey revealed low relief coral knolls; gorgonians were abundant and conspicuous. Goldberg characterized the deep outer reef slope off Palm Beach County similarly. I. schrammi was the most common gorgonian occupying these knolls in both areas and is also abundant on the steep slopes of Pulaski Shoal at Dry Tortugas, Florida (personal observation).

Goldberg reported sixteen species from the deep slope off Palm Beach County (Table 8). Only five of these (I. schrammi, Muriceopsis petila, Eunicea palmeri, E. pinta and E. barbadensis) were considered common and comprised 93% of the funa surveyed in those depths. Thirteen species were recorded from the deep outer reef slope at Carysfort Reef (27.4 m) (Table 6). Five of these (B. asbestinum, I. schrammi, P. flexuosa, E. pinta and N. schmitti) were included in Goldberg's list of 16 species; I. schrammi and E. pinta were among his five most common species. Eight species were reported from the deep outer reef slope at French Reef (33-35.4 m) (Table 6), three of which (I. schrammi, E. pinta and M. petila) were among the five most common deep slope species listed by Goldberg.

Sanctuary and Discovery Bay deep outer reef slope gorgonian faunas were dominated by different species. Pseudopterogorgia bipinnata was common off Key Largo; however, the asymbiotic anthothelid, I. schrammi, overtook the gorgoniid in dominance P. elisabethae, dominated at Discovery Bay. Iciligorgia schrammi was not particularly common on Discovery Bay's reef slope; however, it was the only gorgonian on very steep cliffs at Rio Bueno (Kinzie, 1973).

Nine species recored on the deep outer reef slope at Discovery Bay occurred in the same zone off Key Largo (Table 8). Several included species represent typically shallower water reef inhabitants.

Six species were included by Goldberg and Kinzie as species of the deep outer reef slope; only Ellisella barbadensis was considered common by both.

FORE REEF

Discovery Bay reefs dropped off almost vertically from depths of about 50 m. Dominant benthic macroinvertebrates were sponges and sclerosponges. Kinzie recorded 11 gorgonian species (Table 8); only five of these (Lignella richardii, Hypnogorgia pendula, S. exserta, P. elisabethae and Nicella spp.) persisted after about 55 m. Hypnogorgia pendula and species of Nicella were most common.

The four reef zones off Key Largo and Palm Beach County consisted of gently sloping rubble plains. In both areas, Gorgonians were conspicuous and occupied island-like aggregations to about 45 m depth. Off Key Largo, nine species were recorded for the fore reef zone (Table 8, French and The Elbow Reef data combined). Goldberg reported 12 species from this zone (Table 8). Four species (S. exserta, N. schmitti, Ellisella sp. and E. barbadensis) were characteristic of the area with S. exserta and N. schmitti (both asymbiotic) represented 60% of his samples. Four of the nine species reported from Key Largo (I. schrammi, S. exserta, N. schmitti and E. barbadensis) are common to both Key Largo and Palm Beach County reefs. The four species characteristic of the fore reef zone off Palm Beach County were the same four commonly observed in similar depths off Key Largo if Goldberg's Ellisella sp. synonymous with Ellisella elongata.

Few gorgonians were observed deeper than about 45 m off Key Largo. Goldberg investigations off Palm Beach County ended at 50 m. Kinzie reported several species from 50-75 m off Jamaica, including the paramuriceds, H. pendula and S. exserta, and the ellisellids, E. barbadensis and Nicella spp. The latter three species were common to the "fore reef" zone in all three geographic localities; assuming N. schmitti was included among Kinzie's unidentified nicellids, the most abundant paramuriceid within the Sanctuary was S. exserta whereas H. pendula was most abundant at Discovery Bay.

DISCUSSION

Observations during the Sanctuary Survey, the Keys Reef Project and comparison with published reports provided information on the general structure of Key Largo reefs and their gorgonian fauna. Bank-barrier reefs of the Sanctuary located 8-11 km offshore, differ from Discovery Bay reefs by their proximity to shore. The reef slope off Key Largo gradually deepens whereas Discovery Bay reefs have a precipitions drop off. Reefs off Palm Beach County are closer to shore than Sanctuary reefs but are comprised of ledges or terraces followed by an outer net platform characterized by low sandy slopes.

Above 20 m, Sanctuary outer reefs (Carysfort) and Discovery Bay are similar in reef structure, zonation and gorgonian species distribution. Gorgonian diversity was greatest at 4-9 m depths off Carysfort reef (personal observation) and between 6-15 m depth off Jamaica (Kinzie, 1973). In both areas, shallow zones of high gorgonian diversity were followed by a zone of A. cervicornis which preceded the beginning of the reef slope. Off Palm Beach County, gorgonian diversity was greatest on the platform in depths of 16-20 m.

Although Key Largo and Palm Beach County reefs differed in structure and gorgonian distribution above 20 m, they had more in common with each other than with reefs off Discovery Bay as depth increased.

I. schrammi, an asymbiotic anthothelid, dominated coral knolls of the deep outer reef slope at both Florida locations. Pseudopterogorgia bipinnata was also common on Sanctuary reefs. Associated gorgonians were members of the Plexauridae and Gorgoniidae (although generally not conspecific with those of shallower water) and a few members of Ellisellidae and Paramuriceidae (typically deeper water families). Likewise, the rubble plain of the fore reef zones of both areas were dominated by the paramuriceid, S. exserta, and the ellisellid, N. schmitti, (both asymbiotic) which became more common below about 30 m.

Pseudoptrogorgia bipinnate was most common at the shallow outer reef slope; P. elisabethae, dominated the deep outer reef slope of Discovery Bay reefs. Abundance of the latter was probably due to its relatively small size and ability to utilize the only substrate (coral rock and dead Montastraea plates of pinnacles) available in this zone (Kinzie, 1973). The fore reef zone (deep fore reef slope) gorgonian fauna of Jamaican reefs was dominated by Paramuriceidae and Ellisellidae. Species of Nicella were common, with S. exserta replaced in dominance by H. pendula. Abundance of H. pendula vs. S. exserta can be partially attributed to lack of preferred habitat for S. exserta (flat rubble plain of Florida).

Observations within the Sanctuary supported findings that numbers of species and individuals of asymbiotic forms increased proportionately with depth below 20 m off southeast Florida (Goldberg, 1973). All three studies also showed that familial dominance of the gorgonian fauna changed from Plexauridae and Gorgoniidae to Paramuriceidae and Ellisellidae at depths from about 30 m (off Florida) to 50 m (off Discovery Bay).

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FISHES

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INTRODUCTION

The reef fish communities of the Key Largo "deep reefs" are important elements of this brief survey. The fishes comprise a ubiquitous component of any reef system. These animals are important as contributors to sport and commercial fishing enterprises as well as their aesthetic input to man's long-term interest in tropical reefs.

Because of the depth of this reef tract (26 to 38 m) the value of the ichthyofauna to the areas economy has been primarily in the form of a hook and line fishery. SCUBA divers have visited these reefs but have been limited because of decompression problems associated with such depths. Hence, most diving/tourist operations have been restricted to shallower reef systems such as Molasses Reef (1-14 m).

As in the case of all our investigations during the one week survey, our results are incomplete. Many weeks and submersible dives could have been expended in observing and collecting the reef fishes alone.

Long duration studies of the fishes of the Florida Keys are somewhat limited. The most exhaustive one is that of Starck (1968) conducted at Alligator Reef some 16 miles southwest of Key Largo. This study listed 517 species (389 coral reef forms) collected over a 10 year period and it ranged from the shallowest reefs in the intertidal zone to a deep patch reef system located at 45 m. The latter may be a homolog of the Key Largo Reef.

A more recent study conducted at Key Largo involved a visual survey of four fish communities within the Sanctuary area. This study was completed in July and August of 1975 by Jones and Thompson (1978). Since the present investigation of the deep reefs was also primarily visual in nature, it was reasonably comparable to that of Jones and Thompson conducted on the adjacent shallow water reefs (1 to 21 m). These comparisons are discussed later in this report.

METHODS

The research submersible JOHNSON-SEA-LINK (Figure 9) was the focal point of the fish study. Although the Key Largo "deep reef" is not beyond SCUBA depths, it is sufficiently deep to severely limit the "bottom time" of an investigator. It is also an extensive area and would require an inordinately large number of SCUBA dives to give a scientist a reasonable look at it. Therefore, the submersible was invaluable in allowing each observer several dives of long duration (2 to 4 hours). Moreover, the mobility of the craft allowed a wide areal coverage that could range from the shallowest to the deepest parts (26 to 38 m) of the reef tract in a single dive.

Most of our fish data were derived from direct visual observations by ichthyologists riding in either the forward or after compartments of the submersible. Fish species were recorded along with relative abundance codes on audio tape recorders or on checklists. Such a visual survey is obviously biased toward the more ubiquitous suprabenthic species and away from the cryptic forms. This had to limit our species list considerably.

We attempted to sample the more cryptic species using rotenone collections. Crystalline rotenone was dissolved in dimethylsulfoxide (DMSO) and then diluted with isopropyl alcohol to form a stupifier substance. The material was injected from a piston operated dispenser attached to the submersible's manipulator arm. The rotenone solution was deployed around the base of isolated coral heads. When fishes began to show signs of stress from encounter with the rotenone, the after compartment of the submersible was pressurized and a diver locked out to collect the fishes.

Only 13 species were collected in the above manner which was a most disappointing return for our effort. We suspect that DMSO and isopropyl are less effective solvents (at least at the depths used) for crystalline rotenone than acetone which is the normal solvent used. The latter is highly effective on shallow reefs but could not be used with the submersible. Acetone acts as a solvent to acrylic and it was thought that it might deface or otherwise damage the large acrylic sphere on the JOHNSON-SEA-LINK.

On at least one occasion, the submersible's manipulator was used to collect "rock" samples which ultimately yielded cryptic fish species from within them.

The submersible is also equipped with an external camera and strobe which was used to photograph many of the fishes associated with the deep reefs. This was especially useful since an ichthyologist could not be present on every dive. Several fish species not seen on ichthyology missions were recorded with the camera by our other scientist colleagues and were later identified on film.

Dive numbers 674, 675, 676, 683 and 684 had ichthyologists participating. Ichthyologists made two dives each in the French Reef and Carysfort operating areas and one in the Elbow operating area. Dive numbers 683 (French) and 684 (Carysfort) included lockout collections at the end of the dives.

RESULTS AND DISCUSSION

Table 10 is a checklist of the species observed in the three operating areas (Elbow, French and Carysfort). The table also compares the total number of fishes observed on the Key Largo deep reefs (110 species) with the total number observed by Jones and Thompson (1978) on the adjacent shallower reefs (1-14 m) of the Sanctuary (146 species, observed on three reefs and one shipwreck).

Two specimens of the pike conger eel, Hoplunnis diomedianus, and one specimen of the island goby, Lythrypnus nesiotes were taken from a large rock specimen collected off French reef in 76 m of water by marine geologist, Gene Shinn (manipulator collection). As noted above, only 13 species (mostly common) were taken during the two lockout collections. More than one half of the 110 species of fishes observed, could be verified from random photos taken with the submersible's camera.

Table 11 compares actual observation time, species, depths and localities between the deep reefs of this survey and the shallower ones of Jones and Thompson (1978). Table 11 shows that observation times were equivalent for the two studies at French Reef and about one hour greater for Jones and Thompson at Carysfort. The extra hour of observation at Carysfort Reef yielded 22% more fishes (81 vs 104) observed by Jones and Thompson (1978) while the nearly equal observation time at French Reef yielded 25% more fishes (88 vs 118). The SCUBA observations of Jones and Thompson are considered somewhat more efficient than submersible observations because divers are able to explore more cryptic microhabitats than are visible to submersible passengers. This is further evident in that their study yields more cryptic species such as gobies (Gobiidae), and cardinalfishes (Apogonidae) (Table 10).

It was also apparent from the data in Table 10 that other non-cryptic species were simply more common in the shallow reef areas than on the deep reef tract. These included many of the grunts (Pomadasyidae) and snappers (Lutjanidae), as well as some of the key species of wrasses (Labridae) and filefishes (Monacanthidae).

Both the present and the Jones and Thompson studies were conducted during daylight hours. It is well known that many of these species aggregate during the day in shallow areas but disperse at night to feed in deeper water (Collette and Talbot, 1972). Therefore, a number of the species absent from the deep reefs during the day might have been seen had night dives been conducted. In spite of the reduction in species richness over the deep reefs, most common families and reef species were found there.

There were several clear cases of common shallow water species being replaced by deeper water forms. The brown chromis, Chromis multilineata, occurs with the blue chromis, Chromis cyanea, as mid-water plankton feeders on the shallow reefs. The species is still found but greatly reduced in number (at least an order of magnitude) on the deep reef tract. Here, the sunshine fish, Chromis insolatus, joins C. cyanea as one of the dominant plankton feeding mid-water species. In another example, Jones and Thompson (1978) found the harlequin bass, Serranus tigrinus, to be the dominant member of this genus in their study while the present study showed the tobaccofish, S. tabacarius, to dominate on the deep reef.

One of the authors (Jones) participated in both the deep and shallow reef studies at Key Largo. His overall subjective impression suggested a decline of species richness with depth. Moreover, many of the species present on both deep and shallow reefs tended to show a decrease in numbers of individuals with depth but an increase in size of individuals. There were no methods available at the time of the study to quantify these observations so they should be regarded as qualitative only.

The reef fish species were found to be well represented over-all on the deep reefs and there was no obvious evidence of either man-made or natural stress on the fishes.

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ALGAE

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INTRODUCTION

The benthic marine algae of the Florida Keys are fairly well know compared to other tropical and subtropical areas in the western Atlantic. Harvey (1852, 1853, 1858), Farlow (1876), Ashmead (1857) and Howe (1903, 1904, 1905 a, b, 1909) were early systematists who collected in this area. Taylor (1928) gave a comprehensive treatment in his Marine Algae of Florida with Special Reference to the Dry Tortugas. More recent studies by Stephensen & Stephensen (1950), Phillips (1959) Croley and Dawes (1970), Dawes, Earle, and Croley (1967), Earle (1969), and Mathieson and Dawes (1975) have added to our knowledge of the ecology of shallow water alage (< 10m) in the Florida Keys but only Taylor gives any information on deep-water algae. These were from dredge collections so the adequacy of sampling is uncertain and the habitats could not be observed. In the present study three collections were made by SCUBA diving in depths of 10, 20 and 30 m at Molasses Reef in the Key Largo Coral Reef Marine Sanctuary (Sanctuary). In addition, two observation and lockout dives were made with the submersible JOHNSON-SEA-LINK I. One of these, J-S-L I Dive #681 (Table 1) was at French Reef where observations were made from 18-42 m and a lockout collection was made at 38 m. The second, J-S-L I Dive #682 (Table 1) explored the rubble zone at Carysfort Reef from 33-67 m with a lockout collection at 52 m.

RESULTS

Sixty species of Chlorophyta, Phaeophyta, and Rhodophyta were collected within the Sanctuary (Table 12). Nineteen species were found on Molasses Reef, 12 at 10 m, 9 at 20 m, and 10 at 30 m. The two lockout dives produced 31 (38 m, French reef) and 38 (52 m, Carysfort reef) species.

There are two classes of habitat for algae present in the sanctuary, the reef tracts which extend to a depth of about 30 m and a *Lithothamnion* cobble zone which extends to undetermined depths on the seaward side of the outer reef tract. The algal species found in these habitats are virtually exclusive. Only *Dictyota dichotoma* was found at all stations.

Halimeda opuntia f. *minor* and *Dictyota dichotoma* were the most characteristic species of the reef tract. *Udotea conglutinata* and *Galaxaura obtusata* were also present in all three collections but were present in small amounts. The other 15 species could probably be found at all three depths except perhaps for *Hypnea volubilis*, *Martensia pavonia*, and Titanophora incrustans which appear to be restricted to deeper water (Eiseman, unpublished data).

No single species can be said to be characteristic of the Lithothamnion cobble zone but it may be characterized by certain growth forms and/or higher (ordinal or familial) taxonomic groups. Virtually all of the species found in the cobble zone have ligulate, foliose, or filamentous growth forms or some modification of one of these. These forms maximize the surface/volume ratio which increases the percentage of photosynthetic tissue.

Taxonomically, the siphonaceous orders of the Chlorophyta account for all but one of the green algal species collected. These orders have pigmentation which is distinct from other green algae (Strain 1951), which may condition them to the lower light levels and/or different spectral qualities which are encountered at depth. Further there is evidence that some of these may have cell wall structures that concentrate available light energy on the photosynthetic apparatus (Ramus 1978). All but one of the Phaeophyta belong to the order Dictyotales. These are ligulate to foliose forms.

Among the Rhodophyta the Nemaliales are represented only by the family Chaetangiaceae. Members of this family have hyaline cells covering the photosynthetic surface which may act as integrating units, concentrating available light. The foliose Cryptonemiales, while few in number of species, are very abundant. The Nemastomataceae of the Gigartinales are not represented in the shallow waters (<10 m) of Florida but are conspicuous in deeper water (>20 m). These are mostly foliose forms which are composed of filaments embedded in a gelatinous matrix. The Rhodymeniales, of various form, are prominent in these collections as are the filamentous and monostromatic Ceramiales. The other families of the Rhodophyta are poorly represented or are absent from the deeper waters (>20 m) in this locality.

DISCUSSION

On examination of Table 12 two trends are striking. One is that the shallower reef tract is very species poor compared to the deeper cobble zone. The second is that there is little overlap in species composition between the two habitats. It may be assumed that the species found on the reef tract are less attractive to the numerous herbivorous fish and echinoderms which inhabit these reefs. Less obvious to the non-specialist is that a large number of those species found in the cobble zone are also found at much shallower depths in the Florida Keys. Twenty-four species found in the cobble zone but not found on the reef tract were collected in water of 0-2 m depth during the same week the samples were collected in the Sanctuary. This may also be attributed to grazing pressure on the reefs.

The species composition and depth distribution in the Sanctuary is strikingly similar to that found in the vicinity of Palm Beach, Florida where an extensive study of deep water algae has been made (Eiseman 1978, 1979, unpublished data). At Palm Beach there is also a reef in the 28-30 m depth range, although a much smaller and less continuous one. Species richness in this area is also lower than in the cobble zone at deeper depths. From 33-42 m there is a relatively uniform benthic flora which resembles the flora collected in the cobble zone in the Sanctuary. There is also a distinct flora which occurs from 60-100 m depths. The 40-60 m depth range at Palm Beach appears to be a transition zone. We have not yet examined the Sanctuary deep enough to determine whether the deep water flora occurs there. If so, it is found much deeper in the Sanctuary than in Palm Beach. From 30 m where the cobble zone begins to 67 m in the Sanctuary the flora resembles that found in the 30-40 m range in Palm Beach. In the Palm Beach area upwelling of deep cold water is a common occurrence which may account for the existence of a distinct deep water group of species. It is not known whether this upwelling occurs at Key Largo or with what frequency and duration.

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ECHINODERMS

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INTRODUCTION

Among the early systematists reporting on the echinoderm fauna of Florida were A. Agassiz (1869, 1880, 1883) echinoids, asteroids; Lyman (1869) ophiuroids, asteroids, Pourtales (1869 a,b) holothuroids, crinoids, and Verrill (1915) asteroids. More recent studies by Clark (1933) Puerto Rico echinoderms; Deichmann (1930, 1938, 1940, 1954) Western Atlantic and Gulf of Mexico holothurians; Downey (1973) Caribbean and Gulf of Mexico asteroids; Kier and Grant (1965) ecology of Key Largo echinoids; Serafy (1979) Gulf of Mexico echinoids and Thomas (1962) Florida amphiurid brittle stars, have added substantially to our knowledge of Floridan echinoderms.

The purpose of the present study was to identify echinoderms specimens obtained during the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey as part of a qualitative inventory of marine flora and fauna. A complete species list by station number and short discussion are included. Little attempt has been made to access the qualitative significance of the species reported since the majority of specimens collected were obtained inadvertently through collections of other groups.

METHODS

Specimens were obtained incidental to major collections of algae and coelenterates using the JOHNSON-SEA-LINK (JSL) submersible. Echinoderms were obtained on JSL Dive # 679, 681, 682, 686, 687, 688 and 690 (Table 1).

RESULTS

Echinodermata Species List by Station Number

JSL-I-679 03-VI-79 French Reef

Class: Echinoidea
Family: Cidaridae
Genus: Eucidaris
Species: tribuloides (Lamarck, 1816)
1 specimen, juvenile

Class: Stelleroidea
Subclass: Ophiuroidea
Family: Ophiactidae
Genus: Ophiactis
Species: algicola (Clark, 1933)
1 specimen

Family: Ophiothricidae
Genus: Ophiothrix (Ophiothrix)
Species: angulata (Say, 1825)
3 specimens

JSL-I-681 04-VI-79 French Reef

Class: Echinoidea
Family: Cidaridae
Genus: Eucidaris
Species: tribuloides (Lamarck, 1816)
1 specimen, juvenile

Family: Arbaciidae
Genus: Arbacia
Species: punctulata (Lamarck, 1816)
1 specimen, juvenile

Class: Stelleroidea
Subclass: Ophiuroidea
Family: Ophiactidae
Genus: Ophiactis
Species: mulleri (Lutken, 1856)
1 specimen, juvenile

Family: Amphiuridae
Genus: Ophiostigma
Species: isacanthum (Say, 1826)
2 specimens, juvenile

Family: Ophiothricidae
Genus: Ophiothrix (Ophiothrix)
Species: angulata (Say, 1825)
4 specimens

JSL-I-682 04-VI-79 Carysfort Reef

Class: Echinoidea
Family: Toxopneustidae
Genus: Pseudoboletia
Species: maculata maculata (Troschel, 1869)
1 specimen

Genus: Lytechinus
  Species: variegatus carolinus (A. Agassiz, 1863)
    1 specimen, juvenile

Family: Brissidae
  Genus: Meoma
    Species: ventricosa (Lamarck, 1816)
      1 specimen

Class: Stelleroidea
  Subclass: Ophiuroidea
    Family: Ophiothricidae
      Genus: Ophiothrix (Ophiothrix)
        Species: angulata (Say, 1825)
          4 specimens

JSL-I-686 06-VI-79 French Reef

Class: Stelleroidea
  Subclass: Ophiuroidea
    Family: Gorgonocephalidae
      Genus: Astrophyton
        Species: muricatum (Lamarck, 1816)
          1 specimen, juvenile

Family: Ophiothricidae
  Genus: Ophiothrix (Acanthophiothrix)
    Species: suensoni (Lutken, 1856)
      1 specimen, juvenile

JSL-I-687 06-VI-79 Carysfort Reef

Class: Crinoidea
  Family: Comasteriadae
    Genus: Nemaster
      Species: rubiginosa (Pourtales, 1869)
        1 specimen

JSL-I-688 06-VI-79 Elbow Reef

Class: Stelleroidea
  Subclass: Ophiuroidea
    Family: Gorgonocephalidae
      Genus: Astrophyton
        Species: muricatum (Lamarck, 1816)
          1 specimen, juvenile

Family: Ophiactidae
  Genus: Ophiactis
    Species: algicola (Clark, 1933)
      1 specimen

Family: Ophiothricidae
Genus: Ophiothrix (Ophiothrix)
Species: angulata (Say, 1825)
2 specimens

Genus: Ophiothrix (Acanthophiothrix)
Species: suensoni (Lutken, 1856)
1 specimen

Family: Ophionereididae
Genus: Ophionereis
Species: olivacea (Clark, 1901)
1 specimen

JSL-I-690 07-VI-79 **Elbow Reef**

Class: Stelleroidea
Subclass: Ophiuroidea
Family: Amphiuridae
Genus: Amphiura
Species: stimpsoni (Lutken, 1859)
1 specimen

Genus: Ophiophragmus
Species: pulcher (Clark, 1818)
3 specimens

Family: Ophiothricidae
Genus: Ophiothrix (Ophiothrix)
Species: angulata (Say, 1825)
2 specimens

Family: Ophiocomidae
Genus: Ophiocoma
Species: pumila (Lutken, 1859)
9 specimens

JSL-I-690 07-VI-79 **Elbow Reef**

Family: Ophiodermatidae
Genus: Ophioderma
Species: brevicaudum (Lutken, 1856)
1 specimen, juvenile

45 specimens: 3 classes, 12 families, 15 genera and 17 species.

DISCUSSION

All 17 echinoderm species collected can be considered members of the tropical West Indian fauna. H.L. Clark (1933) listed 16 of the species in his "Handbook of the Littoral Echinoderms of Porto Rico and the Other West Indian Islands." The remaining species, *Pseudoboletia maculata muculata* Troschel, 1869, has been reported as part of the Floridan fauna by Pawson (1978) in summarizing literature records.

Eleven species belong to the subclass Ophiuroidea. Ophiuroids (brittle stars), noted for their cryptic behavior, are often found in association with algae, sponges and soft corals. The paucity of species in other echinoderm classes may be considered an artifact of selective collecting for corals and algae, rather than an indication of a depauperate echinoderm fauna. The absence of members from the class Holothuroidea (sea cucumbers) and subclass Asteroidea (sea stars) supports this assumption. Undoubtedly a more concerted effort at collecting echinoderms would yield many additional species. Kier and Grant (1965), although restricting their research area to depths less than 33 meters, reported 17 species of echinoids alone. At least 5 of these species, *Astropyga magnifica* A.H. Clark, 1934, *Clypeaster subdredressus* (Gray, 1925), *Diadema antillarum* (Philippi, 1845), *Plagiobrissus grandis* (Gmelin, 1788) and *Paraster floridiensis* (Kier and Grant, 1965) were reported by them from depths sampled by the present study.

Interesting to note was the collection of *Lytechinus variegatus carolinus* A. Agassiz, 1863, at 51.2 meters off Carysfort Reef. Serafy (1979 reports the known depth range for this species to be 0-75 meters but Kier and Grant (1965) found *Lytechinus* restricted to less than 10 meters, in direct correlation with the presence of turtle grass, *Thalassia testudinum*. Although it is well known that *Lytechinus* utilizes *Thalassia* as a primary food source, Moore et al. (1963), it appears to have the ability to exist on alternative diets.

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MOLLUSKS

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INTRODUCTION

The mollusks of the Florida Keys have been the subject of considerable study. Surveys of various localities have been provided by Melville (1881), Bartsch (1937), Bales (1940), Clench (1945), and Voss et al. (1955, 1969), while numerous authors (Bayer, 1941; Bartsch, 1946; Foster, 1946; Abbott, 1951; Schwengel, 1951; Moore, 1956; and others) have contributed taxonomic studies.

The purpose of this work was to identify molluscan specimens obtained during the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey as part of a qualitative inventory and to possibly provide new information on the ecology of the mollusks in this area.

METHODS

Specimens were obtained incidental to major collections of algae, corals and rocks using the JOHNSON-SEA-LINK submersible, on dive numbers 679, 682, 687, 688 and 690 (Table 1).

