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Coastal and Estuarine Data Archaeology and Rescue Program

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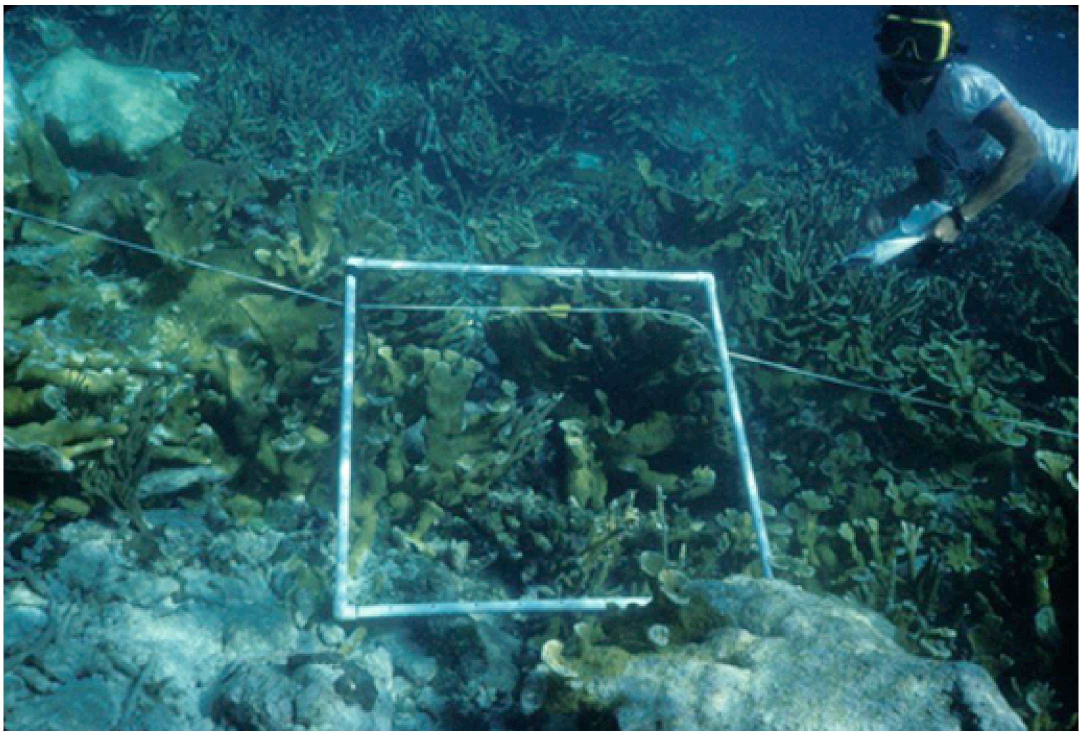
(Unpublished 1983 Report)



November 2002

US Department of Commerce
National Oceanic and Atmospheric Administration
Silver Spring, MD

University of Miami
Rosenstiel School of Marine and Atmospheric Science
Miami, FL

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AN ENVIRONMENTAL ASSESSMENT OF THE JOHN PENNEKAMP CORAL REEF STATE PARK AND THE KEY LARGO CORAL REEF MARINE SANCTUARY

(Unpublished 1983 Report)

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(Editors, 2002)

November 2002

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ABSTRACT

The Pennekamp Coral Reef State Park was established in 1960 and the Key Largo National Marine Sanctuary in 1975. Field studies, funded by NOAA, were conducted in 1980 - 1981 to determine the state of the coral reefs and surrounding areas in relation to changing environmental conditions and resource management that had occurred over the intervening years. Ten reef sites within the Sanctuary and seven shallow grass and hardbottom sites within the Park were chosen for qualitative and quantitative studies. At each site, three parallel transects not less than 400 m long were run perpendicular to the reef or shore, each 300 m apart. Observations, data collecting and sampling were done by two teams of divers. Approximately 75 percent of the bottom within the 18-m isobath was covered by marine grasses, predominantly turtle grass. The general health of the seagrasses appeared good but a few areas showed signs of stress. The inner hardbottom of the Park was studied at the two entrances to Largo Sound. Though at the time of the study the North Channel hardbottom was subjected to only moderate boat traffic, marked changes had taken place over the past years, the most obvious of which was the loss of the extensive beds of Sargassum weed, one of the most extensive beds of this alga in the Keys. Only at this site was the green alga *Enteromorpha* encountered. This alga, often considered a pollution indicator, may denote the effects of shore run off. The hardbottom at South Channel and the surrounding grass beds showed signs of stress. This area bears the heaviest boat traffic within the Park waters causing continuous turbidity from boat wakes with resulting siltation. The offshore hardbottom and rubble areas in the Sanctuary appeared to be in good health and showed no visible indications of deterioration. Damage by boat groundings and anchors was negligible in the areas surveyed. The outer reefs in general appear to be healthy. Corals have a surprising resiliency to detrimental factors and, when conditions again become favorable, recover quickly from even severe damage. It is, therefore, a cause for concern that Grecian Rocks, which sits somewhat inshore of the outer reef line, has yet to recover from die-off in 1978. The slow recovery, if occurring, may be due to the lower quality of the inshore waters. The patch reefs, more adapted to inshore waters, do not show obvious stress signs, at least those surveyed in this study. It is apparent that water quality was changing in the keys. Water clarity over much of the reef tract was observed to be much reduced from former years and undoubtedly plays an important part in the stresses seen today over the Sanctuary and Park.