RESULTS

SPECIES LIST

GASTROPODA

Columbellidae: *Costoanachis lafresnayi* (Fischer & Bernardi, 1856)
I-679; rock; 1 spm; IRCZM 65:764

Thaididae: *Morula (Trachypollia) nodulosa* (C.B. Adams, 1845)
I-679; rock; 1 spm; IRCZM 65:763

Bursidae: *Bursa (Colubrellina) granularis cubaniana* (Orbigny, 1842)
I-679; rock; 2 spms; IRCZM 65:762
Bursa (Colubrellina) corrugata (Perry, 1811)
I-679 rock; 1 spm; IRCZM 65:761

Turbinidae: *Turbo (Marmarostoma) castanea* Gmelin, 1791
I-682 algae; 1 juvenile spm; IRCZM 65:760

Eratoidae:

Erato (*Hespererato*) *maugeriae* Gray, 1832
I-682 algae; 1 spm; IRCZM 65:759
Trivia (*Pusula*) *quadripunctata* (Gray, 1827)
I-687 Scleractinia; 1 spm; IRCZM 65:758

Turridae:

Splendrillia ?janetae Bartsch, 1934
I-688; Octocoral; 1 spm; IRCZM 65:770

Nassariidae:

Nassarius (*Hinia*) *albus* (Say, 1826)
I-690; *Monastraea*; 1 spm; IRCZM 65:769

Marginellidae:

Hyalina (*Volvarina*) sp.
I-690; *Monastraea*; 1 spm; IRCZM 65:768

Fissurellidae:

Diodora cayenesis (Lamarck, 1822)
I-688; *Siliquaria*; 1 spm; IRCZM 65:766

Siliquariidae:

Siliquaria ?modesta Dall, 1881
I-688; *Siliquaria*; 1 colony: IRCZM 65:767

BIVALVIA

Arcidae:

Barbatia (*Acar*) *domingensis* (Lamarck, 1819)
I-679; rock; 1 spm; IRCZS 64:832
I-690; *Monastraea*; 1 spm; IRCZM 64:841
I-688; *Siliquaria*; 1 spm; IRCZM 64:838
Arca imbricata Bruguiere, 1789
I-679 (#2); rock; 1 juvenile spm; IRCZM 64:831
Arcopsis adamsi (Dall, 1886)
I-688; *Siliquaria*; 2 spms; IRCZM 64:839

Ungulinidae:

Diplodonta (*Diplodonta*) *?punctata* (Say, 1822)
I-682; algae; 1 spm; IRCZM 64:830

Isognomonidae:

Isognomon radiatus (Anton, 1839)
I-690; *Monastraea*; 1 spm; IRCZM 64:842

Chamidae:

Chama sp.
I-688; *Siliquaria*; 2 empty left valves; IRCZM 64:840

POLYPLACOPHORA

Acanthochitonidae:

Acanthochitona pygmaea (Pilsbry, 1893)
I-690; *Monastraea*; 1 spm; IRCZM 61:018

Ischochitonidae:

Stenoplax floridana (Pilsbry, 1892)
I-688; Octocoral; 1 spm; IRCZM 61:023

SPECIES LIST BY STATION

I-679; rock; 76.2 m
- *Costoanachis lafresnayi*
- *Morula nodulosa*
- *Bursa granularis cubaniana*
- *Bursa corrugata*
- *Barbatia domingensis*
- *Arca imbricata*

I-682; algae; 51.2 m
- *Turbo castanea*
- *Erato maugeriae*
- *Diplodonta ?punctata*

I-687; Scleractinia; 27.4 m
- *Trivia quadripunctata*

I-688; Octocoral; 40.5 m
- *Splendrillia ?janetae*
- *Stenoplax floridana*

I-688; *Siliquaria*; 56.4 m
- *Siliquaria ?modesta*
- *Diodora cayenesis*
- *Chama* sp.
- *Arcopsis adamsi*
- *Barbatia domingensis*

I-690; *Monastraea*; 18.3 m
- *Hyalina* sp.
- *Nassarius albus*
- *Isognomon radiatus*
- *Barbatia domingensis*
- *Acanthochitona pygmaea*

DISCUSSION

The molluscan collection yielded a total of 20 species in 16 families. These were distributed as follows: Gastropoda, 12 species in 10 familes; Bivalvia, 6 species in 4 families; and Polyplacophora, 2 species in 2 families. The list included no new species and was largely typical of the substrates sampled. However, because the collection of mollusks was entirely incidental to collections of other phyla, the species list cannot be regarded as comprehensive. Three gastropods, *Bursa granularis cubaniana*, *B. corrugata*, and *Siliquaria modesta*, are uncommon and therefore worthy of special mention. The large colony of *Siliquaria* is being investigated further to obtain information regarding shell morphology and internal anatomy. These results will be reported elsewhere in the future.

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DECAPOD CRUSTACEANS

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INTRODUCTION

Although there have been many short papers and incidental records relating to the general distribution of decapod crustaceans in the Florida Keys, with the exception of the well-known monographs by Rathbun this geographical area has not been intensively studied. As might be expected, shallow water crabs, shrimps and lobsters comprise a relatively well-known fauna when compared to the assemblages occurring in deeper waters. This is especially true for the coral reef, and coral-associated decapod fauna found on deep water coral reefs in the Florida Keys. What little data are available have generally been obtained using SCUBA, because surface-towed dredges and trawls cannot be effectively employed on the highly complex topography of a coral reef. Until this report, there has been no deep water coral-related collections using a manned submersible in this region. Although the sampling method was admittedly crude, employing manipulators on the submersible, and haphazard collecting by lockout diver, the results were quite gratifying, primarily because the biotope itself has been so poorly investigated. The following report lists the decapod crustaceans obtained during the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey, as part of a larger qualitative inventory of the biology of the study area, and allows brief consideration of their ecology and zoogeography in this deep water area. More comprehensive attention will be directed toward all of the species in two publications (Kensley and Gore 1981; Gore 1981).

METHODS

The following collection is the result of JOHNSON-SEA-LINK Dive #679, 681, 682, 687, 688, and 690 (Table 1). In most cases specimens were taken from samples of coral, algae or gorgonians.

Holotypes and paratypes of new taxa, described in the publications noted above have been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC.

RESULTS

Dive	Family	Genus/species	No./Sex	Comments
679	Alpheidae	Alpheopsis trispinosus (Stimpson)	1 f	Range extension U.S.
	Processidae	Processa cf. tenuipes Manning & Chace	1 f	Probably new species
	Bresiliidae	Discias atlanticus Gurney	1 f	3rd continental record
	Axiidae	Undescribed axiopsine shrimp	1 f	New genus, new species
	Galatheidae	Munida angulata Benedict	1 f ov.	
	Xanthidae	Micropanope sculptipes Stimpson	1 m 2 f	
		Pseudomedaeus distinctus (Rathbun)	1 f juv	
	Majidae	Mithrax acuticornis Stimpson	1 m	
681	Alpheidae	Synalpheus sanctithomae Coutiere	1 m	Known previously from 3 syntypes; 1st continental record
	Galatheidae	Munida angulata Benedict	1 m	
	Xanthidae	Actaea bifrons Rathbun	1 f ov.	
		Micropanope sculptipes Stimpson	1 m juv.	
682	Palaemonidae	Pontoniopsis paulae Gore	1 m	New species; range extension for genus
	Galatheidae	Munida angulata Benedict	3 f ov.	
	Hippolytidae	Thor manningi Chace	1 f ov.	
687	Palaemonidae	Pseudocoutierea antillensis Chace	2 f ov.	Known previously from female holotype; 1st continental record
688	Alpheidae	Alpheopsis trispinosus Stimpson	3 m 2 f	As noted above for stn. 679
	Galatheidae	Munida angulata Benedict	1 m 1 f ov.	
	Xanthidae	Micropanope sculptipes Stimpson	1 m 2 f 1 juv.	
		Micropanope sp.	1 juv.	
		Melybia thalamita	1 f	
		Juvenile xanthid crab	?	Crushed; too small for ID
	Stenopodidae	Odontozona libertae Gore	2 m 1 f ov. (spent)	Second record for genus in the western hemisphere; previously Africa-Red Sea, Indo-Pacific genus
690	Alpheidae	Alpheus amblyonyx Chace	1 f	
		Alpheus normanni Kingsley	1 m 1 f ov.	
		Synalpheus townsendi Coutiere	1 m	
		Synalpheus sp.	1 m	Probably S. townsendi

Dive	Family	Genus/species	No./Sex	Comments
690				
		Synalpheus sanctithomae Coutiere	1 f ov.	As noted for stn. 681
		Synalpheus pandionis Coutiere	1 m	Rare species
	Palaemonidae	Veleroniopsis kimallynae Gore	1 m	New western Atlantic genus and species
	Galatheidae	Munida angulata Benedict	1 m	
			1 f	
	Paguridae	Nematopaguroides cf. fagei Forest & St. Laurent	1 m	1st continental record; possibly new species
	Xanthidae	Actaea bifrons Rathbun	1 f	
		Pilumnus sp.	1 m juv.	
		Micropanope nuttingi (Rathbun)	1 f	
		Melybia thalamita Stimpson	1 m	
			1 f	
690	Alpheidae	Alpheus amblyonyx Chace	1 f	
		Alpheus normanni Kingsley	1 m	
			1 f ov.	
		Synalpheus townsendi Coutiere	1 m	
		Synalpheus sp.	1 m	Probably townsendi
		Synalpheus sanctithomae Coutiere	1 f ov.	Notes as above
		Synalpheus pandionis Coutiere	1 m	
	Galatheidae	Munida angulata Benedict	1 m	

TOTALS:

Families:	11	Interesting Records: 2
Genera:	19	New records: 4
Species:	23	New taxa: 2 new genera, 4 new species
Individuals:	55	

DISCUSSION

A total of 53 individuals of decapod crustaceans were obtained during the sampling program, distributed in 11 families, 19 genera and 23 species. Of these, 4 were new species in the sections Caridea, Thalassinidea, and Stenopodidea, all of which contain coral-associated shrimp. At least 2 other taxa, a processid shrimp and a pagurid hermit crab, may eventually prove to be new species when additional material becomes available. Another 3 - 4 species in the caridean shrimp families Alpheidae and Palaemonidae, and perhaps in the anomuran hermit crab Paguridae, were new records for the continental United States. The single bresiliid shrimp species was of interest in that it represented an additional recent record of an extremely rare species. The discovery of a second, and undescribed species of the stenopodid shrimp genus Odontozona off Key Largo firmly establishes this cleaning shrimp genus in the western hemisphere. Previously it was known from the Indo-West Pacific. It was also of much interest to discover that of the 4 specimens of pontoniine shrimp (Palaemonidae), 1 was an undescribed genus and species, another seems to be a new species, and the other 2 belonged to an extremely rare species previously known from the lesser Antilles.

The remaining species (13) consisted of more common forms previously known as associates of coralline habitats. These included caridean shrimp in the genera Alpheus and Synalpheus (Alpheidae), and Thor (Hippolytidae). The other anomuran decapods were represented by the genus Munida (Galatheidae). Brachyuran crabs were divided among the genera Micropanope, Melybia, Actaea, Pseudomedaeus, Pilumnus (Xanthidae), and Mithrax (Majidae). All of the above taxa are small species, well adapted to life in crevices of coralline substrata.

The overriding interest in this small, but remarkable, collection is the presence of at least 4 new species and 4-6 new records for decapod crustaceans. The occurrence of these new or rare forms only serves to emphasize the paucity of our knowledge for the deep-water coralline biotope, an area which, by virtue of its topography and complexity, will undoubtedly remain poorly sampled using conventional surface-operated gear. It may yet yield rich results when examined by SCUBA or manned submersibles.

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SPONGES

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INTRODUCTION

Sponges are a major element in coral reef ecosystems. However, little work has been done on factors which influence their distribution. It is generally agreed that mechanisms such as feeding specialization and interspecific competition for substrate, which influence distribution of other phyla, are not major factors in niche partitioning for sponges (Vacelet, 1959; Hartman, 1957; Sara, 1970; Koltun, 1970; Reiswig, 1973). Rather, a combination of several minor factors controls patterns of zonation. Sedimentation, wave action, light, and the availability of food contribute to differences in zonation patterns which occur from the shallow to the deep reef (Goreau & Hartman, 1963; Reiswig, 1973).

Research on the ecology of coral reef sponges has been concentrated in areas other than the Florida reef tract. Taxonomic literature available for Florida reef sponges indicates, however, that species assemblages are generally the same as those in the Bahamas and the Caribbean. These records are supported by personal field observations by the author.

A bibliography which includes research done on sponges in the Florida Keys is appended.

METHODS

Samples were obtained during collections made by the JOHNSON-SEA-LINK.

RESULTS

Sponges collected during the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey are listed in Table 13. Also listed in Table 13 are species observed by the author during transect studies of Carysfort Reef in 1975, 76. The two surveys are listed together for comparison purposes.

DISCUSSION

DeLaubenfels (1950) has selected 50 m as a lower limit for West Indian shallow water sponges. All sponges collected during the deep reef survey are, therefore, considered shallow water sponges. *Haliclona compressa*, *Niphates erecta*, *Niphates digitalis*, *Iotrochota birotulata*, and the axinellid are characteristic reef species. Ircinia strobilina, Aplysina fistularis, and Spinosella tenerrima are restricted to rocky substrates and can occur in reef communities. Xestospongia muta is generally confined to the deeper rock pavements and reef communities. Spheciospongia vesparium occurs on rocky substrates and in reef habitats, but can also occur in a sediment substrate with its base extending down to the bedrock for attachment. The other species, Haliclona sp., ?Epipolasis or ?Jaspis, ?Myriastra sp., and Prostylissa spongia, are generally found in areas of moderate to dense vegetation and are not common in reef communities.

Most of the species collected have been reported from various areas within the West Indian region. None occurs outside the West Indian region. This survey reports new records of occurrence in the Florida Keys for ?Epipolasis sp. or ?Jaspis sp., Prostylissa spongia, and Iotrochota birotulata. (Although I. birotulata is and has been very common in the Florida reef tract, its abundance has evidently never been reported in the taxonomic literature.) The epipolasids (?Epipolasis sp. or ?Jaspis sp. and ?Myriastra sp.) could be new species. Since the Siliquaria - sponge complex comprised a fairly distinct habitat, and since a similar complex between related species occurs in shallow water, more research on this community should be conducted.

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GEOLOGY

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Two dives were made on June 3, 1979, as part of the Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey. The first dive was seaward of French reef in the southern area of the Sanctuary, and the second was on an isolated reef between The Elbow and Carysfort reefs in the northern area. The two dives are described separately in a travelog fashion.

J-S-L Dive #679, Off French Reef (Duration of Dive: 9:10 a.m. to 1:51 p.m.)

J-S-L Dive #679 (Table 1) was initiated in 30 m of water seaward of French Reef, where the bottom temperature was 27°C, visibility was between 12 and 15 m, and the current was flowing northward at 0.1 knots. The bottom at 30 m was similar to the shallower, nearby reef in 12 to 18 m of water. The principal living reef-builder observed was Montastraea cavernosa; minor smaller, flattened colonies of M. annularis, the principal builder in the shallower reefs, were also present. Numerous gorgonian species and sponges were common on hard rock surfaces. All the rock surfaces consisted of 1 to 2 meter high prominences forming 2 to 10 m long spurs generally less than 5 m wide, which were arranged parallel to the platform margin rather than perpendicular, as are the true spurs and grooves of the shallower reefs. These rock features are estimated to occupy approximately 50 percent of the bottom, the remainder being composed of carbonate sand with coral rubble. Nearly all the visible flora and fauna were restricted to the rocky surfaces.

Of particular interest at 33.5 m was the occurrence of several domelike algal stromatolites, Phormidium hendorsonii. This is probably the first recorded occurrence of these features, described by Golubic and Focke (1978), in a water depth greater than 9 m. They are most abundant in the intertidal-to-shallow subtidal zone through the Florida Keys and Caribbean.

The most conspicuous feature in the intra-reef sand areas at depths between 30 and 35 m consisted of small mounds of coral and algal cobbles piled up by either tile fish or octopi.

At a depth of 35.4 m, the rocky outcrops graded transitionally into a level bottom covered with numerous cobbles coated with fleshy algae. The rose coral, Manicina aerolata, scattered between the algal-covered cobbles, was fairly abundant. Algae included the red types, such as Laurencia. The green algae, Caulerpa sp. and Penicillus sp., and the codeacean alga, Halimeda, were also abundant. The Halimeda was of the large plate variety generally described as H. tuna. Some scattered colonies of the finger coral, Porites, were also observed in this zone. This community continued seaward, and at a depth of 38 m several of the cobbles were collected. Later examination showed that the cobbles were Lithothamnion nodules constructed by alternating concentric, sheetlike growth of the coralline red alga, Lithothamnion, over a nucleus generally consisting of coral fragments. Similar nodules were described by Logan et al. (1969) for depths ranging from 15 to 61 m on the Yucatan Shelf and were later renamed Rhodolites by Bosellini and Ginsburg (1971) from their work at Bermuda. The author and Paul Enos (SUNY, Binghamton) had previously collected these nodules from 39.6 m off Molasses reef while scuba diving in 1968.

Virtually 100 percent of the bottom was littered with these nodules over a distance of a kilometer or more out to a depth 45.7 m. Numerous mounds of these nodules up to 30 cm in height were observed throughout the area (Fig. 41). Sand tile fish, thought to be the builders, were often seen to retreat beneath the mounds. Evidence that the nodules are alive and growing is suggested by the pink color of the Lithothamnion and the size variation, ranging from the tiniest pebble size to cobble size of more than 10 cm across.

Farther seaward in depths between 45.7 and 54.9 m, the percentage of nodules decreased and white sand with a thin algal scum coating increased. At 55.5 m, burrowing echinoid trails, distinct because they break through the algal scum, became numerous (Fig. 42). At 54.9 m a thermocline was encountered where visibility was reduced to less than 12 m and temperature dropped to 25°C. At this level, the nodules were no longer present, only sand.

At 70 m we encountered low, 30-cm-high, sinuous and terraces which appeared to be sand mega-ripples with the foresets generally facing to the north. This orientation is consistent with the observed current direction; however, current velocity was not sufficient to induce sediment transport and ripple development. At approximately 70 m small slabs of rock were noted. Small patches of this rock increased with depth, and at 76 m a sample was collected and photographed (Fig. 43) from a small patch of rock exposed by removal of overlying sand. Several red fish, called "big eyes," had made a home under the rocks and apparently had exposed the rock by excavating away the overlying sand. Slabs of this rock were apparently extensive about 15 cm below the sand, but they were only visible where the overlying sand had been removed by burrowing. The collected rock was later thin-sectioned and examined in the laboratory. The rock consists of coral and algal sand with numerous large foraminifera cemented together by extremely fine-grained, high-magnesium calcite cement. Although the cement is almost certainly of submarine orgin, the fibrous aragonite so diagnostic of submarine cementation was not observed.

We continued our traverse eastward to the outer sanctuary boundary at approximately 85 m of depth and turned westward to traverse the area back to the shallow reef. The time was 12:10 p.m. and the bottom temperature was 20.8°C.

The return trip revealed the same vast expanse of flat bottom covered by algal nodules, with a notable occurrence of large clusters of Diadema sp. in 45.7 m of water. We did not encounter significant coral and rocky outcroppings until we reached a depth of 24.4 m. Again, the rocky outcrops consisted of elongate masses aligned parallel to the platform margin; however, at 19.8 m the first true spurs and grooves aligned perpendicular to the platform margin were encountered.

The staghorn coral, Acropora cervicornis, was first observed at 15 m. The dive terminated in 12 m of water at 1:51 p.m.

J-S-L Dive #680, On Isolated Reef Between The Elbow and Carysfort Reefs

(Duration of Dive: 5:10 p.m. to 6:55 p.m.)

Two perpendicular transects (Table 1) were made across an isolated linear reef aligned parallel to the platform margin. The transect began in 33.5 m of water on a smooth Lithothamnion nodule-coated bottom seaward of the reef. The seaward side of the reef rose abruptly to form a scarp approximately 3-4 m high. The water was much cleaner, with visibility in excess of 18 m. The staghorn coral, Acropora cervicornis, was fairly abundant, as were gorgonians and sponges. Head corals were noticeably rare. One ledge was seen to be oriented perpendicular to the reef trend; however, a well-developed spur and groove system was not observed here. Attempts to collect a piece of the well-cemented ledge failed.

As we traversed the reef in a westerly direction, it was seen to be approximately 100 m wide, and the topography changed from rugged to a smoother bottom with numerous gorgonians, sponges, and scattered heads of Montastraea cavernosa. Although our transect did not reach a sandy bottom on the landward side, side-scan sonar indicated that it is bordered by sand and thus is not a seaward extension of a shallower, more landward reef. The return west-to-east traverse revealed only a 5-cm-high rise above the sand, with no distinct vertical scarp. The seaward scarp was again observed to be 3-4 m high with an abrupt transition to the flat nodule-coated bottom. Maximum diversity of corals, gorgonians, and sponges appears to occur in a band 30 m wide on the seaward side of the reef. After turning back westward toward the reef, we paralleled the seaward side for at least 500 m, where we observed evenly spaced lobster traps without floats. Near the northern end of the reef, several evenly spaced channels aligned perpendicular to the reef were observed. They appear to represent a relict spur and groove system. The reef eventually died out to the north and the bottom became coated with nodules. The dive ended at 6:55 p.m.

DISCUSSION

Through these submersible dives, previous scuba dives, and discussions with other divers, and with Paul Enos (who recently published the most thorough study of the area: Enos, 1977), the collective observations are made that coral reefs or rock prominences do not extend beyond a depth of approximately 40 m in the middle keys area. Whereas reefs are present beyond these depths in other parts of the Caribbean, the lack of reefs in these depths off the middle Florida Keys may be explained in one of three ways: (1) water depth is too great for corals to become established on the sandy bottom, which lacks a hard substrate for coral attachment; (2) reefs did grow there in the near past but have been covered by sediment accumulation; or (3) sea-level rise during the past 18,000 years has been too rapid for reefs to become established. Thus, only during the past 5,000 years, when sea-level rise slowed down and reached near-present level, did coral growth become established.

Probably the most significant finds were the algal stromatolitic structures Phormidium hendersonii in 33.5 m or water and the vast expanses of algal nodules between 33.5 and 54.9 m of water.

Algal stromatolites, which span time from the Precambrian to the present, traditionally have been interpreted as shallow-to-intertidal indicators. This interpretation is probably biased, because most of the work in the modern environment, which provides the information for interpreting ancient analogues, has been mainly in shallow environments. In Florida and the rest of the Caribbean, this type of algal "head" is more abundant in less than 1 m of water. The deepest recorded occurrence is 9 m (Golubic and Focke, 1978). The observations during this dive more than triple its known depth range.

The occurrence of Lithothamnion nodules at the depth described here is not new. They have been described from similar depths around other Caribbean reefs (Logan et al., 1969; Bosellini and Ginsburg, 1971). It would appear that level bottom accumulations of such nodules in ancient to near-Holocene deposits would provide an indication of water depth. Although found in shallow to intertidal conditions at Bermuda (Bosellini and Ginsburg, 1971), those occurrences were associated with rugged reef topography rather than occurring as level bottom accumulations as described here and elsewhere. The vast expanse of these accumulations, forming a strip more than 1,000 m wide and at least 50 km long, is probably the largest accumulation yet described. These deposits probably parallel the entire Florida Keys reef tract. Future diving in other areas of the reef tract could easily determine their true extent.

Finally, the observation is interesting that submarine cementation of bottom sediments was found seaward of the reef. It is well known that cementation is rapid within reefs, but cementation in sandy sediments behind the reef in Florida is rare (Enos, 1977). Although the true extent could not be determined in our dives, the presence of cementation beneath a thin cover of sediment suggests that it might possibley have a widespread distribution beneath the sediment. Furthermore, its occurrence in deep water fits the known requirements for its formation, that is, time and slow rate of accumulation. At such depths the rate of sediment accumulation and reworking is probably considerably slower than in the shallow waters behind the reef, mainly because of the relative lack of sediment-producing organisms. These sediments have had considerably more time for cementation during the Holocene sea level transgression, but only an extensive and expensive coring program could adequately determine its distribution.

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ARCHAEOLOGY

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INTRODUCTION

Tales abound of Spanish galleons and other ships that are thought to have sunk in the Marine Sanctuary. In the mid to late 1600's the reefs of the Florida Keys contributed to the tragic demise of cumbersome Spanish galleons. Poor navigational techniques and lack of understanding of water patterns caused many ships to meet a violent end on the coral heads that loomed from the ocean floor. The coral reefs grounded many ships throughout the 1800's and provided the justification for the Carysfort Reef Lighthouse (Fig. 44).

One of the earliest ship disasters was in 1733, when almost the entire fleet of a 21-ship Spanish flotilla was lost off Key Largo. Of these ships, two galleons, EL INFANTE and SAN JOSE LOS AMENAS, have been located outside the southern boundary of the Marine Sanctuary. Apparently the fleet was hit by a hurricane while returning to Spain. A hurricane may also have played the dominant role in the grounding of the Plata flotilla fleet of 13 galleons near Carysfort Reef in 1755, although the number of ships lost is unknown and no ship of this fleet has even been located.

Today several wreck sites exist in the Marine Sanctuary, providing exciting dives for visitors. One of the best known wrecks is the 60-gun British frigate, HMS WINCHESTER. Thrown on the reef by a storm in 1695, the wreck lies in 9.1 m (30 feet) of water 2.5 km (1.5 miles) southeast of Carysfort Reef Lighthouse, in direct line with Elbow Light. The WINCHESTER was 44.5 meters (145.8 feet) long, but is now badly broken and scattered throughout the area. Two of the WINCHESTER's cannons recovered by C.M. Brookfield in 1940 are on display at the John Pennekamp Coral Reef State Park headquarters.

Because of the interesting archaeological history of Key Largo and the availability of side scan sonar an investigation of possible shipwrecks in Marine Sanctuary deep waters was appropriate.

METHODS

A side scan sonar survey was conducted March 26-30, 1979, as described on page 11. "Layback" corrections were applied to the position of the ship to obtain the position of the side scan sonar target. Targets were plotted on a Del Norte overlay to facilitate relocation.

Del Norte navigational control was established July 16-19, 1979 as described on page 11. Possible shipwreck target areas were located using Del Norte and buoyed on July 20, 1979.

With the help of divers and side scan sonar equipment from Jacques Cousteau's ship CALYPSO efforts were made to relocate and visually document the existence of shallow water targets on July 20, 21 and 22, 1979.

RESULTS

Three possible shipwrecks were located during Phase I operations (Figure 8). One, located in 58 meters (190 feet) of water off the Elbow, and appears to be steel-hulled. Another possible steel-hulled vessel is located in 86.8 meters (285 feet) of water near the southern boundary of the Marine Sanctuary. The third wreck (Rib wreck) based on the side scan sonar record, appeared to be a wooden-hulled vessel with its rib structure visually apparent in 39.6 meters (130 feet) of water between the Elbow and French Reef.

Personal communication with Halas (1979) indicates the shipwreck in 58 meters (190 feet) off the Elbow is a steel-hulled barge, based on his personal dives at this site. The other vessel in 86.8 meters (285 feet) at the southern end of the Marine Sanctuary is outside Marine Sanctuary boundaries, based on Del Norte calculations and was not investigated at this time.

These facts known, the "Rib wreck" was concentrated on exclusively. Efforts in cooperation with Cousteau divers using side scan sonar and diver searches for three days to document the existance of this target were unfruitful.

DISCUSSION

No historically significant shipwrecks were located in the Marine Sanctuary deep waters during the survey. Because extensive side scan sonar and diver searching was unsuccessful in locating the "Rib wreck" its existence is doubtful.

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A BRIEF COMPARISON OF THE REEF SYSTEM OFF KEY LARGO FLORIDA WITH THE FLOWER GARDEN REEF SYSTEM, NORTHWESTERN GULF OF MEXICO

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GEOGRAPHIC LOCATION AND HYDROGRAPHY

The East and West Flower Garden Banks are approximately 720 nautical miles West Northwest of Key Largo and 160 nautical miles north of the Key Largo latitude. The Flower Gardens are thus the northernmost reef ecosystems on the continental shelf of the United States wherein hermatypic scleractinian corals dominate major portions of the sea floor, forming tropical Atlantic coral reefs.

The Florida and Texas reef tracts exist in water masses which are basically influenced by warm near surface Caribbean water entering the Gulf of Mexico through the Yucatan Straits and reaching Key Largo with the Gulf Stream from the Florida Straits and the Bahama Channel. Because the Flower Gardens are 110 nautical miles offshore, they are rarely, if ever, exposed to coastal water of greatly reduced temperatures and salinities or high turbidity. Flower Garden water is generally clear, with salinities varying little from approximately 36^{o}/oo (lowest measured surface salinity 32^{o}/oo, lowest measured salinity at depth of reef 34^{o}/oo, these are rare) and temperatures between 20°C and 30°C, averaging approximately 25°C.

The Key Largo reef tract is directly adjacent to an insular land mass which is effectively an extension of the east Florida coast line. Local hydrography is complicated by the influence of water from Florida Bay which is periodically introduced to the area through passes between the Keys.

Florida Bay water is highly variable in salinity, temperature and turbidity and is considered to be a major factor limiting distribution of shallow coral reefs in the Florida Keys (Shinn, personal communication). Occasional southward flowing longshore currents are suspected of carrying coastal water from the Miami area to the vicinity of the Key Largo reef tract. Disregarding the possible impact of anthropogenic contaminants on the reef tracts (domestic and industrial effluents in Florida and offshore drilling effluents and ocean dumping contaminants at the Flower Gardens) it is suspected that reefs at Key Largo exist in a more variable hydrographic regime than do the reefs at the Flower Gardens.

The Key Largo reef tract is in close proximity to reef systems in the other Florida Keys, the Bahamas and Cuba. The closest coral reefs to the Flower Gardens are off Tampico, Mexico, approximately 44 kilometers (400 miles) south. Components of Caribbean coral reef communities also occur off the west coast of Florida, particularly at the Florida Middle Ground, approximately 805 kilometers (500 miles) east of the Flower Gardens. The Flower Gardens are, therefore, substantially more isolated from other assemblages of Atlantic coral reef organisms than is the Key Largo reef tract. This geographical isolation may be a significant factor influencing benthic community composition and structure at the Flower Gardens.

BENTHIC COMMUNITIES, BIOTIC ZONATION AND DEPTH

The Key Largo reef tract is partly comprised of a group of emergent patch reefs and bank barrier reefs separated from Key Largo by a wide, shallow, sandy lagoon. The crests of many of these reefs are partly exposed during low tide. Base depths of lagoonal patch reefs are rarely greater than 3.04 meters (10 feet) and seaward base depths of the bank barrier forereefs are generally less than 12.19 meters (40 feet). Patch reefs may be dominated by any number of combinations of gorgonacean or scleractinian corals. Emergent portions of the bank barrier reefs are dominated by Acropora palmata and Millerpora complanata with substantial growths of Acropora cervicornis, Porites porites and colonial zoanthids (Palythoa sp.). None of this exists at the Flower Gardens. The shallowest depth reported at the Flower Gardens is 13.7 meters (45 feet) and that is an exception. Generally, the coral reef top is at 22.8-27.4 meters (75 to 90 feet) with the reef face extending down to between 42.7 and 45.7 meters (140 and 150 feet).

The coral reefs at the Flower Gardens are classified as submerged reef-banks (Bright and Pequegnat, 1947; Bright, 1977) (Fig. 45). Coral reefs, however, cover only a small percentage of the large diapiric topographical features which are the East and West Flower Garden Banks. The majority of the banks' substratum occurs between 45.7 and 76.2 meters (150 and 250 feet) and is primarily covered with living coralline algal nodules over coarse carbonate sand. Exposures of hard substratum and reef structures heavily encrusted with the dominant coralline algae are common. Depauperate scleractinian reef structures occur as deep as 54.9 meters (180 feet).

Valid comparisons between biota of the Key Largo reef tract and the Flower Gardens can only be made within the depth range wherein reef and coralline algal dominated communities are known to exist at the two locations 13.7-76.2 meters (45-250 feet). The populations of algae, corals, other invertebrates and fishes in both areas are drawn basically from the general Atlantic reef assemblage. Therefore a majority of the species found at the Flower Gardens are probably present also within the Key Largo track, though there are certainly exceptions to this. I suspect but cannot verify that the diversity of organisms is greater between 13.7-76.2 meters (45 and 250 feet) in the Key Largo tract than at the Flower Gardens.

The most conspicuous discrepancy in community structure is the lack of shallow water gorgonacean corals at the Flower Gardens in contrast to the dominance of these organisms on the reef patches observed between 24.4 and 80.5 meters (80 and 100 feet) at Key Largo. Gorgonaceans are virtually absent at the Flower Gardens above 45.7 meters (150 feet). The alyconarians which occur in deeper water at the Flower Gardens are small (mostly paramuriceids and ellisellids) and are not dominant elements of the community.

Reasons for the near absence of common shallow-water gorgonacenas from the Flower Gardens are not known. It is suspected that their geographical isolation from the closest substantial gorgonacean populations east of the Mississippi and south of Tampico is itself a barrier hampering or precluding the transport of gorgonacean larvae. Environmentally, there seems to be no reason why shallow water gorgonaceans should not survive at the Flower Gardens.

From the crests of the Flower Garden Banks down to 45.7 meters (150 feet), the dominance of massive scleractinian corals is overwhelming. Where the typical large platform-like reefs are established (many acres in extent), live coral cover averages 65% on the hard bottom (Montastraea annularis accounting for approximately half of the live cover). Adjacent to the massive scleractinian reefs are knolls dominated by "fields" of small branching colonies of the coral Madracis mirabilis, and other knolls bearing covers of leafy and coralline algae.

Nothing comparable in size or structure to the submerged, Flower Garden scleractinian reefs occurs in the Key Largo reef tract. The submerged reef structures in the Key Largo tract are generally much smaller, bearing an abundance of gorgonaceans and a limited living scleractinian cover. I do not believe that extensive Madracis beds such as those found at the Flower Gardens will be found in the Key Largo tract nor are greatly elevated hard knolls bearing profuse covers or crustal coralline algae and leafy algae to be expected.

For the coral Montastraea annularis, growth rates, as measured by sclerochronological methods, are similar (6-8 mm/yr) at 3.04 meters (10 feet) depth in the Key Largo tract and 24.38 meters (80 feet) depth at the Flower Gardens (Shinn and Hudson, personal communication). Lateral encrusting growth of scleractinians at the Flower Gardens proceeds at rates which are probably comparable to what one would expect for the Key Largo tract. Where measured, mortality rates for scleractinians at the Flower Gardens are much greater (by approximately an order of magnitude) than lateral encrusting growth. A balance between mortality and growth at the Flower Gardens is probably functionally achieved insofar as encrusting growth is a universal process occurring along the majority of living coral borders, whereas mortality, though capable of proceeding at much faster rate, occurs only along a limited portion of the living borders.

Quantitative encrusting growth and mortality measurements are not available for the Key Largo tract. It is hoped that a suitable balance exists to insure the "status quo" of living scleractinian coral cover. However, the Key Largo tract is afflicted with a serious disease-causing blue-green alga, Oscillatoria submembranacea, which attacks and kills scleractinian coral heads (Antonius, 1977, personal observation). O. submembranacea is not known from the Flower Gardens, through we have detected apparent less potent scleractinian diseases there.

Above 42.7 meters (140 feet) at both locations the differences in community structure and reef morphology as described above are more conspicuous than the simila rities. Below 42.7 meters (140 feet), the reverse may be so, at least in a limited sense.

The Flower Gardens platform between 42.7 and 76.2 meters (140 and 250 feet) is covered extensively with living coralline algal nodules, finger-size to fist-size, underlain by coarse carbonate sand, with abundant leafy algae and a diverse assemblage of sessile and mobile invertebrates, including sizeable populations of thin, unifacial plates of agariciid corals and small branching species of Madracis and, in places, the green calcareous alga Halimeda.

A zone similar to this occurs below 42.7 meters (140 feet) in the Key Largo tract. The suficial substratum is basically coarse carbonate and overlain by small, bolder-sized, algal nodules with substantial populations of leafy algae and Halimeda. I suspect that species diversity may be less in this zone in the Key Largo tract than at similar depths at the Flower Gardens, primarily because the larger sized nodules at the Flower Gardens must provide more numerous opportunities for microhabitat development.

Patch reefs covered with coralline algae and limited growths of scleractinians are common between 42.7 and 60.9 meters (140 and 200 feet) depth at the Flower gardens. Some of these structures are rather large 30.5 to 60.9 meters (100 to 200 feet) across and can actually be classified as scleractinian coral reefs dominated by Stephanocoenia sp., Montastrea cavernosa, Colpophyllia sp., Diploria sp., and Millepora sp. Such deep reefs do not occur in the Key Largo tract as far as I known.

Nevertheless, the general aspects of the level bottoms and the benthic communities below 42.7 meters (140 feet) at both locations appear to be basically similar. In fact this "algal nodule terrace" is the one clearly identifiable link between the Key Largo reef track and the Flower Gardens in terms of biotic zonation. Still, there may be substantial differences in species composition, diversity and abundance between even these comparable zones at the two locations. Not enough is known about either to say conclusively how similar they are.

SUMMARY

The Key Largo and Flower Gardens reef systems, though located at comparable latitudes and representing northern extensions of the tropical Atlantic reef system, differ greatly in physical structure, distance from land, isolation, hydrography and biotic zonation. In many ways valid comparisons between them are difficult. Although they possess in common many, possibly a majority, of species of fishes, invertebrates and algae, the manners in which communities comprised of these species are structured at the two localities differ substantially. The most obvious differences are the absence of emergent reefs and of shallow-water gorgonaceans at the Flower Gardens, and the absence of large platform-like scleractinian reefs, Madracis "fields," and deep coralline alga and scleractinian patch reefs at Key Largo.

The greatest zonational similarity between the Key Largo tract and the Flower Gardens Banks is the presence at both of an "algal nodule terrace" on the level bottom below 42.7 meters (140 feet) depth. Even here, though, the degree of biotic similarity may be little more than superficial.

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Bright, T.J. and L.H. Pequegnat, editors, 1974. Biota of the West Flower Garden Bank. Gulf Publishing Company, Houston, Texas. 435 pp.

CONCLUSION

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Office of Coastal Zone Management

With the use of side scan sonar and the JOHNSON-SEA-LINK submersible, OCZM along with a team of distinguished researchers completed a survey of approximately fifty square miles of a deep water tropical ecosystem within the Key Largo Coral Reef Marine Sanctuary. This unique effort mapped the extent of these coral reefs, qualitatively inventoried major marine life, described the biological zonation and submarine geology, discovered several species new to science and investigated possible cultural resources. This effort provided OCZM with valuable management related baseline data that will allow Sanctuary managers to better understand the ecosystem they are charged with protecting and aid OCZM in setting management priorities.

The amount of scientific information gathered in the short time span of seven days was a tribute to the outstanding researchers who contributed to this effort.

Based on the findings of this survey future research topics of interest in these deeper waters could include the following.

The inventory of the deeper part of the sanctuary (100-300 feet) should be continued to the level now completed or in progress for the shallow reef tracts in the Sanctuary. This deep water survey has shown that there is a rich and diverse biotic community in the deeper zones, which make up approximately one half of the sanctuary.

Light and temperature should be continuously monitored throughout the depth range of the Sanctuary. These parameters affect all organisms. Man-induced temperature changes are unlikely to impact the Sanctuary but knowledge of temperature regimes is necessary to understand the ecology. In particular, it is unknown whether the upwelling which occurs to the north of the Sanctuary occurs in the Sanctuary also. Knowledge of light regimes is also essential to understanding the ecology of the Sanctuary. Further, reduced light penetration may result from increased human population in the Keys. This would have a profound impact on the Sanctuary.

Information on decapod crustaceans is needed to understand trophic dynamics, systematics, zoogeographical relationships and community structure and function.

The deep water paramuriceid *Swiftia exserta* and the ellisellid *Nicella schmitti* have been included in the Gulf of Mexico Fishery Management Plan as a harvestable resource. The Sanctuary would provide an excellent environment to gather information for proper management of this resource.

Lobster fishery related research would be a useful management area to investigate.

The mollusks of the Florida Keys are a diverse and interesting group, of which this has only skimmed the surface. Further investigations should include additional samples of rock, algae, and coral, as well as benthic samples of sand and/or coral rubble in and around the reef. Specifically sampling for members of this phylum, rather than relying on incidentally collected specimens, would undoubtably yield a more diverse and representative faunal list.

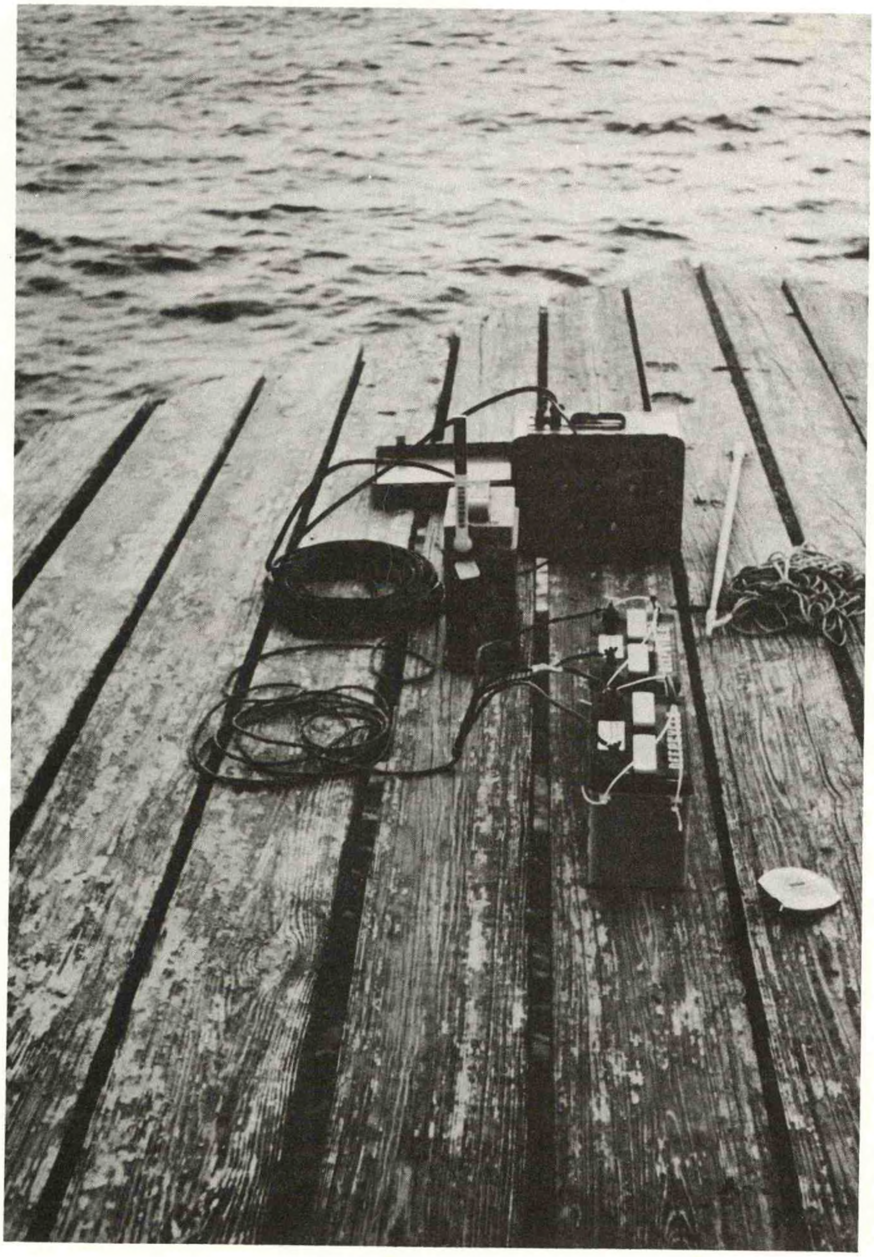

Figure 1.--Del Norte navigation system.

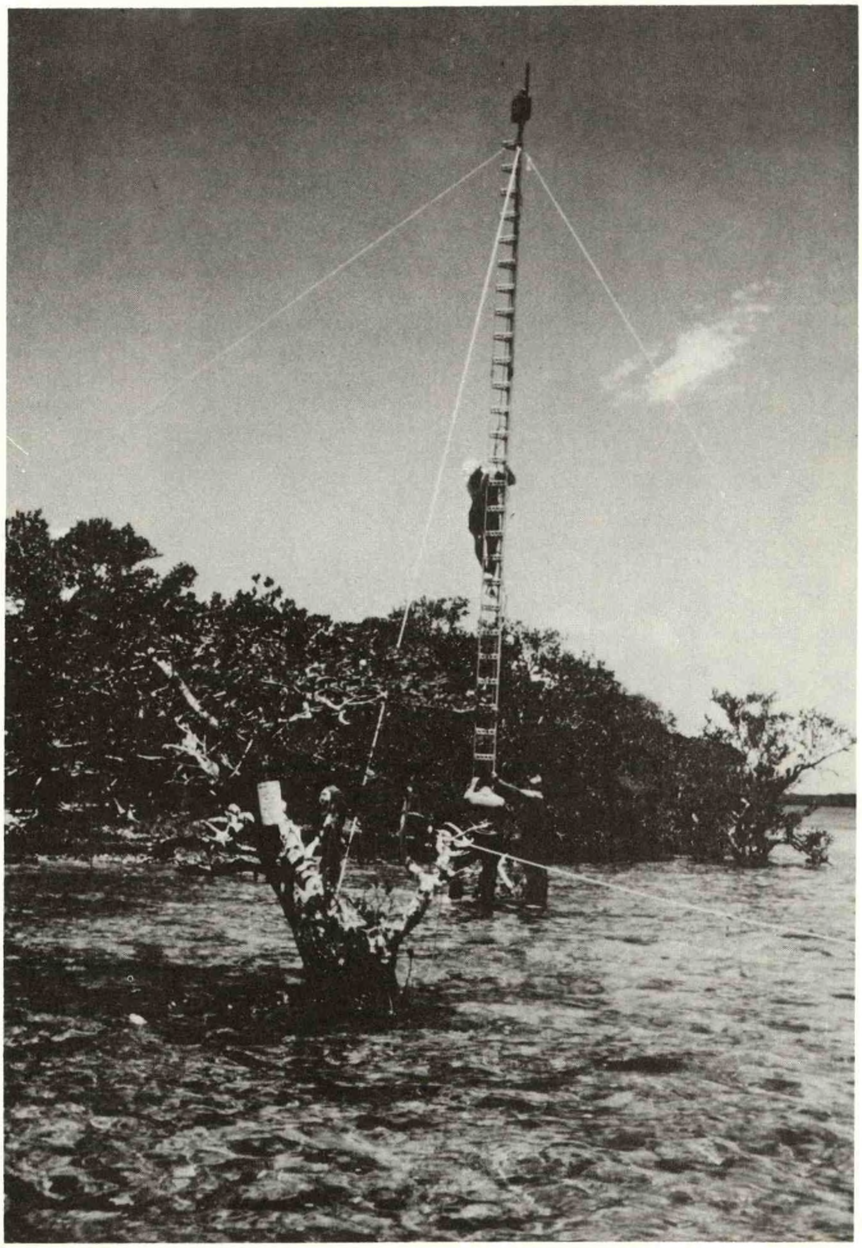

Figure 2.--Del Norte towers.

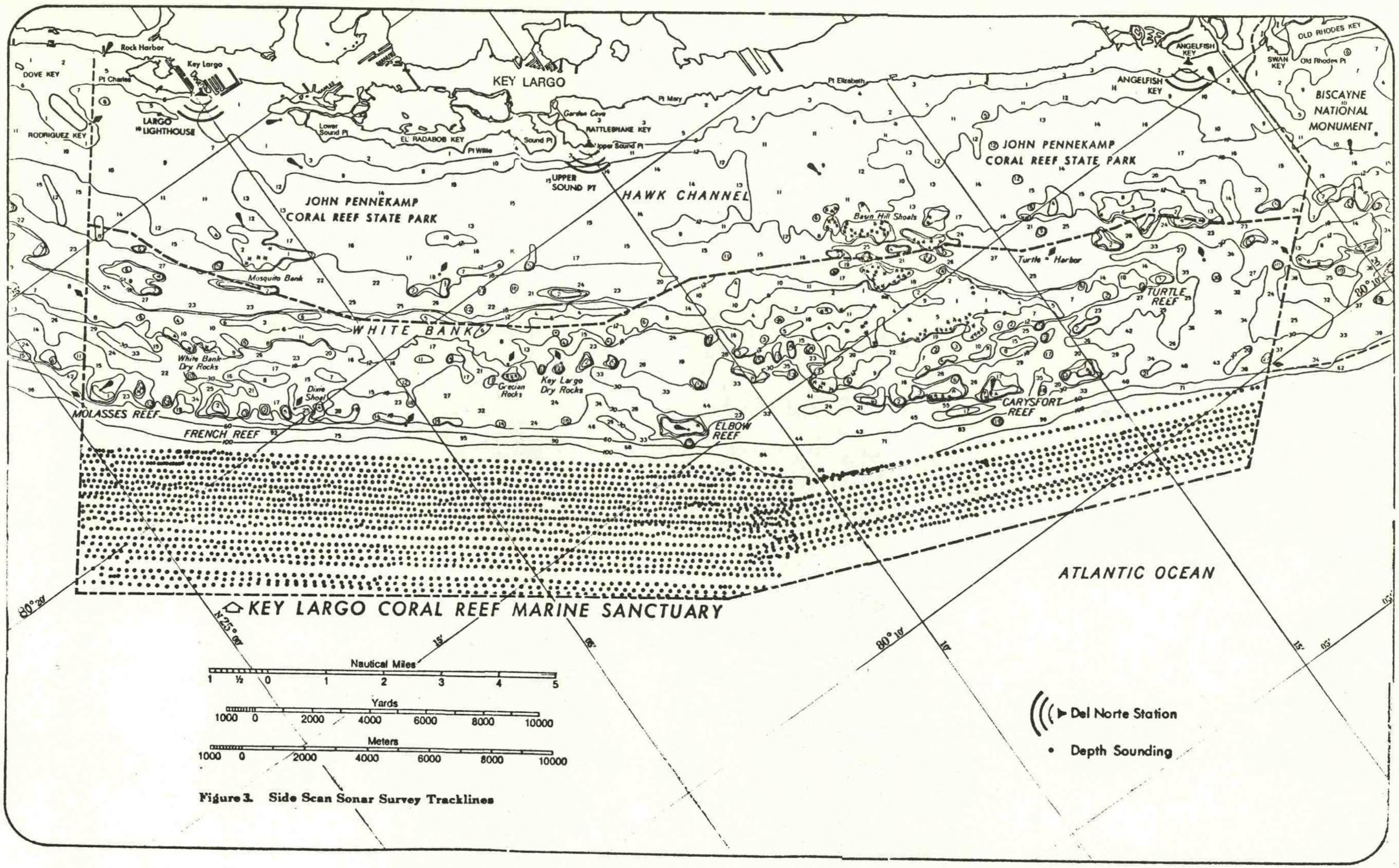

Figure 3.--Side scan sonar survey tracklines.

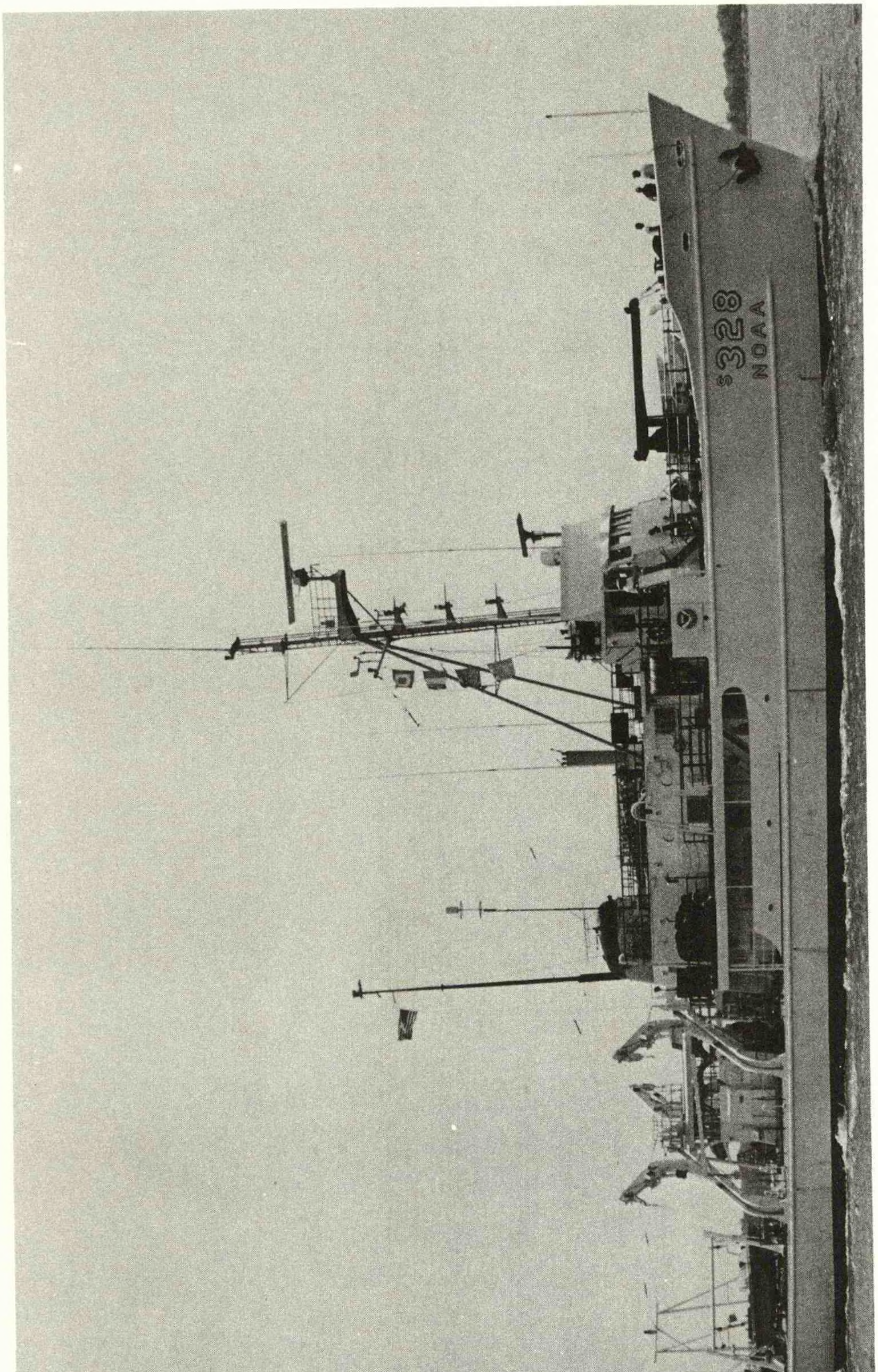

Figure 4.--NOAA Ship PEIRCE.