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AN ENVIRONMENTAL ASSESSMENT OF THE KEY LARGO NATIONAL MARINE SANCTUARY

by

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[Prepared in 1983]

1. INTRODUCTION

The Florida Keys form a crescentric chain of limestone islands extending from near Miami to Key West, a distance of about 240 km. Between the line of the Keys and the Florida Current lies an extensive shallow platform bearing scattered coral reefs, the whole known as the Florida reef tract. The reef tract has an average width of about 6.5 km.

The Florida reef tract supports a wide range of water oriented activities: boating, water skiing, sport fishing, spear fishing, scuba diving and sightseeing. Prior to 1960 the area was being despoiled by treasure hunters, commercial coral, shell and tropical fish collectors and spear fishermen (Voss, 1960). Construction work on the Keys converted natural shoreline into developed marinas, and boat channels were cut through the seagrass meadows.

In 1957, Voss proposed that an extensive area of the Hawk Channel, bank, and coral reefs seaward of Key Largo should be preserved from these depredations and, in 1960, the Pennekamp Coral Reef State Park was formed by the State of Florida and the Federal Government (Voss, 1960; Griswold, 1965). The park waters extended in the south from near Rodriguez Key to the north end of Key Largo and seaward to the 18 m isobath. In 1975, under the Marine Protection, Research and Sanctuary Act of 1972, the Federal area was extended to the 91 m isobath. The Federal preserve, now known as the Key Largo Coral Reef Marine Sanctuary, is approximately 32.2 km long and 8.05 km wide (Jameson, 1981) (Figure 1a).

To assist in the management and protection of the Sanctuary and Park fauna and flora, various studies were supported or encouraged to determine the state of the health of the coral reefs and their associates. Among these studies are Antonius (1974) on the health of the outer and middle reefs, Dustan *et al.* (1975), Dustan (1977a) on coral reef mortality, Hudson (1981) on coral growth rates, and Jameson (1981) on the deep-water environment beyond the 18 m isobath. A series of habitat maps of the area were published by Marszalek (1982).

The present study was requested by the Office of Coastal Zone Management to assess the environmental resources of the Sanctuary shoreward of the 18 m isobath and to provide a base-line study of the fauna and flora for use in management, planning and future studies. Ten reef sites within the Sanctuary and seven shallow grass and hardbottom sites within the Park were chosen for study (Figure 1b). A brief survey of earlier studies in the Florida reef tract may aid in placing the present report in perspective.