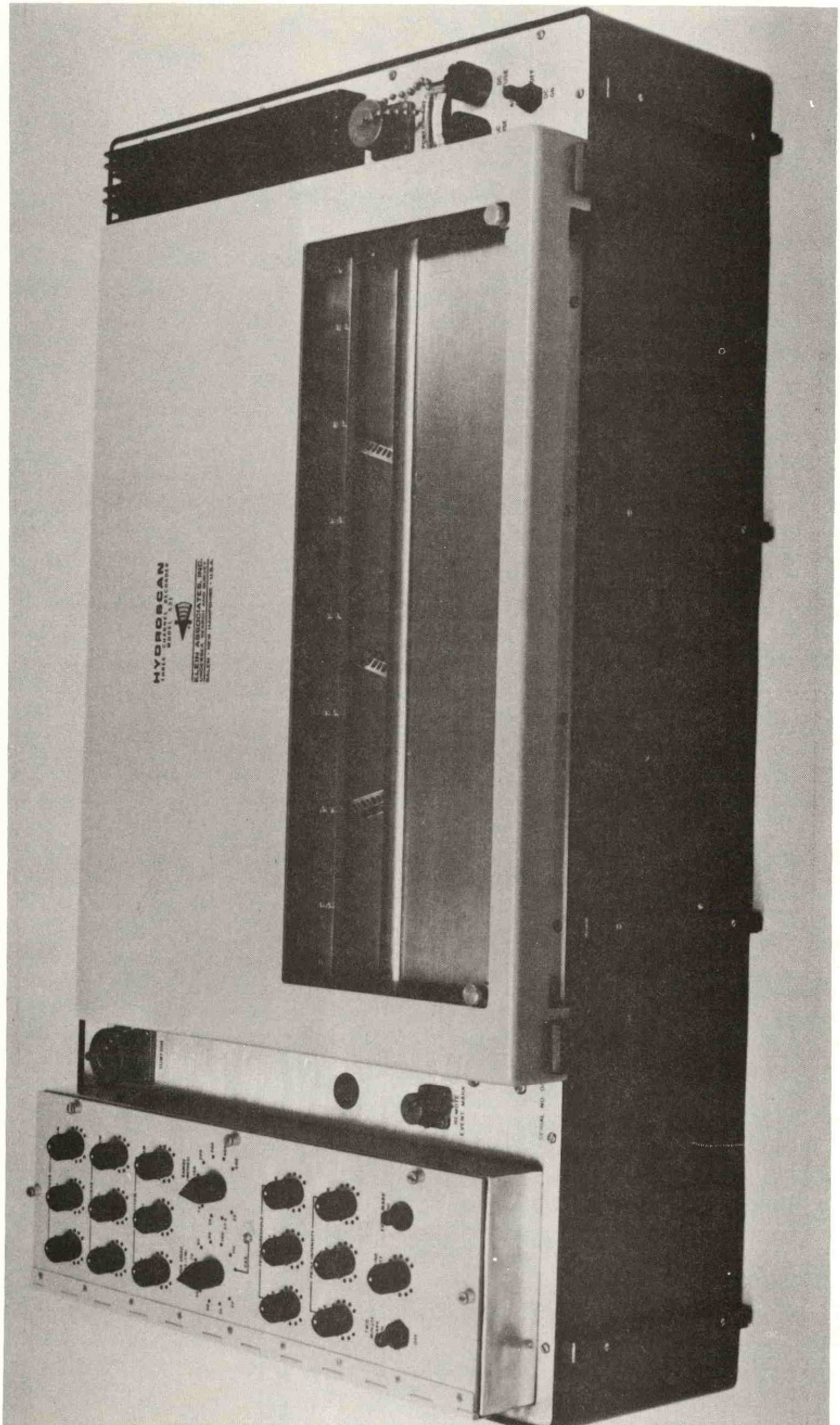

Figure 5.--Klein Model 530 side scan sonar receiver.

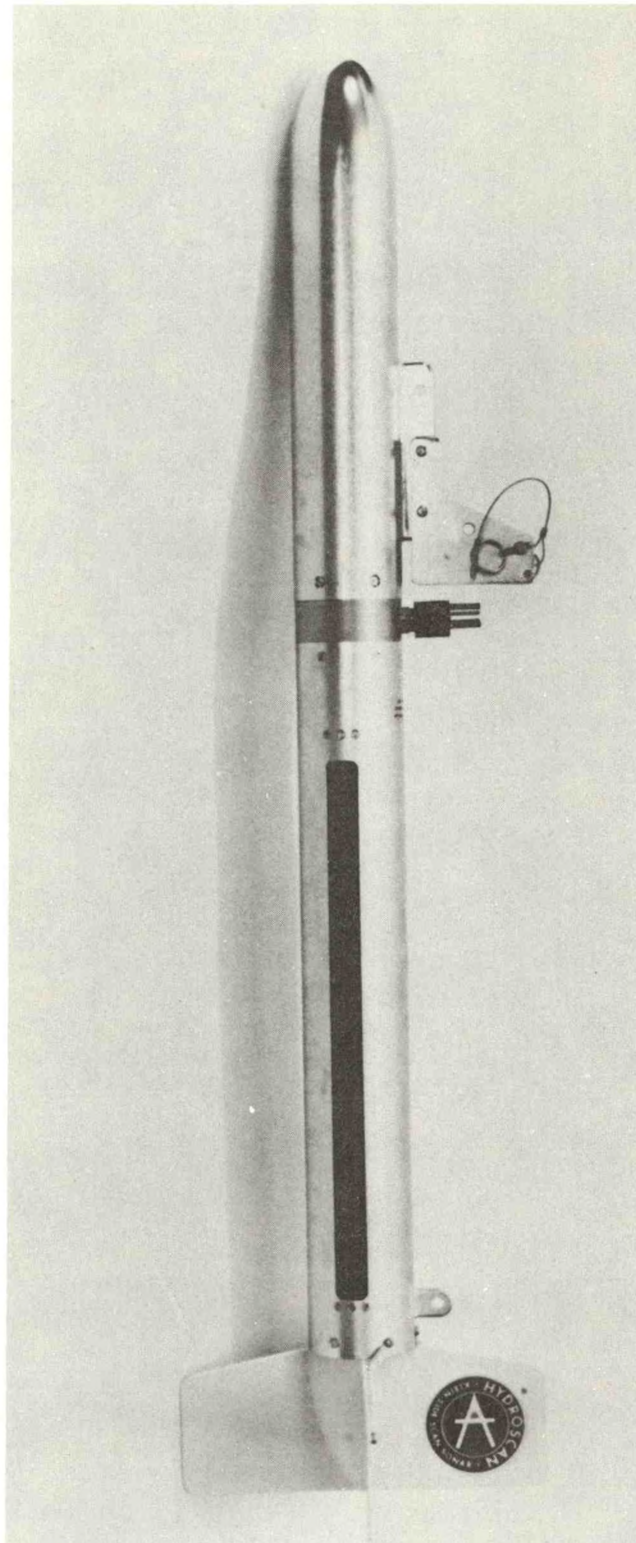

Figure 6.--Klein Model 530 side scan sonar transducer.

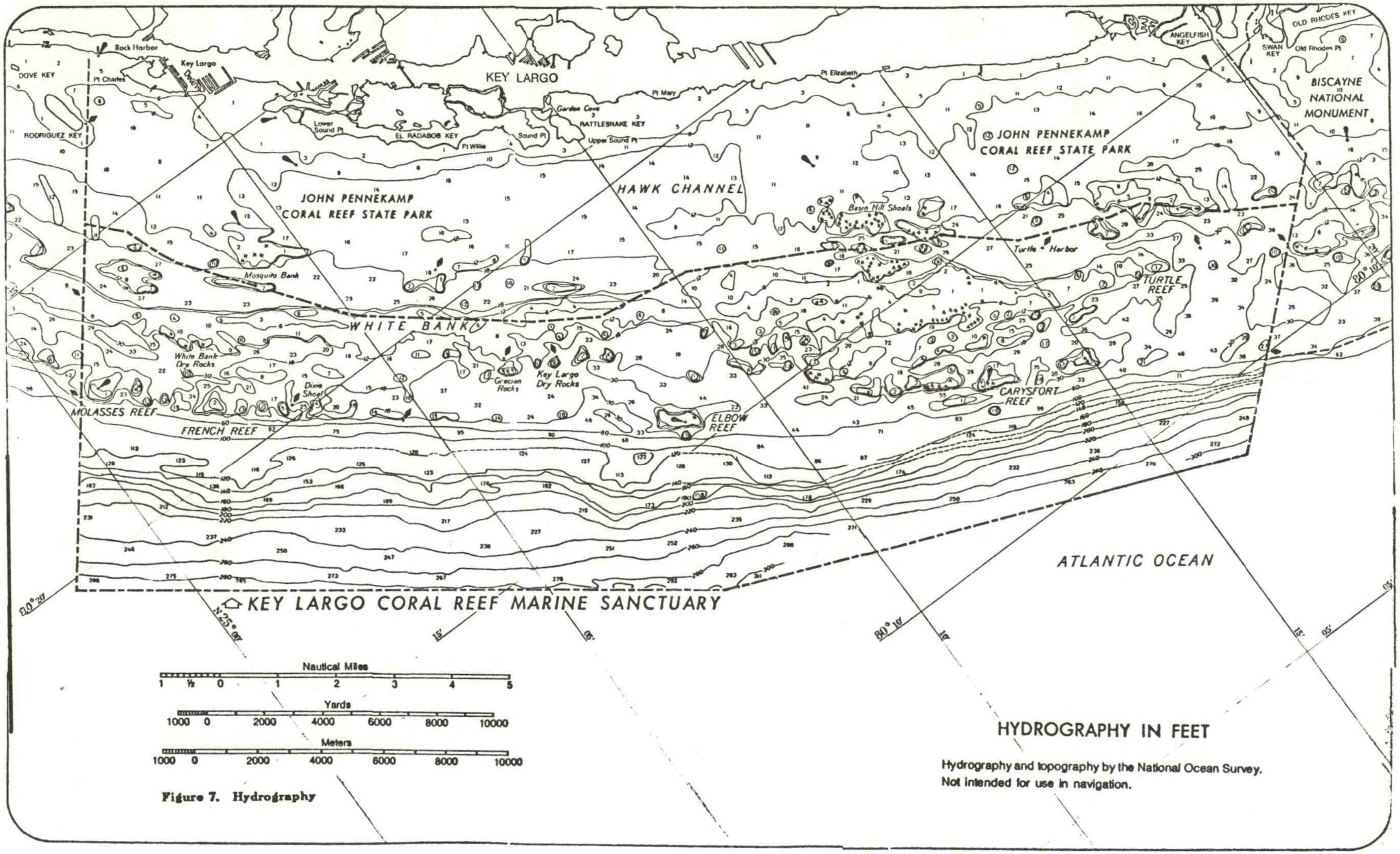

Figure 7. Hydrography

Figure 7.--Hydrography.

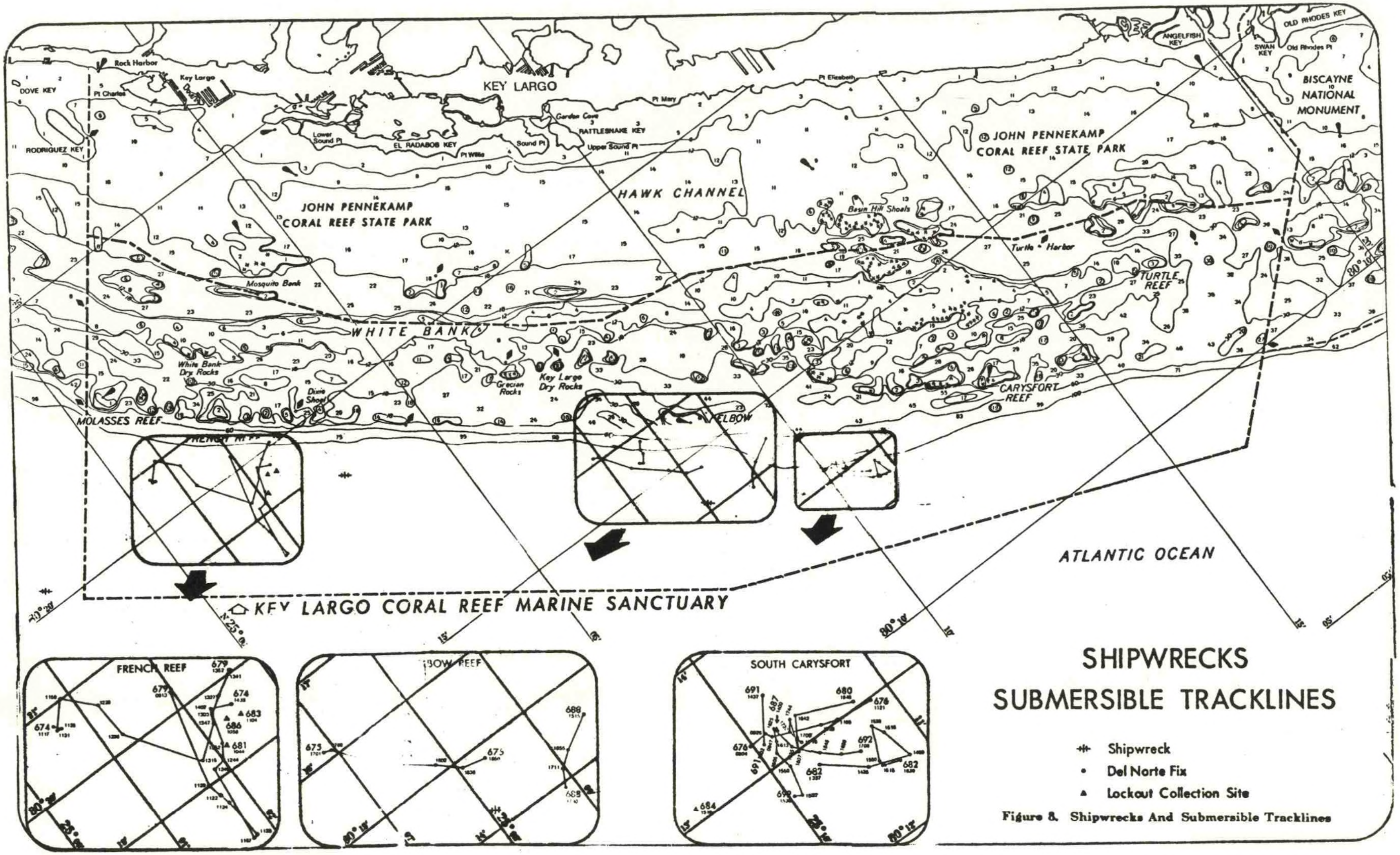

Figure 8.--Shipwrecks, submersible tracklines.

Figure 9.--JOHNSON-SEA-LINK.

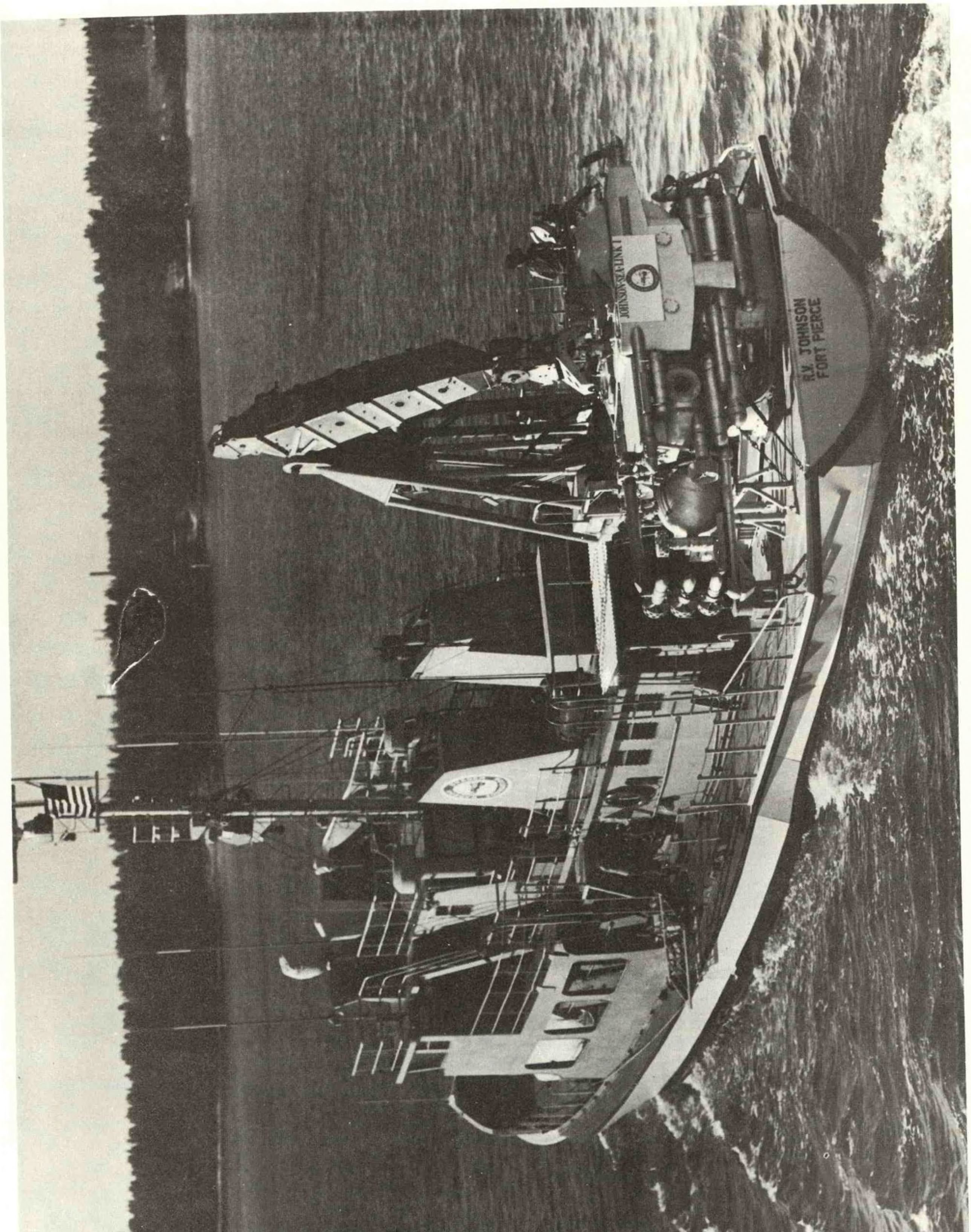

Figure 10.--R/V JOHNSON.

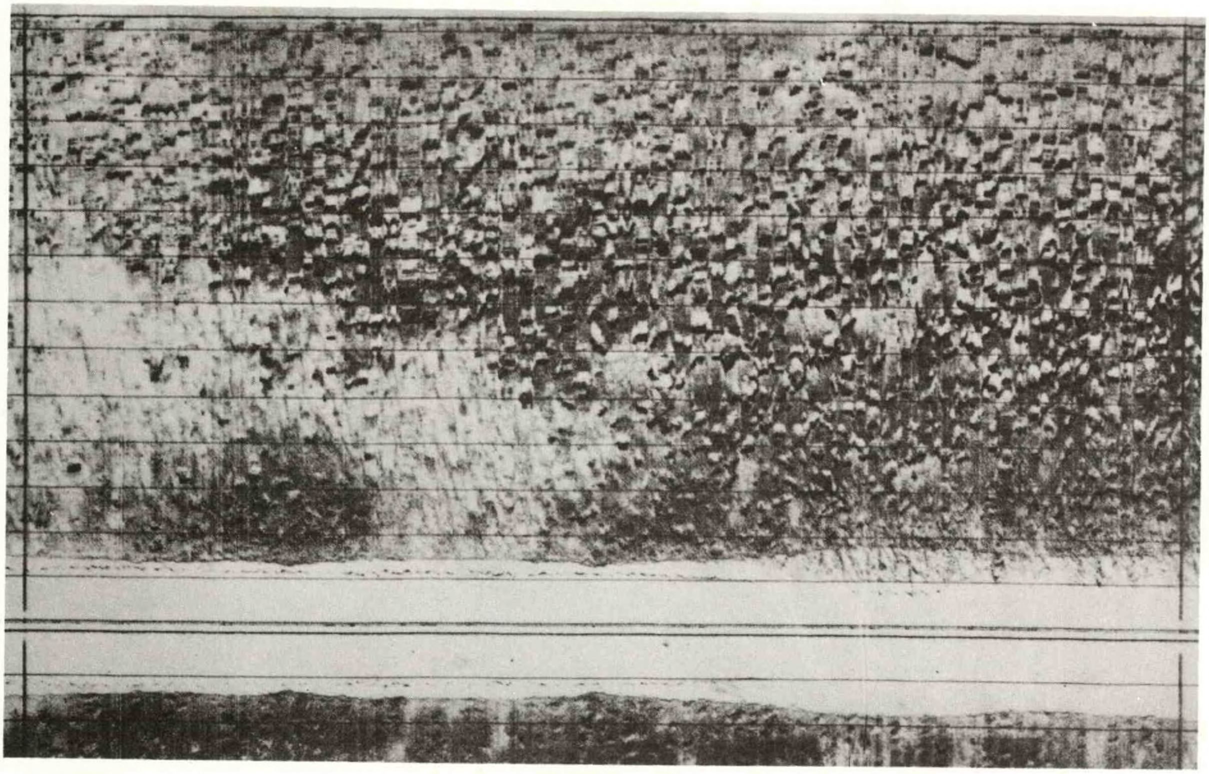

Figure 11.--Side scan sonar data showing coral reef.

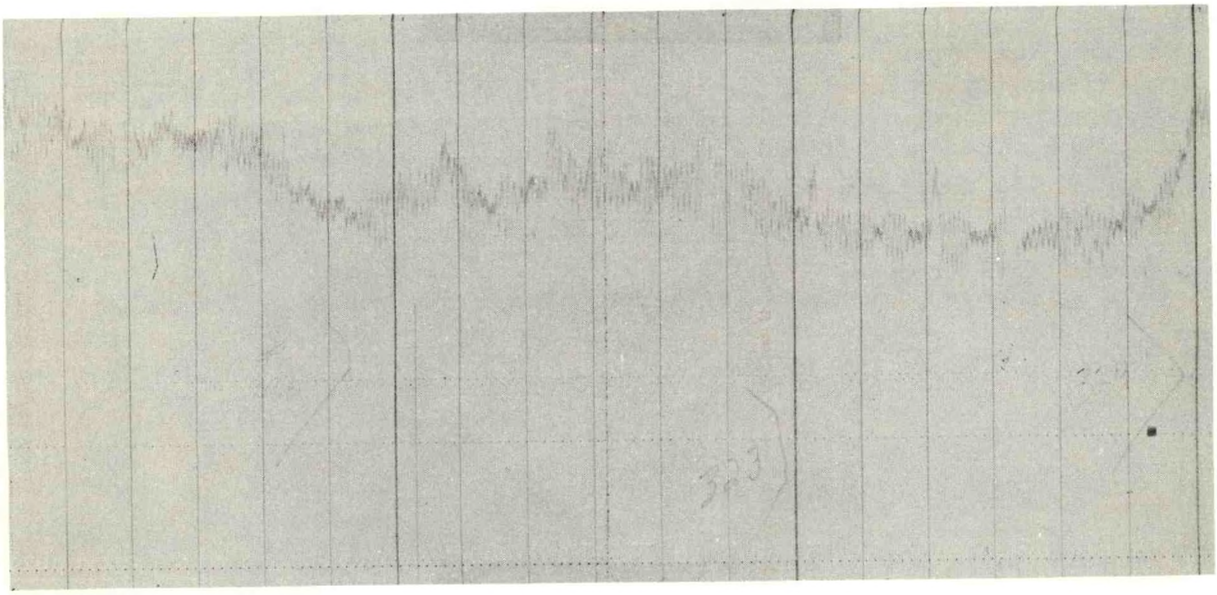

Figure 12.--Fathometer record showing coral reef.

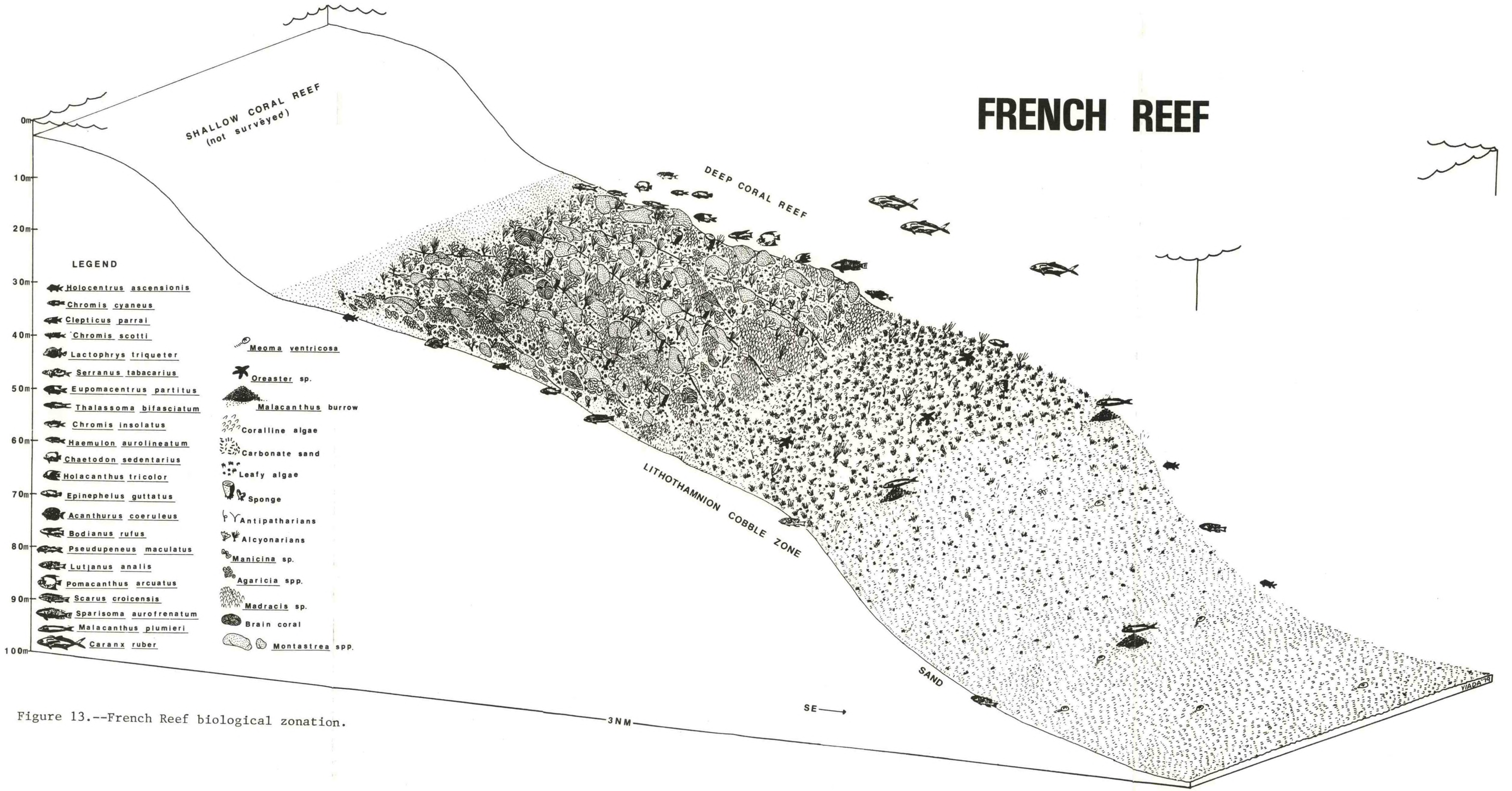

Figure 13.--French Reef biological zonation.

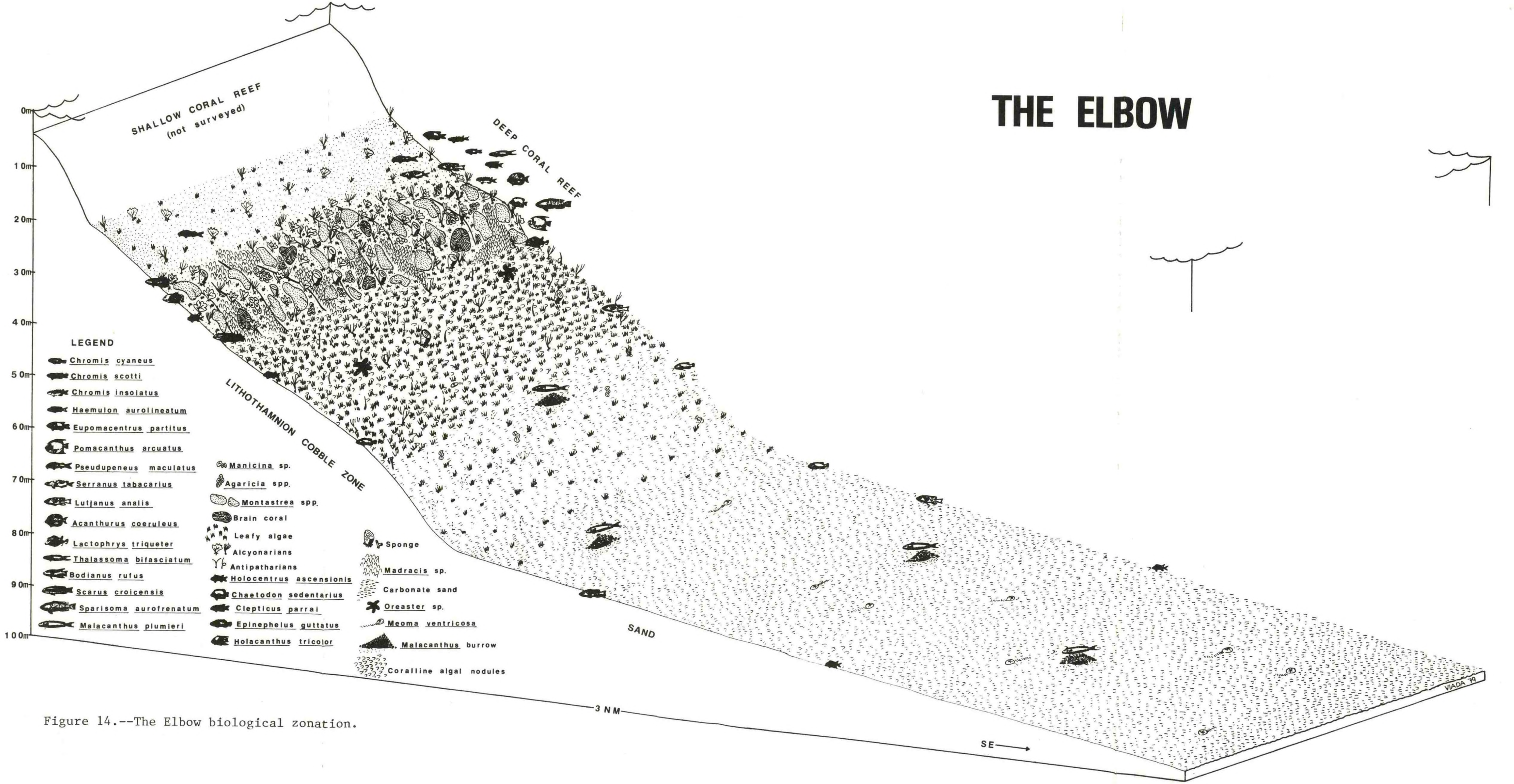

Figure 14.--The Elbow biological zonation.

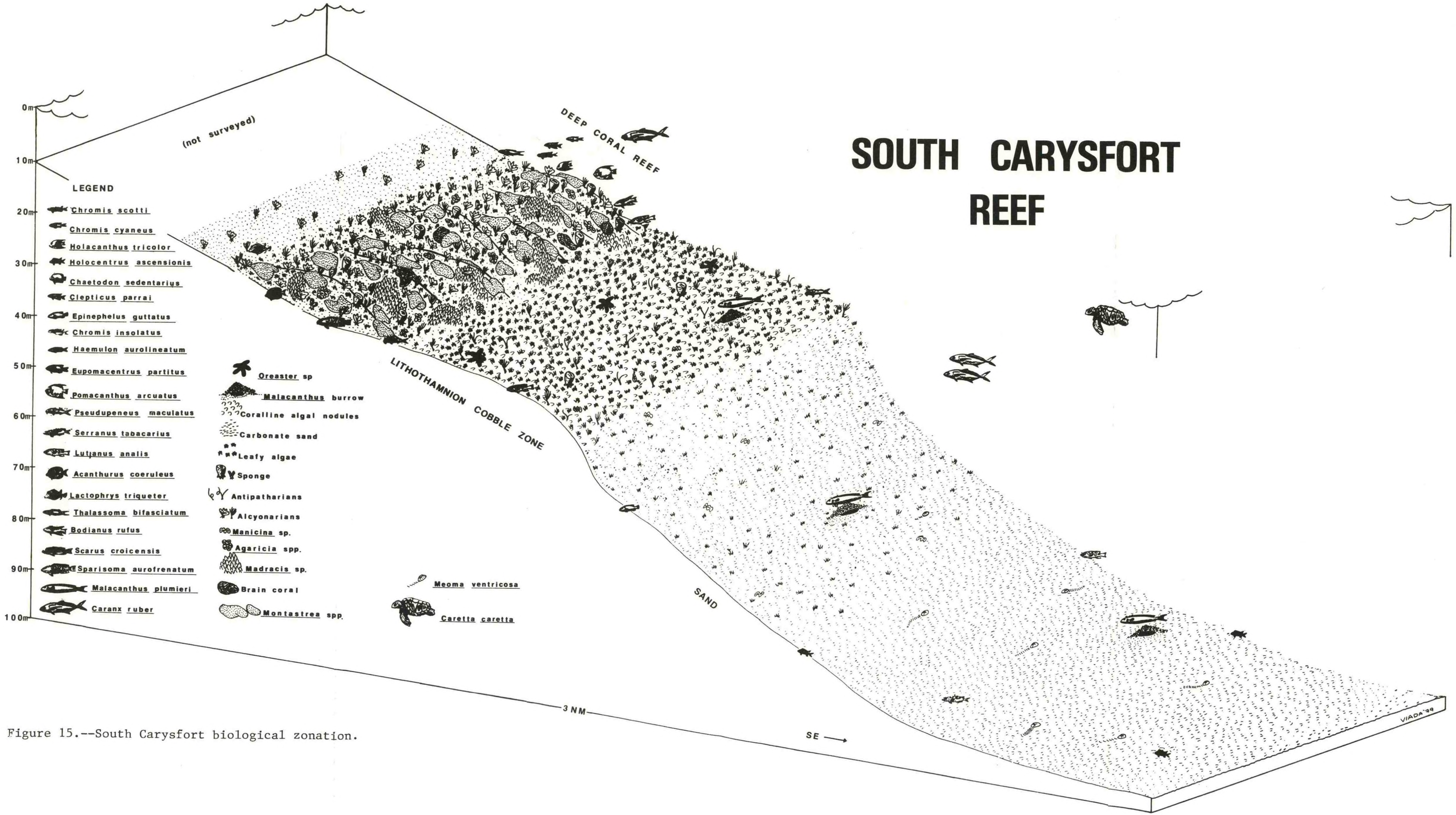

Figure 15.--South Carysfort biological zonation.

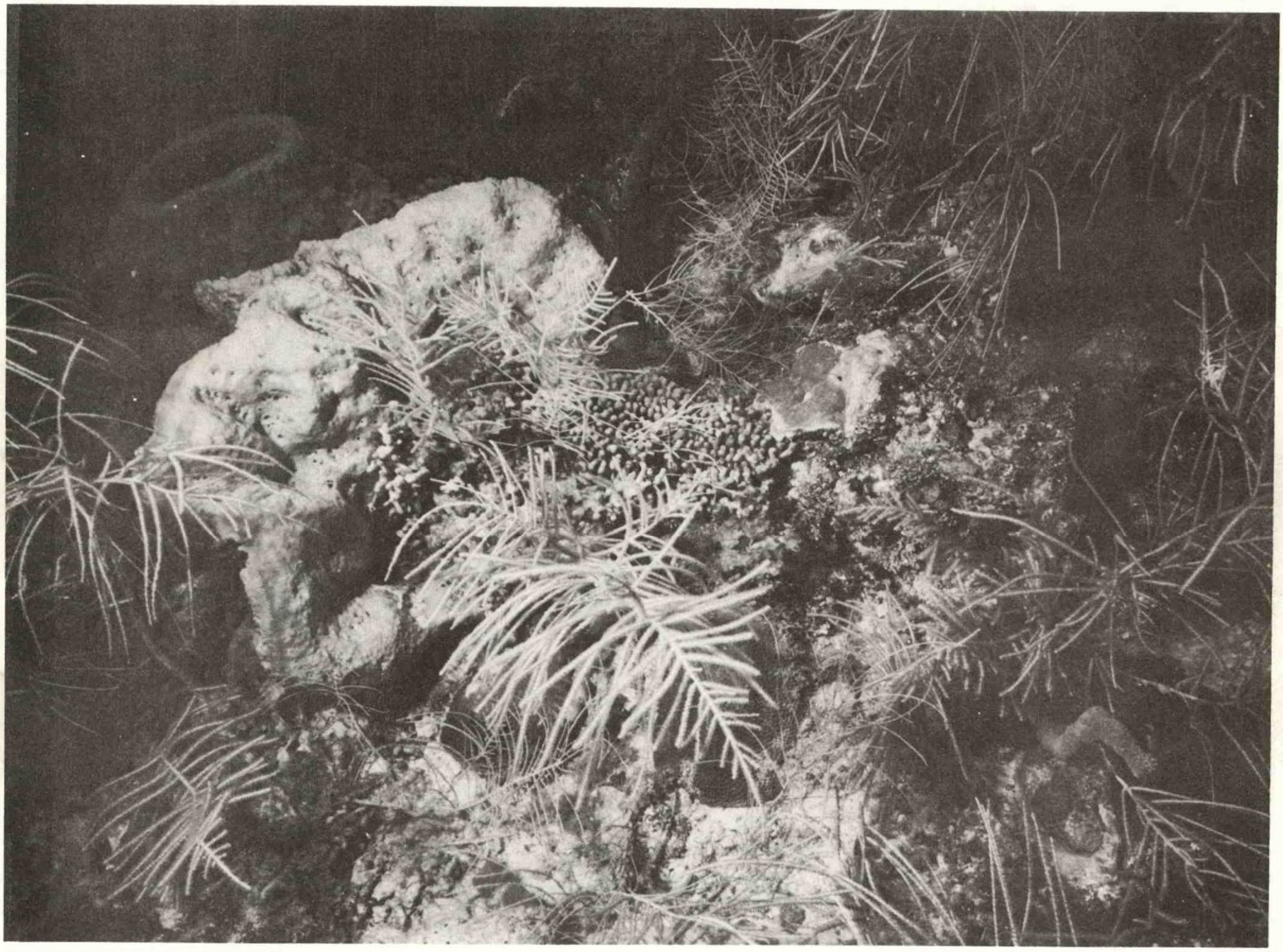

Figure 16.--Diver lockout site, French Reef, about 36 m, Montastraea-cavernosa, to left; Madracis mirabilis, dense cluster in center; Siderastrea siderea below M. mirabilis, obscured by Pseudopterogorgia octocorals; large sponges in background.

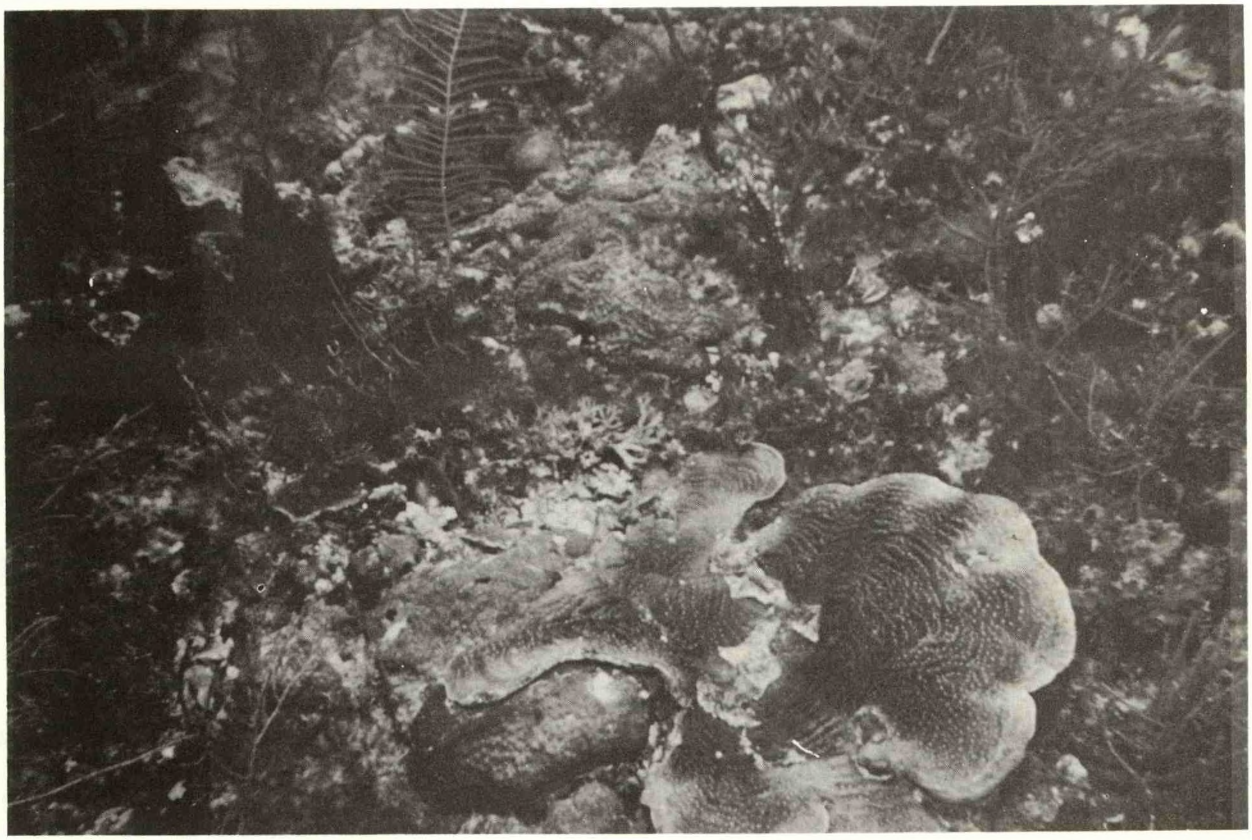

Figure 17.--French Reef lockout site, Agaricia lamarck in foreground.

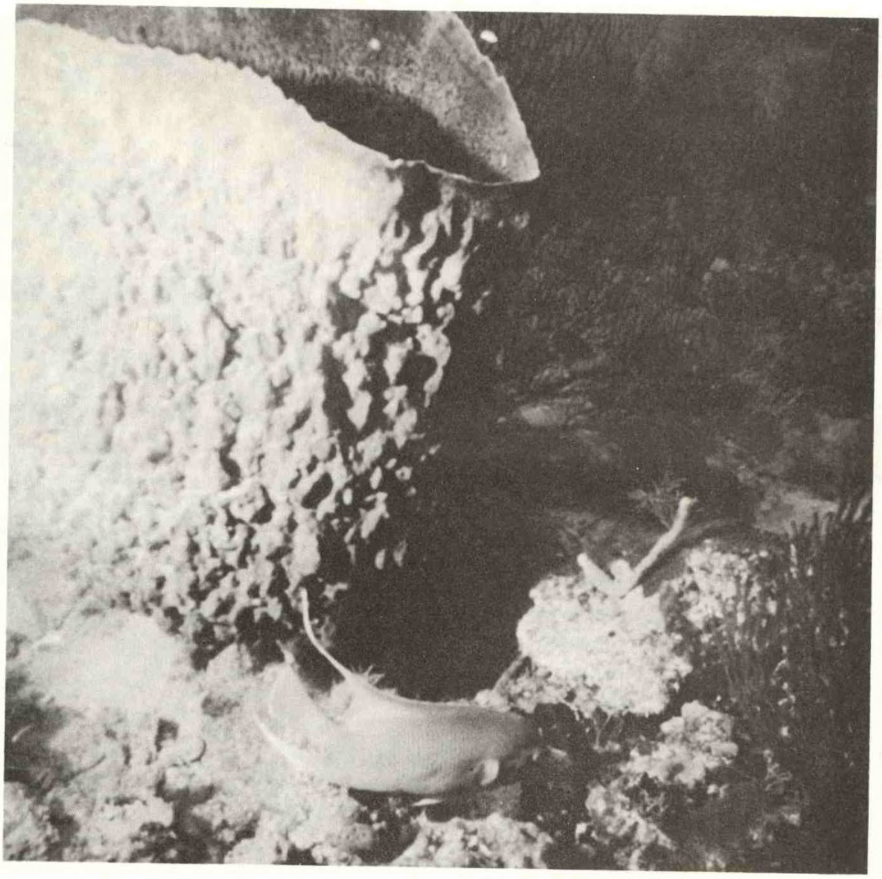

Figure 18.--Barrel sponge (Xestospongia muta).

Figure 19.--Tropical fish (Haemulon).

Figure 20.--Green turtle (Chelonia mydas).

Figure 21.--Lithothamnion cobble zone.

Figure 22.--Sea bisquit (Meoma ventricosa) tracks in Lithothamnion cobble zone.

Figure 23.--Sand at 55 meters with starfish Oreaster.

Figure 24.--Lockout diver.

Figure 25.--Coral disease.

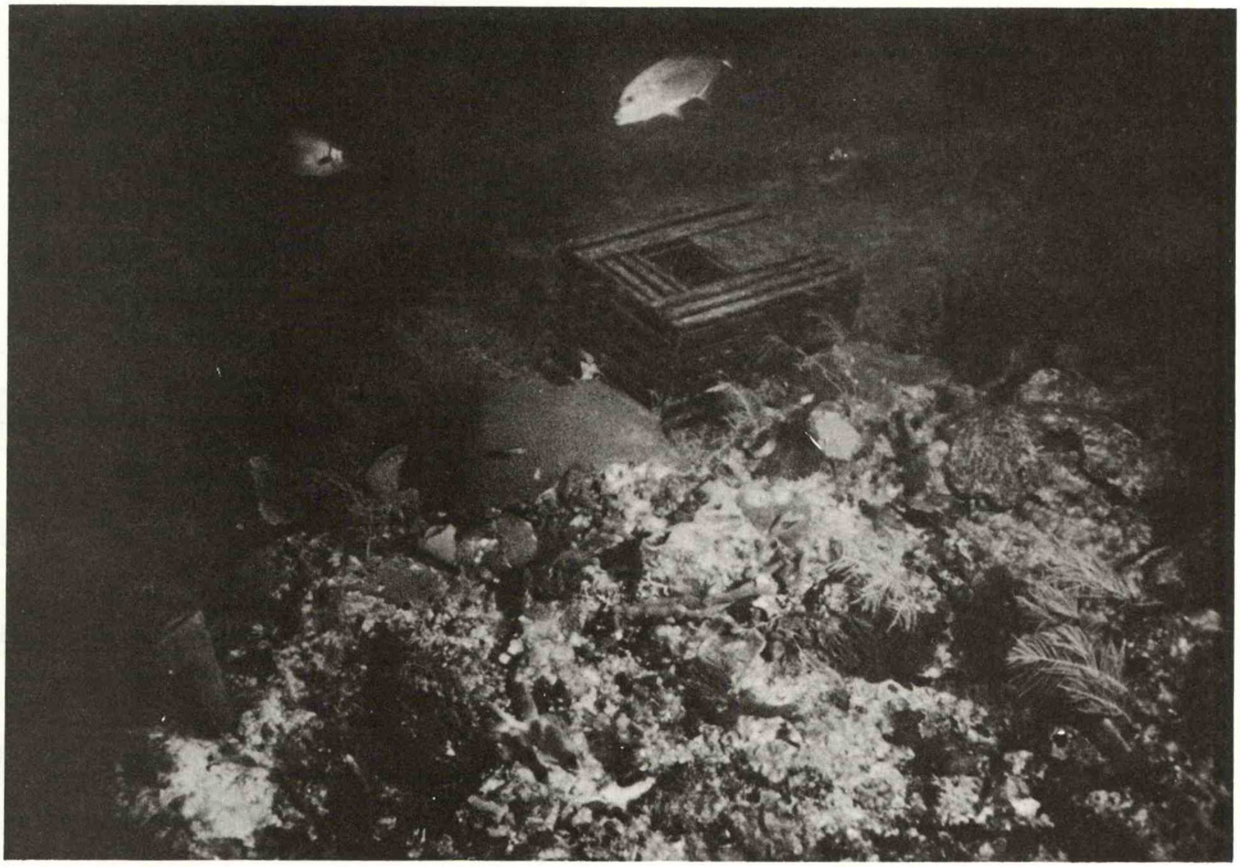

Figure 26.--Abandoned lobster trap.

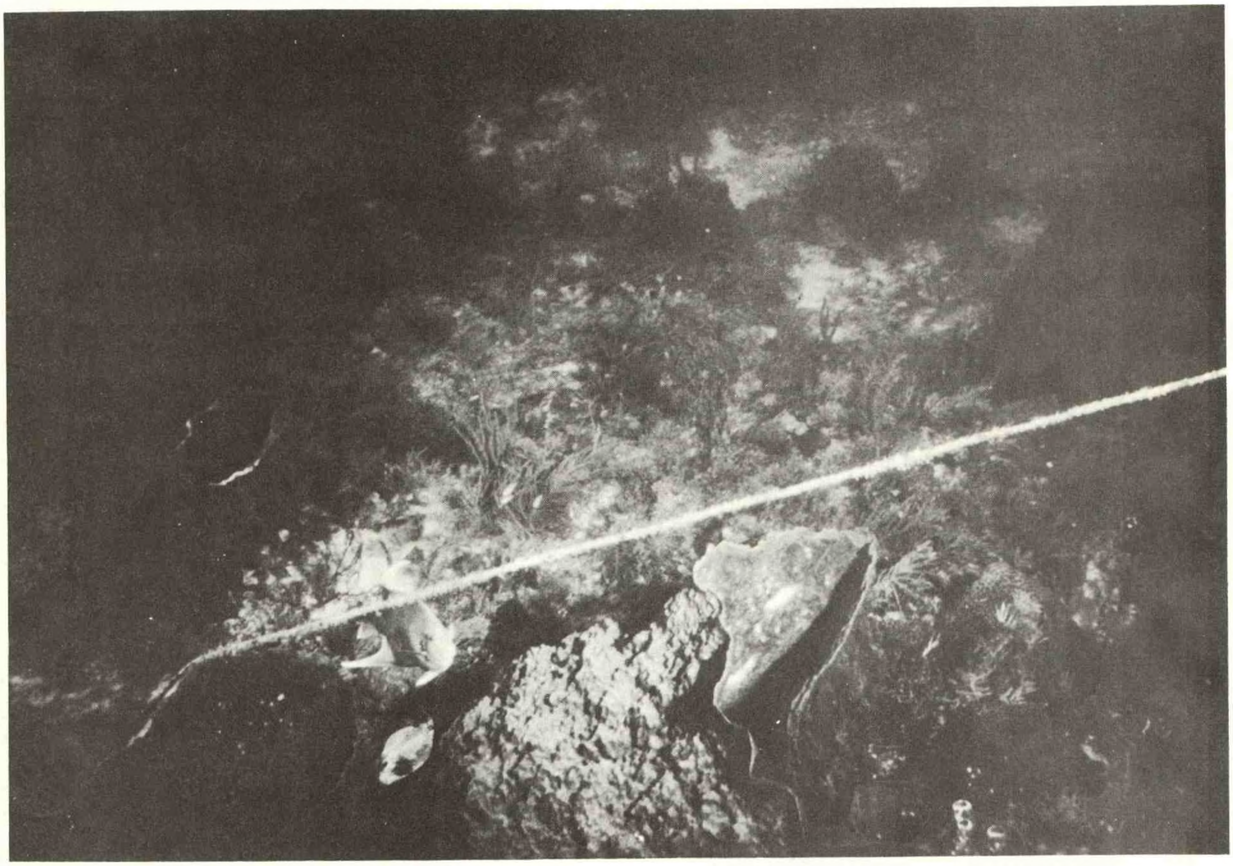

Figure 27.--Discarded line.

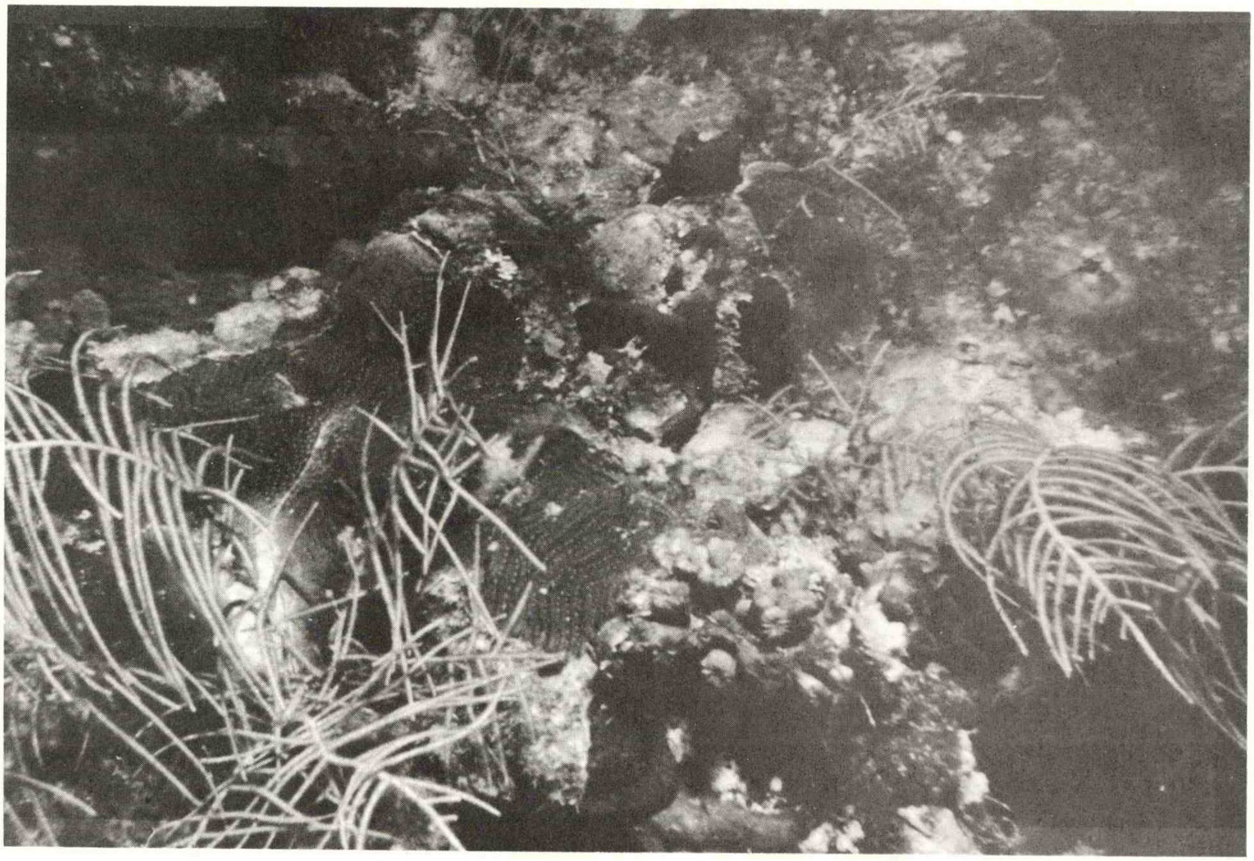

Figure 28.--French Reef lockout site; Eusmilia fastigiata, lower center, Agaricia lamarcki, left center.

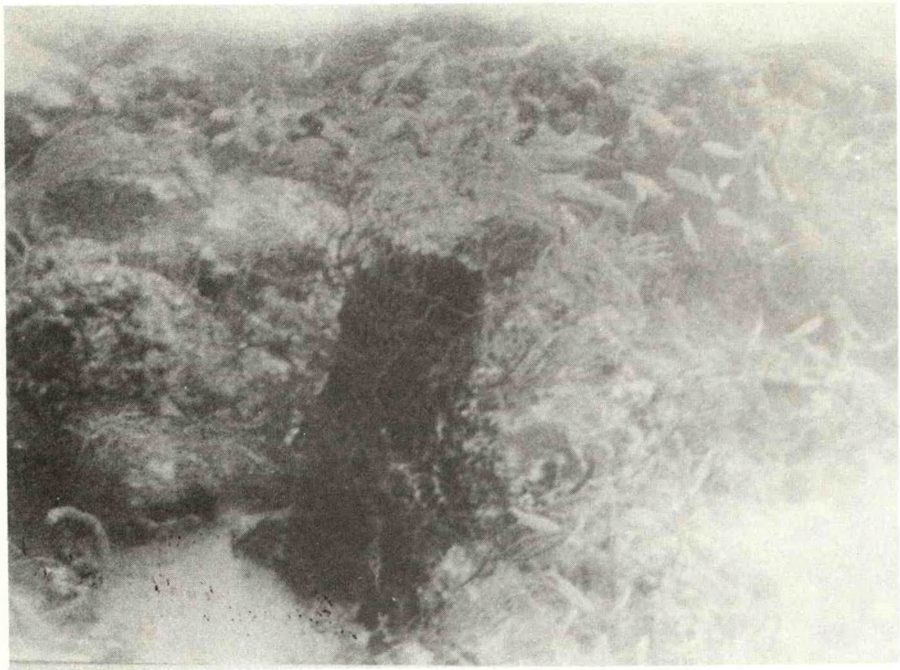

Figure 29.--Coral mound, French Reef.

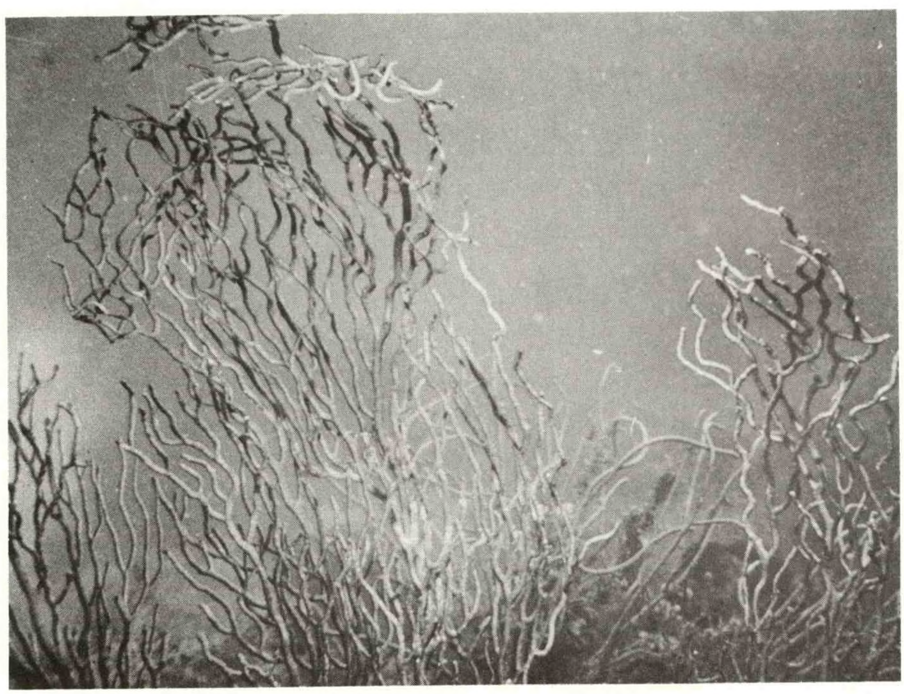

Figure 30.--*Iciligorgia schrammi* (in situ), French Reef.

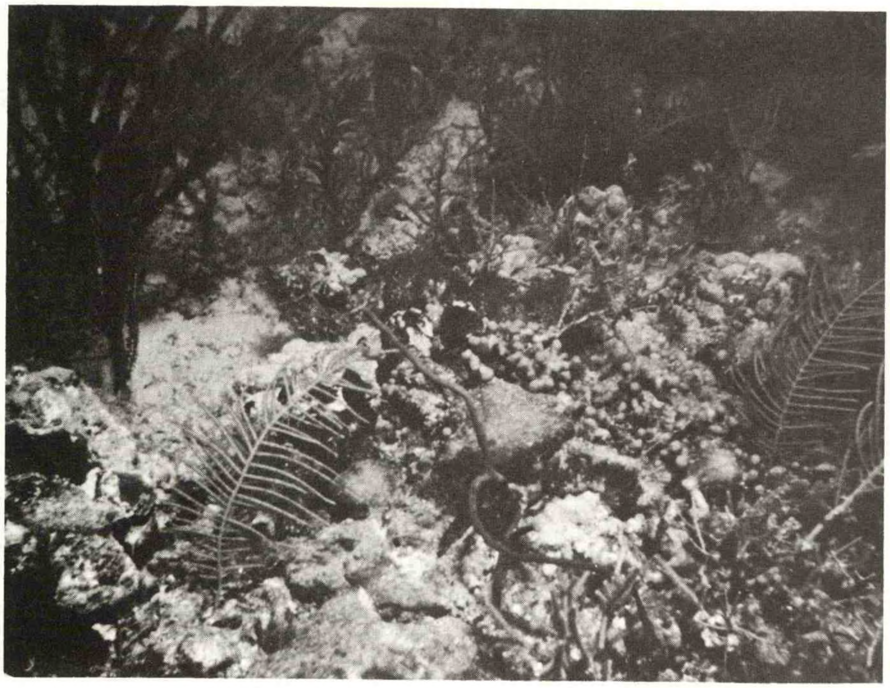

Figure 31.--Pseudopterogorgia bipinnata (in situ, foreground), French Reef.

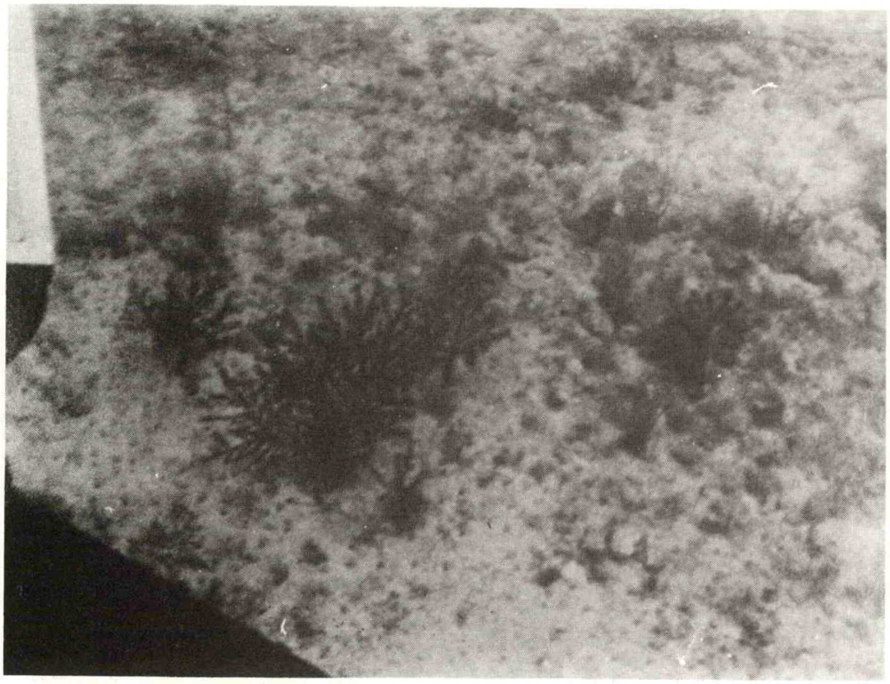

Figure 32.--Swiftia exserta (in situ), off French Reef.

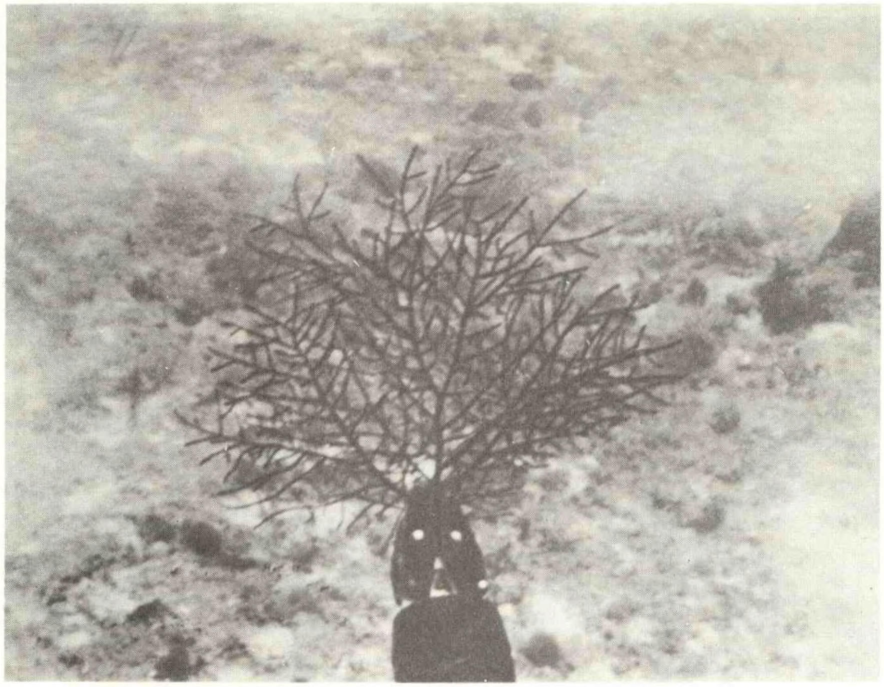

Figure 33.--Swiftia exserta (in jaws of manipulator arm), French Reef.

Figure 34.--Coral mound, South Carysfort Reef.

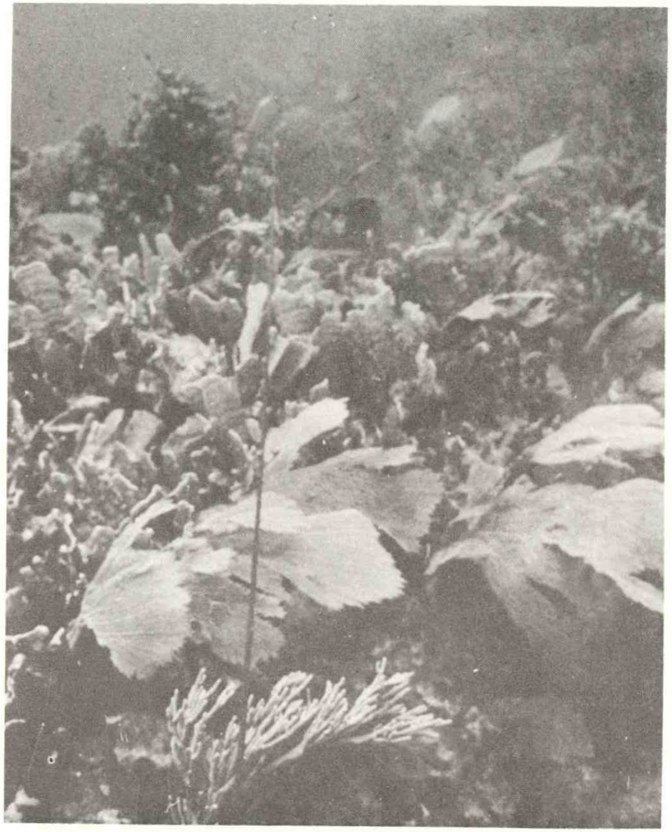

Figure 35.--*Millepora complanata* zone (3-4.5 m depth), Carysfort Reef.

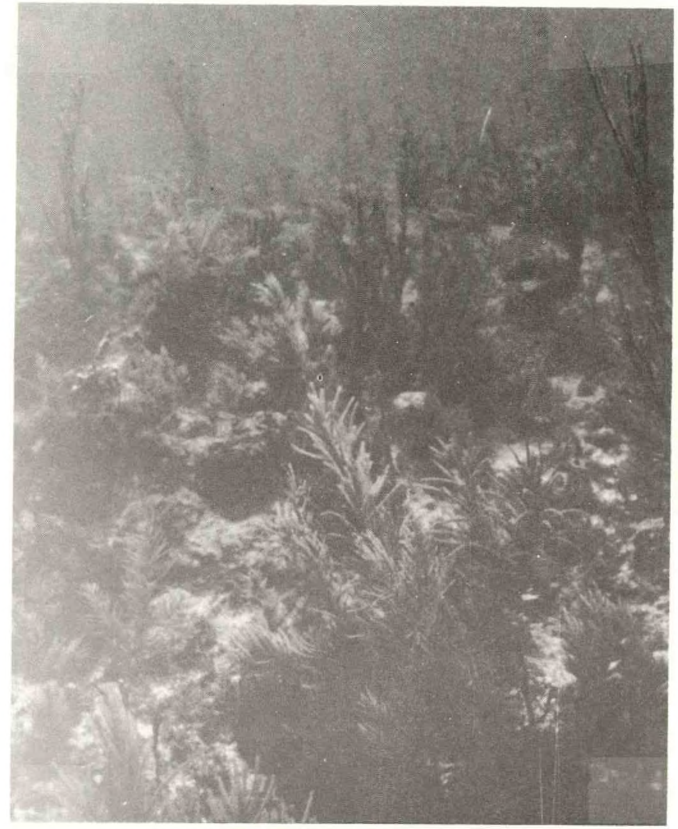

Figure 36.--Gorgonian zone (4.5-9 m depth), Carysfort Reef.

Figure 37.--<u>Acropora cervicornia</u> zone (11-14 m depth), Carysfort Reef.

Figure 38.--"Barren" zone (14-15 m depth), Carysfort Reef.

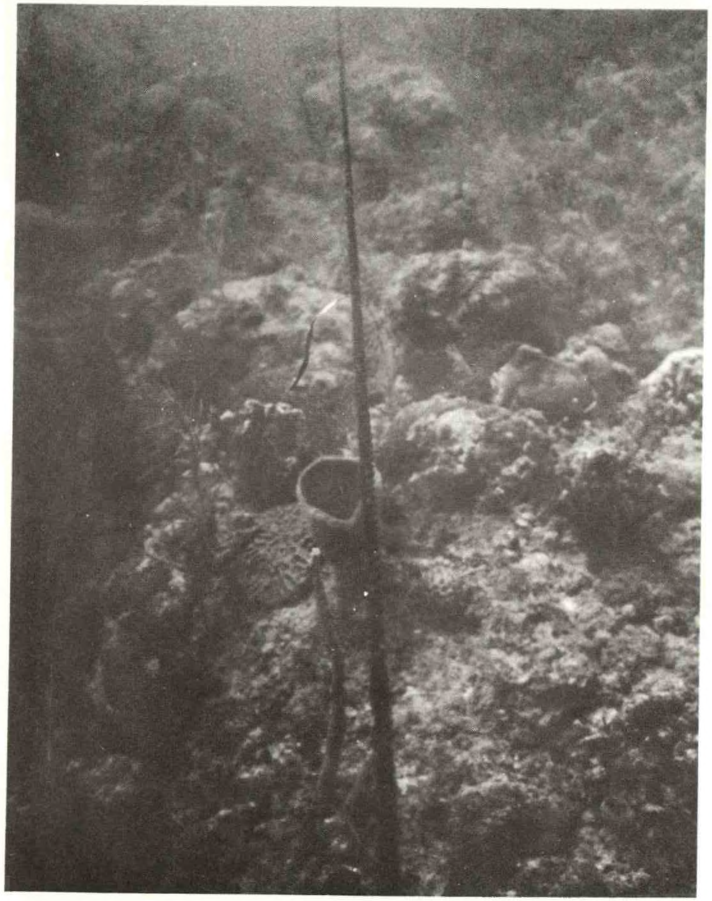

Figure 39.--Beginning of reef slope (16 m depth), Carysfort Reef.

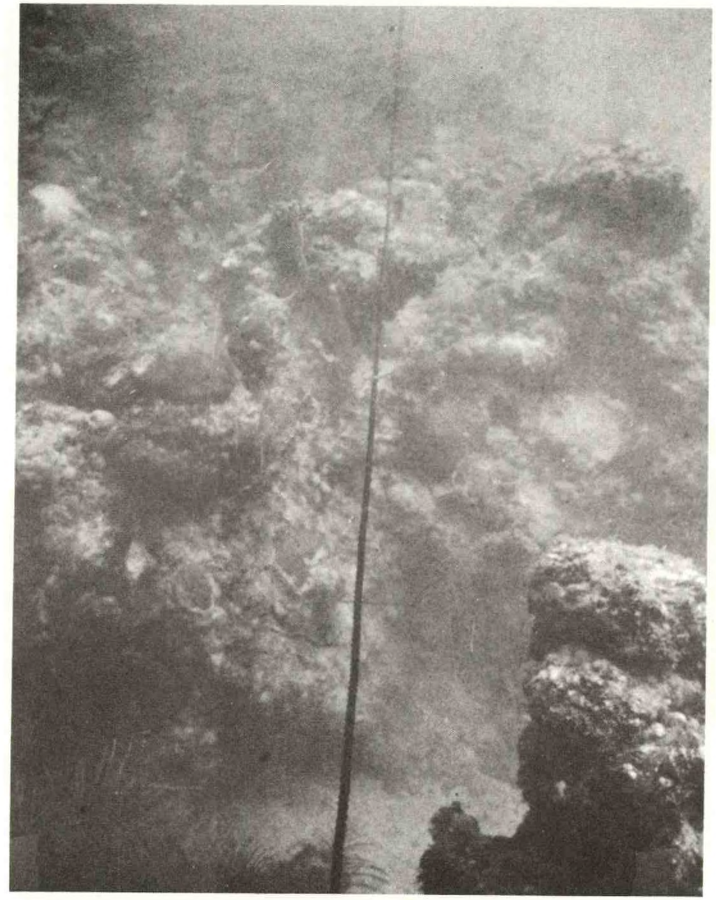

Figure 40.--Edge of reef (21.3 m depth), Carysfort Reef.

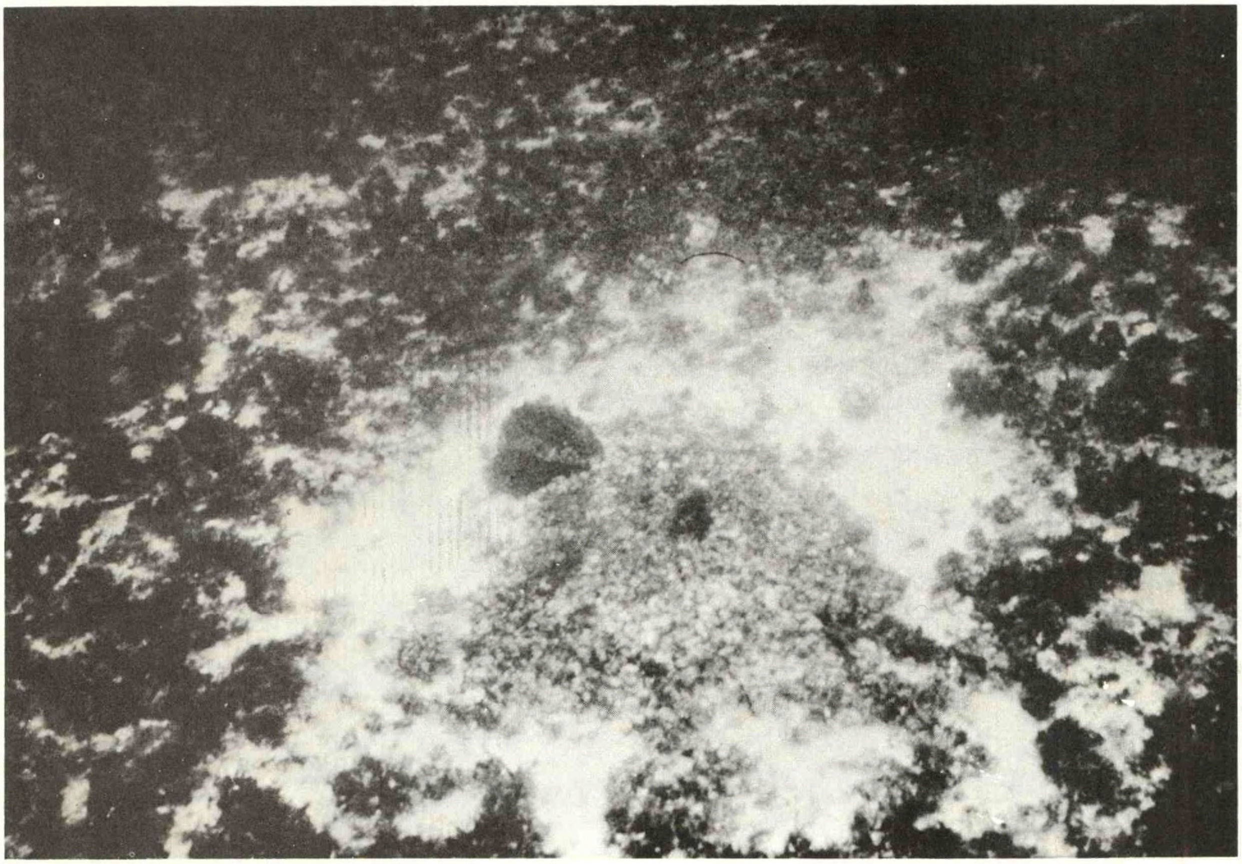

Figure 41.--Bottom photograph of Lithothamnion nodules piled up by sand tile fish at a depth of 46 meters, off French Reef.

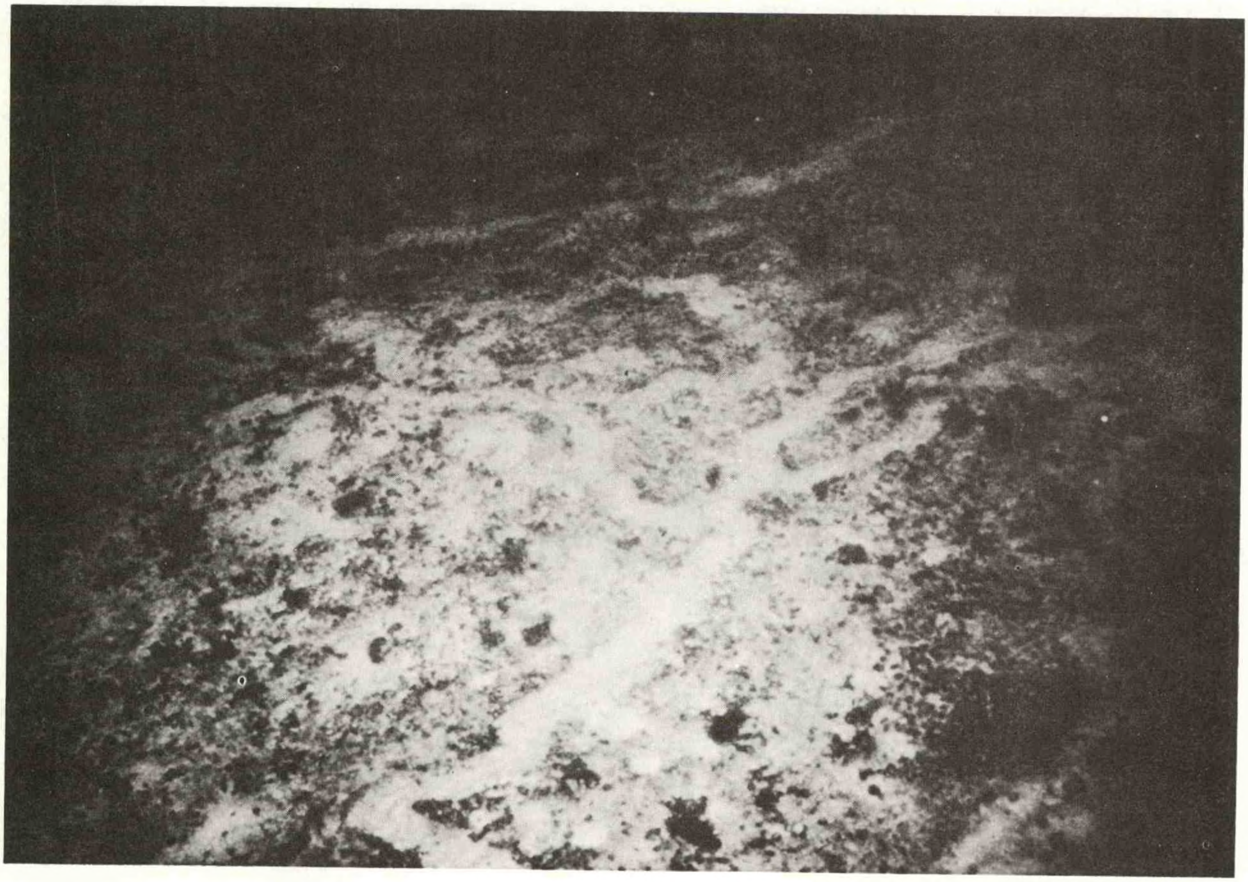

Figure 42.--Trails made by burrowing echinoids which have broken through a surficial algal scum at a depth of 56 meters, off French Reef.

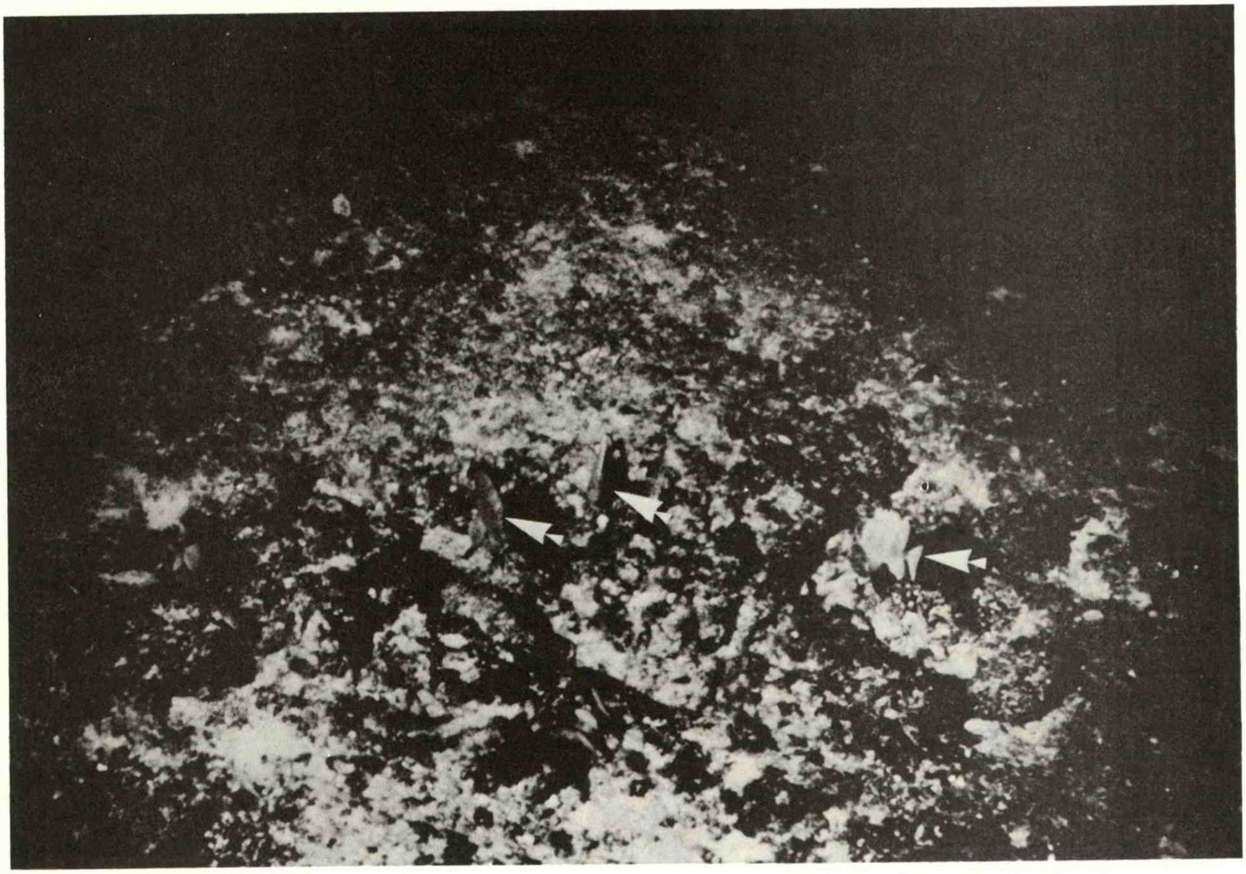

Figure 43.--Carbonate sand which has been cemented to form rock under submarine conditions at a depth of 76 meters, off French Reef. The rock was thought to be part of a more extensive subsurface layer that was exposed by burrowing organisms. Three "big eye" fish (arrows) had taken residence in the rocks.

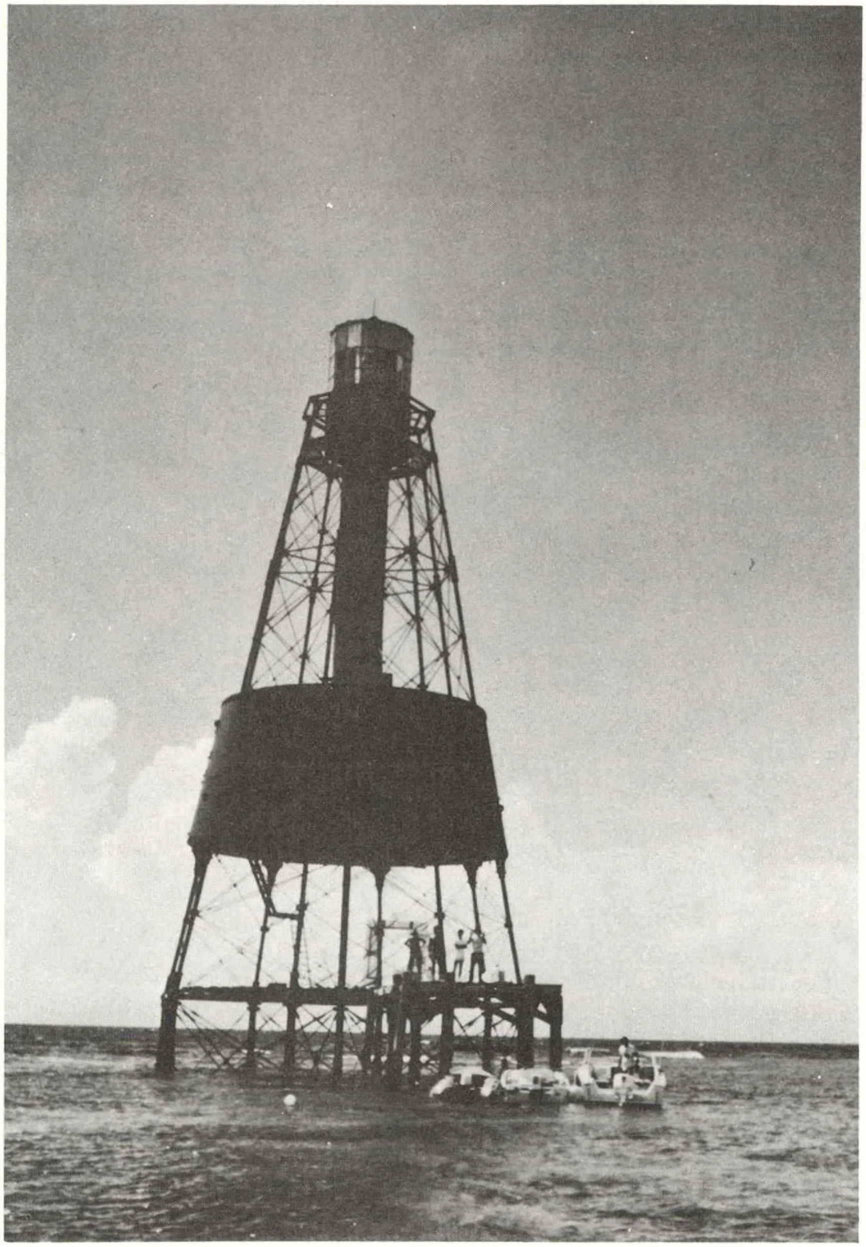

Figure 44.--Carysfort Reef lighthouse.

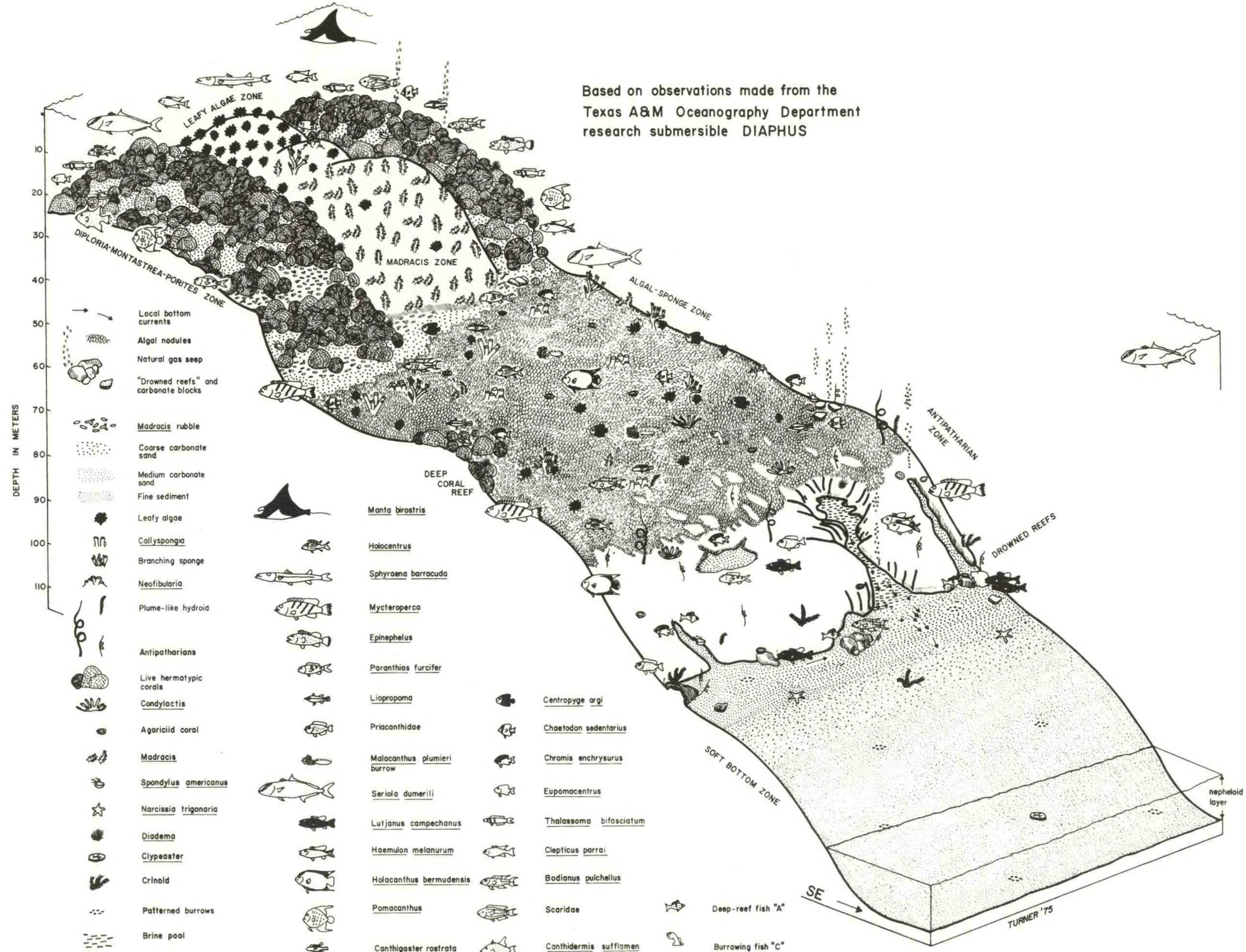

Figure 45.--East Flower Garden Bank.

Table 1.--Dive Log

J-S-L Dive #	Date	Time	Area	Depth	H_2O Temp.	Visability	Current	OBSERVERS Forward	Dive Chamber	Mission
674	6/1/79	1115-1445	French Reef	33.5m-39.6m 110'-130'	27.4°C	12.2m-15.2m 40'-50'	From 240° at 0.2 KT	Askew/ Jameson	Poesch/ Jones	Biological zonation, reef recon., fish inventory, place pinger
675	6/1/79	1700-1900	Elbow Reef	30.5m-38.1m 100'-125'	27.4°C	7.6m-12.2m 25'-40'	From 250° at 0.4 KT	Askew/ Jones	Mitchell/ Clark	Reef recon., fish inventory
676	6/2/79	0850-1152	South Carysfort	25.9m-48.8m 85' - 160'	27.2°C	15.2m-18.3m 50'-60'	From 240° at 0.8 KT	Cook/ Jameson	Poesch/ Reed	Biological zonation, reef recon., place pinger
677	6/2/79	1427-1510	Molasses Reef	33.5m-34.1m 110'-112'	27.0°C	9.1m-12.2m 30'-40'	From 240° at 0.2 KT	Cook/Stone	Roesch/ Keefe	Ecological observations by Senator Stone
678	6/2/79	1555-1755	Molasses Reef	33.5m-35.6m 110'-117'	27.1°C	7.6m-9.1m 25'-30'	From 240° at 0.2 KT	Cook/Frank	Roesch/ Greenberg	Ecological observations by NOAA Administrator Frank
679	6/3/79	0908-1400	French Reef	33.5m-76.2m 110'-250'	27.0°C	12.2m-15.2m 40'-50'	From 190° at 0.1 KT	Cook/Shinn	Mitchell/ Pond	Geological observations
680	6/3/79	1709-1900	South Carysfort	30.5m-50.3m 100'-165'	27.4°C	15.2m-18.3m 50'-60'	From 220° at 0.2 KT	Cook/Shinn	Liberatore/ Hoskin	Geological observations
681	6/4/79	0940-1130	French Reef	35.6m-37.5m 117'-123'	27.1°C	18.3m-21.3m 60'-70'	From 220° at 0.1 KT	Cook/ Eiseman	Mitchell/ Clark	Algae inventory and lockout collections
682	6/4/79	1307-1637	South Carysfort	29.9m-51.2m 85'-168'	22.0°C	12.2m-15.2m 40'-50'	From 210° at 0.4 KT	Cook/ Eiseman	Roesch/ Reed	Algae inventory and lockout collections
683	6/5/79	1856-1150	French Reef	30.5m-39.6m 100'-130'	27.0°C	15.2m-21.3m 50'-70'	From 220° at 0.1 KT	Cook/Jones	Mitchell/ Clark	Fish inventory and lockout poison station
684	6/5/79	1335-1616	South Carysfort	29.9m-33.5m 85'-110'	27.2°C	18.3m-24.4m 60'-80'	From 250° at 0.5 KT	Cook/Jones	Roesch/ Reed	Fish inventory and lockout poison station
685	6/5/79	1709-1809	South Carysfort	24.4m-27.4m 80'-90'	27.1°C	15.2m-21.3m 50'-70'	From 220° at 0.2 KT	Cook/Meir	Liberatore/ Dawson	Ecological observations by Congressional staff members
686	6/6/79	0916-1143	French Reef	36.6-42.7m 120'-140'	26.6°C	15.2m 50'	From 220° at 0.1 KT	Cook/Smith	Roesch/ Jaap	Soft coral inventory, lockout collection of stony corals, recover pinger

Table 1.--Continued

Table 1. Dive Log

J-S-L Dive #	Date	Time	Area	Depth	H_2O Temp.	Visability	Current	OBSERVERS Forward	OBSERVERS Dive Chamber	Mission
687	6/6/79	1320-1457	South Carysfort	29.9m-33.5m 85'-110'	26.4°C	18.3m-21.3m 60'-70'	From 220° at 0.1 KT	Cook/ Jaap	Liberatore/ Knoll	Stoney coral inventory and lockout collection, recover pinger
688	6/6/79	1545-1800	Elbow Reef	36.6m-56.4m 120'-185'	26.5°C	18.3m 60'	From 220° at 0.1 KT	Cook/ Smith	Mitchell/ Jaap	Soft coral inventory, and manipulator collection
689	6/7/79	0942-1052	French Reef	33.5m-36.6m 110'-120'	27.0°C	18.3m-21.3m 60'-70'	From 350° at 0.2 KT	Cook/ Gillen	Roesch/ O'Kane	Ecological observations by Marine Sanctuary on-site manager and Florida DNR Naturalist
690	6/7/79	1202-1315	Elbow Reef	18.3m-35.9m 60'-118'	27.2°C	15.2m 50'	From 350° at 0.1 KT	Cook/ Roberts	Liberatore/ Knoll	Ecological observations by Florida DNR District Manager, Filming by NOAA photographets
691	6/7/79	1403-1443	South Carysfort	30.5m-36.6m 100'-120'	27.0°C	15.2m 50'	From 320° at 0.1 KT	Cook/ Stewart	Mitchell Bright	Biological zonation, filming by Sport Diver Magazine
692	6/7/79	1530-1710	South Carysfort	27.4m-51.2m 90'-168'	27.0°C	15.2m 50'	From 320° at 0.1 KT	Cook/ Bright	Mitchell Stewart	Biological zonation, hydrophone search, filming by Sport Diver Magazine

Table 2.--Stony Corals from Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey in FDNR Marine Research Laboratory Invertebrate Reference Collection

Species	Museum Collection Number (Prefix FSBC I)	Site
Millepora alcicornis	22034	French
Stephanocoenia michelinii	22036	French
Scolymia sp.	22063	French
Mycetophyllia lamarckiana	22044	French
Siderastrea siderea	22048	French
Porites astreoides	22049	French
Diploria strigosa	22052	French
Montastraea annularis	22055	French
Madracis decactis	22039	French
" "	22040	Carysfort
Madracis mirabilis	22041	Carysfort
Madracis asperula	22037	Elbow
Eusimilia fastigiata	22065	Carysfort
Agaricia lamarcki	22045	Carysfort
Helioseris cucullata	22046	Elbow
Porites porites forma divaricata	22050	Elbow
Meandrina meandrites forma braziliensis	22059	Elbow

Table 3.--Stony Corals from Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey.

Class HYDROZOA Owen, 1843		
Order MILLEPORINA Hickson, 1901		
Family Milleporidae Fleming, 1828		
Millepora alcicornis Linne, 1758	2C	T
Class ANTHOZOA Ehrenberg, 1834		
Subclass HEXACORALLIA Haeckel, 1896		
Order SCLERACTINIA Bourne, 1900		
Suborder ASTROCOENIINA Vaughan and Wells, 1943		
Family Astrocoeniidae Koby, 1890		
Stephanocoenia michelinii Milne Edwards and Haime, 1849	1C	T
Family Pocilloporidae Gray, 1842		
Madracis asperula Milne Edwards and Haime, 1850	2C	N
M. decactis (Lyman, 1857)	2C	T
M. mirabilis (Duchassaing and Michelotti, 1861)	1C	T
Suborder FUNGIINA Verrill, 1865		
Superfamily Agariciicae Gray, 1847		
Family Agariciidae Gray, 1847		
Agaricia agaricites (Linne, 1758)	0	T
A. fragilis (Dana, 1846)	1C	T
A. lamarcki Milne Edwards and Haime, 1851	2C	T
Helioseris cucullata (Ellis and Solander, 1786)	2C	T
Family Siderastidae Vaughan and Wells, 1943		
Siderastrea radians (Pallas, 1766)	0	T
S. siderea (Ellis and Solander, 1786)	1C	T
Superfamily Poriticae Gray, 1842		
Family Poritidae Gray, 1842		
Porites astreoides Lamarck, 1816	1C	T
P. porites (Pallas, 1766)	0	T
P. porites forma divaricata LeSueur, 1821	2C	T
Suborder FAVINNA Vaughan and Wells, 1943		
Superfamily Faviicae Gregory, 1900		
Family Faviidae Gregory, 1900		
Diploria labyrinthiformis (Linne, 1758)	0	T
D. strigosa (Dana, 1846)	1C	T
Diploria sp.	1C	T
Manicina areolata (linne, 1758)	1C	T
Colpophyllia natans (Houttyn, 1772)	0	T
Montastraea cavernosa (Linne, 1767)	0	T

Table 3.--Continued

M. annularis (Ellis and Solander, 1786)	2C	T
Family Meandrinidae Gray, 1847		
Meandrina meandrites (Linne, 1758)	0	T
M. meandrites forma braziliensis, Milne Edwards and Haime, 1848	1C	N*
Family Mussidae Ortmann, 1890		
Scolymia spp.	2C	T
Mycetophyllia lamarckiana Milne Edwards and Haime, 1849	2C	T
Suborder CARYOPHYLLIINA Vaughan and Wells, 1943		
Superfamily Caryophylliicae Gray, 1847		
Family Caryophylliidae Gray, 1847		
Subfamily Caryophylliinae Gray, 1847		
Paracyanthus pulchellus (Philippi, 1842)	3C	N
Subfamily Eusmiliinae Milne Edwads and Haime, 1857		
Eusmilia fastigiata (Pallas, 1766)	1C	T

C = specimen collected
O = observed, not collected
T = typical deeper zone reef species
N = non-reef species

*M. m. forma braziliensis is an unusual taxa, in that it is adapted to life in sedimentary environments and is not found on hard substratum, but it does posses zooxanthellae.

Table 4.--Comparative Occurrence of Stony Corals at Various South Florida and Bahamian Reefs.

Species	Sanctuary 27-55m	Carysfort 8m	*Pourtales, 1871	Long Key Reef Dry Tortugas 17-21m	Hydro-lab Grand Bahamas 25-55m
Stephanocoenia michelinii	X	X		X	X
Madracis decactis	X		X	X	
M. asperula	X				
M. mirabilis					X
M. pharensis					X
M. formosa					X
Acropora palmata		X	X		
A. cervicornis		X	X		X
A. prolifera			X		
Agaricia agaricites	X	X	X	X	X
A. undata			X		X
A. lamarcki	X			X	X
A. fragilis	X		X	X	X
Helioseris cucullata	X			X	X
Siderastrea siderea	X	X	X	X	X
S. radians	X				
Porites astreoides	X	X	X	X	X
P. branneri					X
P. porites	X	X	X		X
P. porites forma *divaricata*	X				
Favia fragum		X	X		X
Diploria clivosa		X	X		
D. labyrinthiformis	X	X	X		
D. strigosa	X	X	X		
Manicina areolata	X		X		
Colpophyllia natans	X	X	X		X
Cladocora arbuscula			X		
Montastraea cavernosa	X	X	X	X	X
M. annularis	X	X	X		X
Solenastrea bournoni			X		
Oculina diffusa			X		
Meandriana meandrites	X	X	X		X
M. meandrites forma *braziliensis*	X		X		X
Dichocoenia stokesii		X	X		X
D. stellaris	X	X		X	X

Table 4.--Continued

Dendrogyra cylindrus			X		
Mussa angulosa		X	X		X
Scolymia lacera			X	X	X
S. cubensis			X	X	X
Isophyllia sinuosa		X	X		
Isophyllastrea rigida					X
Mycetophyllia lamarckiana	X	X	X	X	X
M. danaana			X		
M. ferox		X			
M. aliciae		X			
Eusmilia fastigiata	X	X	X		X
Paracyathus pulchellus	X				
Millepora alcicornis	X	X	X	X	X
M. complanata		X			
TOTAL	26	25	33	14	29

*General survey species list

Table 5.--Jaccard Coefficient of Association, Faunal Comparison of Reefs.

	Carysfort	Long Key	Hydro-Lab Grand Bahama Island 25-55 m
Sanctuary (27-55 m)	0.4167	0.4286	0.4865
Carysfort Reef (8 m)	-	0.2581	0.4211
Long Key Reef, Dry Tortugas (17-21 m)	-	-	0.4333

$$\text{Jaccard Coefficient of Association} = \frac{A}{A + B + C}$$

A=number of attributes in one state shared by both entities.
(species common in both samples)
B=number of attributes possessed by the first entity but not the second.
C=number of attributes possessed by the second entity but not the first.

Table 6.--Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey. Octocoral Observations and Collections by Site.

Species	Depth (m)
FRENCH REEF	
Briareum asbestinum	33.5*
Plexaura flexuosa	33.5*
Iciligorgia schrammi	35.4
Eunicea pinta	35.4
Muriceopsis petila	35.4
Plexaurella nutans	35.4
Muricea laxa	35.4
Pseudopterogorgia bipinnata	35.4
Nicella schmitti	36.6*
Swiftia exserta	36.6,37.2
Ellisella barbadensis	36.6,37.2
Eunicea species indeterminata	
ELBOW REEF	
Eunicea tourneforti	18.3**
Eunicea clavigera	18.3**
Pseudopterogorgia acerosa	18.3**
Iciligorgia schrammi	38.1
Eunicea pinta	38.1
Eunicea ?succinea f. plantaginea	38.1
Pseudopterogorgia bipinnata	38.1,40.5
Ellisella elongata	38.1,40.5
Swiftia exserta	38.1,48.8
Nicella schmitti	38.1*
CARYSFORT REEF	
Iciligoria schrammi	27.4
Plexaura flexuosa	27.4
Pseudoplexaura porosa	27.4
Eunicea pinta	27.4
Eunicea calyculata	27.4
Plexaurella nutans	27.4
Muricea laxa	27.4
Pseudopterogorgia bipinnata	27.4
Pseudopterogorgia americana	27.4
Gorgonia ventalina	27.4
Pterogorgia citrina	27.4
Pterogorgia guadalupensis	27.4
Nicella schmitti	27.4

*Observed only
**Incidental collections by other investigators

Table 7.--Key Largo Coral Reef Marine Sanctuary Deep Water Resource Survey, 1979. Octocorallia Observed and/or Collected.

Taxa	Collection Depths (m)
Gorgonacea	
Briareidae	
Briareum asbestinum	33.5*
Anthothelidae	
Iciligorgia schrammi	27.4-38.1
Paramuriceidae	
Swiftia exserta	36.6-48.8
Plexauridae	
Plexaura flexusoa	27.4
Pseudoplexaura porosa	27.4
Eunicea pinta	27.4-38.1
Eunicea ?succinea F. *plantaginea*	38.1
Eunicea tourneforti	18.3
Eunicea clavigera	18.3
Eunicea calyculata	27.4
Eunicea species indeterminata	76.2
Muriceopsis petila	35.4
Plexaurella nutans	27.4-35.4
Muricea laxa	27.4-35.4
Gorgoniidae	
Pseudopterogorgia bipinnata	27.4-40.5
Pseudopterogorgia acerosa	18.3
Pseudopterogorgia americana	27.4
Gorgonia ventalina	27.4
Pterogorgia citrina	27.4
Pterogorgia guadalupensis	27.4
Ellisellidae	
Ellisella barbadensis	36.6-37.2
Ellisella elongata	38.1-40.5
Nicella schmitti	27.4-36.6

*Observed only

Table 8.--Geographical Comparison of Gorgonian Distribution by Reef Zone

	Reef Zone Outer Reef Slop* Shallow	 Deep	 Fore Reef**
Briareum asbestinum (Pallas, 1766)	PKJ	PK	
Iciligorgia schrammi Duchassaing, 1870	P J	PKJ	PK
Diodogorgia nodulifera (Hargitt, 1901)	J	J	P
Erythropodium caribaeorum (Duchassaing & Michelotti, 1860)	J		
Lignella richardii (Lamouroux, 1816)			J
Hypnogorgia penula Duchassaing & Michelotti, 1864			J
Swiftia exserta (Ellis & Solander, 1786)		P	PKJ
Plexaura homomalla (Esper, 1792) f. *kukenthali* (Moser, 1921)	J	J	J
Plexaura nina Bayer & Dechmann, 1958	J		
Plexaura flexuosa Lamouroux, 1821	P J	PKJ	
Pseudoplexaura porosa (Houttuyn, 1772)	J	KJ	
Pseudoplexaura flagellosa (Houttuyn, 1772)	J	J	
Pseudoplexaura wagenaari (Stiasny, 1941)	J		
Pseudoplexaura crucis Bayer, 1961			P
Pseudoplexaura sp.		P	
Eunicea pinta Bayer & Deichmann, 1958	P	PKJ	K
Eunicea mammosa Lamouroux, 1816	J		
Eunicea ?succinea (Pallas, 1766) f. *plantaginea* (Lamarck, 1815)			K
Eunicea fusca Duchassaing & Michelotti, 1860	J	P J	
Eunicea palmeri Bayer, 1961	P	P	
Eunicea laciniata Duchassaing & Michelotti, 1860	P J	J	
Eunicea calyculata Ellis & Solander, 1786	PK	K	P
Eunicea calvigera Bayer, 1961	PKJ	J	J
Eunicea tourneforti Milne Edwads & Haime, 1857	PK	P	
Eunicea sp. indet.			K
Muriceopsis flavida (Lamarck, 1815)	J		
Muriceopsis petila Bayer, 1961	J	PKJ	J
Plexaurella dichotoma (Esper, 1791)	P J	J	
Plexaurella fusifera Kunze, 1916	J	KJ	
Plexaurella nutans (Duchassaing & Michelotti, 1860)		P	
Plexaurella pumila Verrill, 1912	J		
Plexaurella grisea Kunze, 1916	J	KJ	P J
Muricea laxa Verrill, 1864			P
Muricea pendula Verrill, 1864	KJ	KJ	KJ
Pseudopterogorgia bipinnata (Verrill, 1864)	KJ		
Pseudopterogorgia acerosa (Pallas, 1766)	PKJ	KJ	
Pseudopterogorgia americana (Gmelin, 1791)		P	
Pseudopterogorgia rigida (Bielschowsky, 1929)	P J	J	P J
Pseudopterogorgia elisabethae Bayer, 1961	K	P	
Pseudopterogorgia navia Bayer, 1961	P		
Pseudopterogorgia sp.	J		
Gorgonia flabellum Linnaeus, 1758	P J	K	
Gorgonia ventalina Linnaeus, 1758	J	J	
Gorgonia mariae Bayer, 1961			P
Lophogorgia cardinalis Bayer, 1961			

Table 8.--Continued

	Reef Zone Outer Reef Slope* Shallow	Deep	Fore Reef**
Pterogorgia guadalupensis Duchassaing & Michelin, 1846	P J	K	
Pterogorgia citrina (Esper, 1792		K	
Ellisella barbadenis Duchassaing & Michelotti, 1864	P J	P J	PKJ
Ellisella elongata (Pallas, 1766)	J	J	K
Ellisella sp.	P	P	P
Nicella schmitti Bayer, 1961	P	PK	PK
Nicella spp.			J

P=Palm Beach Co. (Goldberg, 1973) K=Key Largo Coral Reef Marine Sanctuary,

1975, 1979 J=Jamaica (Kinzie, 1973)

* Goldberg's shallow slope (20-25 m), deep slope (25-30 m)
Sanctuary shallow slope (16-25 m), deep slope (25-35.4 m)
Kinzie's upper fore reef slope and pinnacles (24-33 m), lower reef slope and pinnacles (33-50/60 m).

**Goldberg's fore reef (30+ m)
Sanctuary fore reef (36+ m)
Kinzie's deep fore reef slope (50-75 m)

Table 9.--Carysfort Transect Studies, 1975. Octocorallia Observed and/or Collected.

Taxa	Collection Depth (m)
Gorgonacea	
Briareidae	
Briareum asbestinum	0.5-21.3
Plexauridae	
Plexaura flexuosa	1.2-5.5
Plexaura homomalla	3.3-4.0
Pseudoplexaura porosa	1.2-5.5
Pseudoplexaura flagellosa	0.9
Pseudoplexaura crucis	0.9-2.4
Eunicea succinea	0.9
Eunicea fusca	3.4-5.5
Eunicea laciniata	1.2-9.1
Eunicea tourneforti	3.4-21.3
Eunicea calyculata	0.9-5.5
Eunicea species indeterminata	3.4-9.1
Muriceopsis flavida	1.2-15.5
Plexaurella dichotoma	11.3-13.7
Plexaurella grisea	5.5
Plexaurella fusifera	1.2-6.4
Muricea atlantica	9.1
Muricea elongata	
Gorgoniidae	
Pseudopterogorgia bipinnata	11.3-21.3
Pseudopterogorgia kallos	3.4-15.5
Pseudopterogorgia rigida	9.1
Pseudopterogorgia acerosa	4.6-9.1
Pseudopterogorgia americana	1.2-21.2
Pseudopterogorgia elisabethae	11.3-13.7
Pseudopterogorgia navia	15.5-16.2
Gorgonia ventalina	1.2-15.5
Pterogorgia guadalupensis	9.1

Table 10.--List of fishes recorded from the Key Largo deep reefs (26-38 m). Column numbers refer to abundance codes (see legend). The total number of deep reef species observed is compared in the last two columns with fishes observed on shallow (1-14 m) Key Largo reefs (Jones and Thompson 1978). Species marked with an asterisk (*) were actually collected on lockout dives or by manipulator.

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
ORECTOLOBIDAE					
Ginglymostoma cirratum	-	-	1	+	o
CARCHARHINIDAE					
Negaprion brevirostris	-	1	-	+	o
SPHYRNIDAE					
Sphyrna sp.	-	-	1	+	o
DASYATIDAE					
Dasyatis americana	-	-	1	+	o
Urolophus jamaicensis	-	-	-	o	+
MYLIOBATIDAE					
Aetobatus narinari	-	-	-	o	+
MURAENESOCIDAE					
*Hoplunnis diomedianus	-	1	-	+	o
MURAENIDAE					
Gymnothorax funebris	-	1	-	+	+
G. moringa	-	-	-	o	+
Muraena miliaris	1	-	1	+	o
CLUPEIDAE					
Harengula sp.	-	-	-	o	+
Jenkinsia sp.	-	-	-	o	+
SYNODONTIDAE					
Synodus intermedius	-	-	-	o	+

Table 10.--Continued

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
BELONIDAE					
Tylosurus crocodilus	-	-	-	o	+
AULOSTOMIDAE					
Aulostomus maculatus	-	-	-	o	+
FISTULARIIDAE					
Fistularia tabacaria	-	1	1	+	o
HOLOCENTRIDAE					
Adioryx coruscus	-	-	-	o	+
A. vexillarius	-	-	-	o	+
Holocentrus ascensionis	-	2	2	+	+
*H. rufus	-	1	1	+	+
*Flammeo marianus	-	1	-	+	o
Myripristis jacobus	-	-	-	o	+
CENTROPOMIDAE					
Centropomus undecimalis	-	-	-	o	+
SPHYRAENIDAE					
Sphyraena barracuda	-	1	2	+	+
SERRANIDAE					
Alpestes afer	-	-	-	o	+
Epinephelus adscensionis	-	-	-	o	+
E. guttatus	-	3	3	+	o
E. striatus	2	2	3	+	+
E. morio	2	1	-	+	o
E. cruentatum	2	2	2	+	+
E. fulva	-	1	-	+	+
Mycteroperca venenosa	-	1	1	+	o
M. bonaci	2	2	2	+	+
M. interstitialis	-	3	3	+	+
M. tigris	-	-	-	o	+
Hypoplectrus puella	2	2	2	+	+
H. unicolor	4	4	3	+	+
H. indigo	-	1	1	+	+
H. nigricans	-	1	-	+	+

Table 10.--Continued

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
SERRANIDAE (Cont.)					
H. guttavarius	-	-	1	+	+
H. gemma	2	2	2	+	+
H. gummiguta	-	-	-	o	+
H. aberrans	-	-	-	o	+
Liopropoma rubre	-	-	-	o	+
Serranus tigrinus	-	2	2	+	+
S. tabacarius	5	5	4	+	+
S. baldwini	-	1	-	+	o
S. annularis	-	2	-	+	o
S. tortugarum	-	3	-	+	o
Paranthias furcifer	-	-	1	+	o
GRAMMISTIDAE					
Rypticus saponaceus	-	-	-	o	+
PRIACANTHIDAE					
Priacanthus arenatus	-	-	-	o	+
P. cruentatus	-	-	-	o	+
Pristiginys alta	-	1	-	+	o
EMMELICHTHYIDAE					
Inermia vittata	-	-	-	o	+
APOGONIDAE					
Apogon binotatus	-	-	-	o	+
A. maculatus	-	-	-	o	+
A. townsendi	-	-	-	o	+
BRANCIOSTEGIDAE					
Malacanthus plumieri	3	3	3	+	+
CIRRHITIDAE					
Amblycirrhitus pinos	-	1	1	+	+
ECHENEIDAE					
Echeneis naucrates	-	-	-	o	+

Table 10.--Continued

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
CARANGIDAE					
Seriola dumerili	-	1	1	+	o
Elagatis bipinnulatus	1	-	-	+	o
Caranx ruber	-	3	3	+	+
C. bartholomaei	-	2	-	+	+
C. latus	-	-	-	o	+
Trachinotus falcatus	-	1	2	+	+
Decapterus sp.	-	-	1	+	+
SCOMBRIDAE					
Scomberomorus regalis	1	1	1	+	+
LUTJANIDAE					
Lutjanus cyanopterus	-	-	1	+	o
L. jocu	-	1	1	+	+
L. analis	3	3	3	+	+
L. apodus	-	-	-	o	+
L. buccanella	-	-	-	o	+
L. griseus	-	-	-	o	+
L. mahogoni	-	-	-	o	+
L. synagris	-	-	-	o	+
Ocyurus chrysurus	-	1	-	+	+
LOBOTIDAE					
Lobotes surinamensis	-	-	-	o	+
POMADASYIDAE					
Haemulon striatum	-	4	-	+	o
*H. aurolineatum	4	4	4	+	+
H. album	3	3	3	+	+
H. flavolineatum	2	-	3	+	+
H. carbonarium	-	-	-	o	+
H. chrysargyreum	-	-	-	o	+
H. macrostomum	-	-	-	o	+
H. melanurum	-	-	-	o	+
H. parrai	-	-	-	o	+
H. plumieri	-	-	-	o	+
H. sciurus	-	-	-	o	+

Table 10.--Continued

		Elbow	French	Carysfort	Total	Jones & Thompson
	Dive #	675	674 & 683	676 & 684		
POMADASYIDAE (Cont.)						
Anisotremis surinamensis		-	2	2	+	+
A. virginicus		-	-	-	o	+
SPARIDAE						
Calamus calamus		-	3	-	+	+
C. bajonado		-	2	-	+	+
SCIAENIDAE						
Equetus acuminatus		-	-	1	+	+
E. punctatus		-	-	1	+	+
Odontoscion dentex		-	-	-	o	+
MULLIDAE						
Pseudupeneus maculatus		3	3	3	+	+
Mulloidichthys martinicus		-	-	-	o	+
EPHIPPIDAE						
Chaetodipterus faber		-	2	-	+	+
PEMPHERIDAE						
Pempheris schombergki		-	-	-	o	+
OPISTOGNATHIDAE						
Opistognathus aurifrons		-	-	1	+	+
KYPHOSIDAE						
Kyphosus sp.		-	-	1	+	+
CHAETODONTIDAE						
Chaetodon capistratus		3	3	3	+	+
C. striatus		-	1	1	+	+
C. ocellatus		3	3	3	+	+
C. sedentarius		5	5	4	+	+
Prognathodes aculeatus		2	-	-	+	o
Pomacanthus arcuatus		3	3	3	+	+
P. paru		2	2	2	+	+
*Holocanthus tricolor		5	5	4	+	+
H. ciliaris		2	2	3	+	+
H. bermudensis		3	3	3	+	+

Table 10.--Continued

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
CHAETODONTIDAE (Cont.)					
*Centropyge argi	3	3	2	+	o
POMACENTRIDAE					
Abudefduf saxatilis	-	-	-	o	+
Pomacentrus planifrons	-	1	-	+	+
P. variabilis	-	-	1	+	+
P. leucostictus	-	1	-	+	+
*P. partitus	4	5	5	+	+
P. fuscus	-	-	-	o	+
P. mellis	-	-	-	o	+
Microspathodon chrysurus	-	-	-	o	+
Chromis multilineata	-	2	2	+	+
C. cyanea	5	5	5	+	+
C. insolatus	5	5	5	+	o
*C. scotti	4	4	4	+	+
C. flavicauda	1	1	-	+	o
LABRIDAE					
Bodianus rufus	3	3	3	+	+
B. pulchellus	2	2	-	+	o
Lachnolaimus maximus	3	3	3	+	+
*Halichoeres garnoti	3	3	3	+	+
H. poeyi	-	3	3	+	+
H. bivittatus	-	-	-	o	+
H. radiatus	-	-	-	o	+
Thalassoma bifasciatum	5	5	5	+	+
Clepticus parrai	4	4	4	+	+
Hemipteronotus splendens	-	-	-	o	+
SCARIDAE					
Sparisoma rubripinne	-	-	1	+	+
S. viridae	-	3	3	+	+
*S. aurofrenatum	5	5	5	+	+
*S. atromarium	-	1	-	+	o
S. chrysopterum	-	-	-	o	+
S. radians	-	-	-	o	+
Cryptotomus roseus	-	-	-	o	+

Table 10.--Continued

	Dive #	Elbow	French	Carysfort	Total	Jones & Thompson
		675	674 & 683	676 & 684		
SCARIDAE (Cont.)						
*Scarus croicensis		4	4	4	+	+
S. taeniopterus		-	1	-	+	+
S. coeruleus		-	-	2	+	+
S. guacamaia		2	2	3	+	+
S. coelestinus		2	2	2	+	+
S. vetula		-	-	-	o	+
OPISTOGNATHIDAE						
Opistognathus aurifrons		-	-	-	o	+
CALLIONYMIDAE						
Callionymus bairdi		-	-	-	o	+
SCORPAENIDAE						
Scorpaena plumeri		-	-	-	o	+
BOTHIDAE						
Bothus lunatus		-	-	-	o	+
GOBIIDAE						
Coryphopterus personatus		-	2	-	+	+
C. glaucofraenum		-	-	-	o	+
*C. sp.		-	1	-	+	o
*Lythrypnus nesiotes		-	1	-	+	o
Gnatholepis thompsoni		-	-	-	o	+
Gobiosoma oceanops		-	-	-	o	+
Ioglossus calliurus		-	-	-	o	+
ACANTHURIDAE						
Acanthurus coeruleus		4	4	4	+	+
A. bahianus		3	3	3	+	+
A. chirurgus		3	3	2	+	+
BALISTIDAE						
Canthidermis sufflamen		2	2	3	+	+
MONACANTHIDAE						
Cantherhines pullus		-	-	-	o	+
C. monoceros		-	2	2	+	+

Table 10.--Continued

	Elbow	French	Carysfort	Total	Jones & Thompson
Dive #	675	674 & 683	676 & 684		
MONACANTHIDAE (Cont.)					
Alutera scripta	-	-	1	+	+
Monacanthus ciliatus	-	-	-	o	+
M. tuckeri	-	-	-	o	+
OSTRACIONTIDAE					
Lactophrys triqueter	3	3	3	+	+
L. bicaudalis	-	-	1	+	+
L. trigonus	-	1	1	+	o
Acanthostracion quadricornis	2	2	2	+	o
TETRAODONTIDAE					
*Canthigaster rostrata	3	3	3	+	+
DIODONTIDAE					
Diodon holocanthus	-	-	-	o	+
D. hystrix	-	-	-	o	+
OGCOCEPHALIDAE					
Ogcocephalus sp.	1	-	-	+	o
TOTAL SPECIES	50	88	81	110	146

*Abundance Code

1 = 1-2 individuals

2 = 3-10 individuals

3 = 11-20 individuals

4 = 21-50 individuals

5 = 51+ individuals

Table 11.-- Observation time, species observed and depth of observations of present study vs Jones and Thompson 1978.

	Jones & Thompson (SCUBA)			Present Study (Submersible)		
	Time	Depth	Species	Time	Depth	Species
Elbow Reef	-	-	-	1h53m	31-38 m	50
French Reef	6h40m	1-14 m	118	6h22m	31-37 m	88
Carysfort Reef	6h40m	1-21 m	104	5h43m	26-37 m	81
Molasses Reef	6h40m	1-14 m	120	-	-	-
Benwood Wreck	6h40m	7-14 m	117	-	-	-
TOTAL	26h40m	1-21 m	146	13h8m	26-38 m	110

Table 12.--Depth distribution of the marine algae of the Key Largo Coral Reef Marine Sanctuary.

	Depth (m)				
CHLOROPHYTA	10	20	30	38	52
Ulotrichales					
Ulvaceae					
Ulva lactuca Linnaeus	-	-	-	-	+
Siphonales					
Codiaceae					
Codium isthmocladum Vickers	-	-	-	+	+
C. spongiosum Harvey	-	-	+	+	-
C. taylori Silva	-	-	-	+	-
H. gracilis Harvey	-	-	-	+	+
H. opuntia (Linnaeus) Lamouroux f. *minor* Vickers	+	+	+	-	-
Penicillus capitatus Lamark	-	-	-	+	-
Pseudocodium floridanum Dawes & Mathieson	-	-	-	+	+
Udotea conglutinata (Ellis & Solander) Lamouroux	+	+	+	-	-
U. flabellum (Ellis & Solander) Lamouroux	+	-	-	-	+
Bryopsidaceae					
Bryopsis pennata Lamourox	-	-	-	-	+
Caulerpales					
Caulerpaceae					
Caulerpa mexicana Sondes ex Kiitzing	-	-	-	-	+
C. microphysa (Weber-van bosse) J. Feldmann	-	-	-	-	+
C. prolifera (Forsskol) Lamouroux	-	-	-	-	+
C. racemosa (Forsskol) J. Agardh V. *macrophysa* (Kiitzing) Taylor	-	-	-	+	-
C. sertularioides (Gmelin) Howe	-	-	-	-	+
Cladophorales					
Cladophoraceae					
Cladophora sp.	-	-	-	-	+
Siphonocladales					
Anadyomeniaceae					
Microdictyon boergesenii Setchell	-	-	-	-	+
Valoniaceae					
Valonia ventricosa J. Agardh	-	-	-	+	+

Table 12.--Continued

	Depth (m) 10	20	30	38	52
PHAEOPHYTA					
Dictyotales					
Dictyotaceae					
Dictyopteris delicatula Lamouroux	-	-	-	-	+
D. jamaicensis Taylor	-	-	-	-	+
D. justii Lamouroux	-	-	-	-	+
Dictyota dichotoma (Hudson) Lamouroux	+	+	+	+	+
Lobophora voriegata (Lamouroux)	-	+	-	-	-
Stypopodium zonale (Lamouroux)Papenfuss	-	-	-	-	+
Sporochnales					
Sporochnaceae					
Sporochnus bolleanus Montagne	-	-	-	+	+
RHODOPHYTA					
Nemaliales					
Chaetangiaceae					
Galaxaura oblongata (Ellis Solander) Lamouroux	+	+	+	-	-
Gelidiales					
Gelidiaceae					
Gelidiella setacea (Feldmann) Feldmann & Hamel	+	-	-	-	-
Cryptonemiales					
Grateloupiaceae					
Cryptonema crenulata J. Agrdh	-	-	+	-	-
Halymenia floresia (Clemente) C. Agardh	-	-	-	+	+
Halymenia sp.	-	-	-	+	-
Kallymeniaceae					
Kallymenia perforata J. Agardh	-	-	-	+	+
Corallinaceae					
Amphiroa tribulus (Ellis & Solander) Lamouroux	+	+	-	-	-
Gigartinales					
Hypneaceae					
Hypnea volubilis Searles	-	+	+	-	-

Table 12.--Continued

	Depth (m)				
	10	20	30	28	52
RHODOPHYTA (Cont.)					
Nemastomataceae					
Predaea masonii (Setchell & Gardner) DeToni	-	-	-	-	+
Titanophora incrustans (J. Agardh) Borgesen	-	-	+	+	-
Unknown No. 1	-	-	-	+	+
Unknown No. 2	-	-	-	+	-
Gracilariaceae					
Gracilaria(?) No. 1	-	-	-	+	+
Gracilaria(?) No. 2	-	-	-	+	-
Phyllophoraceae					
Petroglossum undulztum Schneider	-	-	-	+	+
Solieriaceae					
Meristotheca floridana Kylin	-	-	-	-	+
Rhodymeniales					
Rhodymeniaceae					
Agardhinula browneae (J. Agardh) DeToni	-	-	-	-	+
Botryocladia occidentalis (Borgesen) Kylin	-	-	-	+	-
Chrysemenia enteromorpha Harvey	-	-	-	+	+
C. halymenioides Harvey	-	-	-	+	-
Coelarthrum albertisii (Piccone) Borgesen	-	-	-	+	+
Cryptarachne planifrons (Melville) Kylin	-	-	-	+	+
Champiaceae					
Champia parvula (C. Agardh) Harvey	+	-	-	-	-
Lomentaria baileyana (Harvey) Farlow	-	-	-	?	+
Ceramiales					
Ceramiaceae					
Ceramium fastigiatum (Roth) Harvey f. *flaccida* H. E. Peterson	+	-	-	-	-
Wrangelia bicuspidata Borgesen	-	-	-	?	+
Delesseriaceae					
Grinnellia americana (C. Agardh) Harvey	-	-	-	-	+
Martensia pavonia (J. Agardh) J. Agardh	-	-	+	-	+
Nitophyllum punctatum (Stackhouse) Greville	+	-	-	-	-
Dasyaceae					
Dasya punicea Meneghini	-	-	-	?	+
D. sp. 1	-	-	-	+	-
D. sp. 2	-	-	-	+	-
Rhodomelaceae					
Waldoia antillana Taylor	-	-	-	+	-
Wrightiella tmanowiczi (Gatty) Schmitz	-	-	-	+	+

Table 13.--Comparison of sponges collected during Key Largo Coral Reef Marine Sanctuary Deep Water Survey with sponges observed during survey of Carysfort Reef.

	Deep Reef Data			
Class Demospongea	Sample #	Depth(m)	Location	Carysfort Reef Survey
Order Keratosa				
Ircinia strobilina[2]	681	37.5	French Reef	X
Ircinia sp.	681	37.5	French Reef	
Aplysina fistularis	682	51.2	Carysfort Reef	X
Verongula ardis				X
Thorecta horridus				X
Order Haplosclerida				
Haliclona compressa	679	42.1	French Reef	X
Haliclona sp.				X
Niphates erecta	681	37.5	French Reef	
Niphates digitalis	683	36.3	French Reef	X
forma digitalis	690	18.3	The Elbow	
Niphates digitalis forma amorpha				X
Spinosella vaginalis				X
Spinosella plicifera				X
Spinosella tenerrima	679,689	42.1,33.5	French Reef	
(Xestospongia muta)	(observed, not collected)			
Order Poecilosclerida				
Agelas schmidti				X
Agelas clathrodes				X
Iotrochota birotulata	690	18.3	The Elbow	
Ulosa ruetzleri				X
Mycale laevis				X
Order Axinellida				
Ectyoplasia ferox				X
?Aulospongus sp.				X
?Axinellid	688	38.1	The Elbow	
Order Hadromerida				
Anthosigmella varians				X
Speciospongia vesparium	679	42.1	French Reef	
Order Epipolasida				
?Jaspis sp. or ?Epipolasis sp.	679	42.1	French Reef	
Prostylissa spongia	681	37.5	French Reef	
Order Choristida				
?Myriastra sp.	688	56.4	The Elbow	
Chondrilla nucula				X

Transect data collected by author during survey of Carysfort Reef in 1975-76.
Depth & location information can be obtained from Harbor Branch Foundation Annual Reports (1974, 75, 76).
Species names from Wiedenmayer, 1977.

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