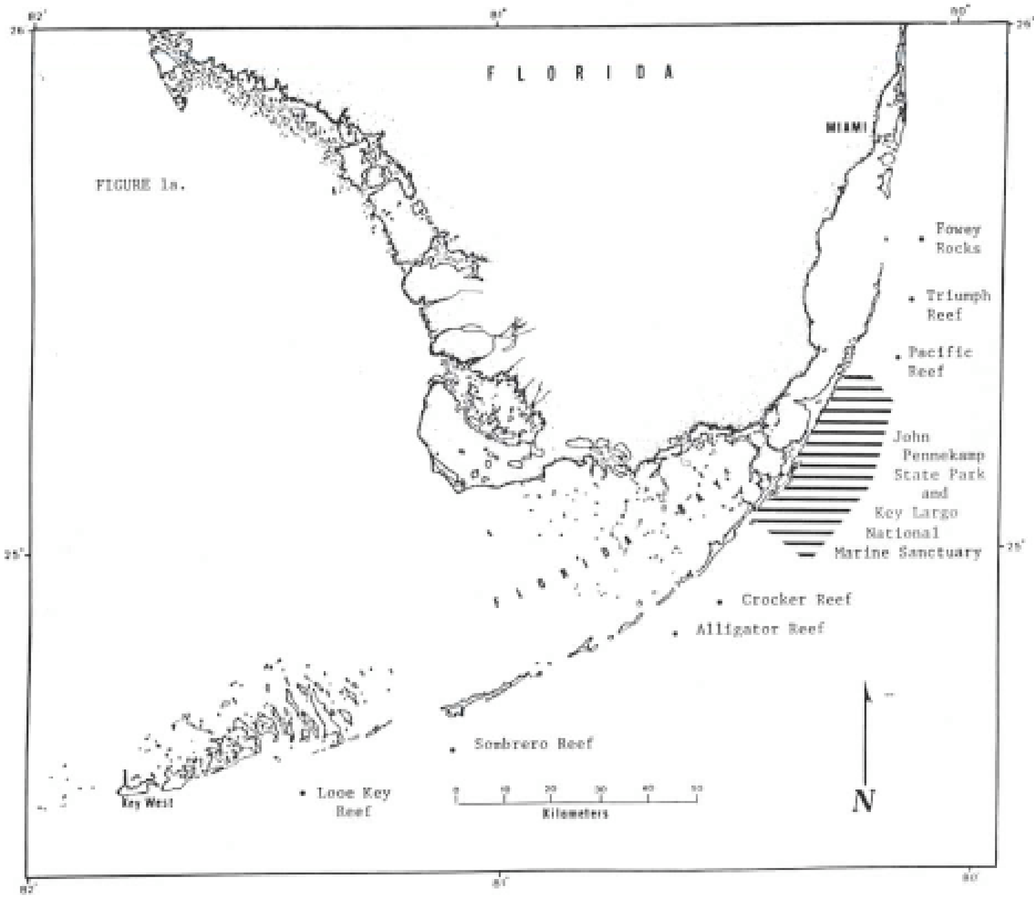

Figure 1a. Map showing the main portion of the Florida reef tract extending from Fowey Rocks off Miami 241 km southwest to Key West, and the position of the study area on the tract.

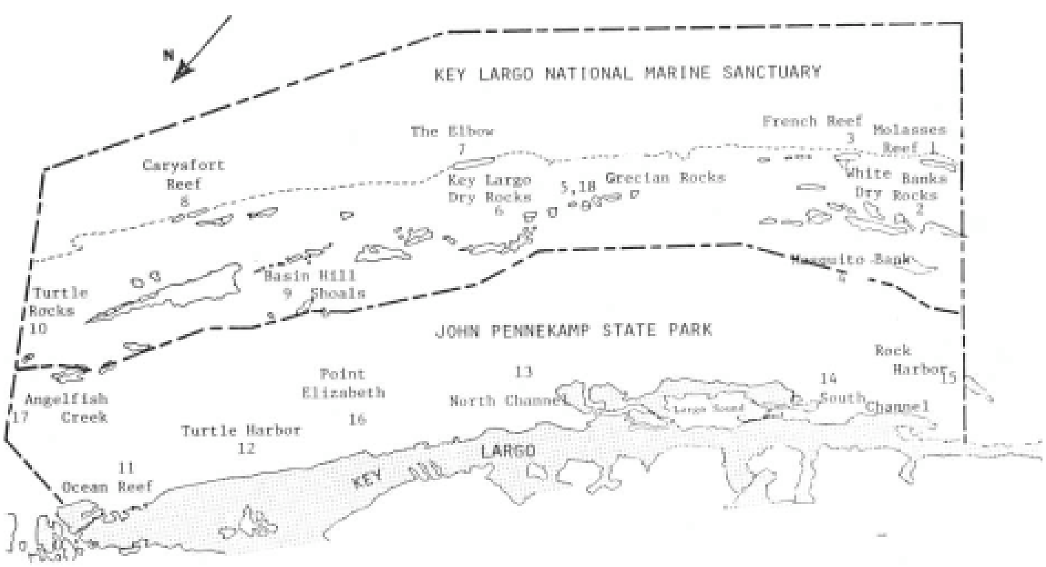

Figure 1b. Map showing John Pennekamp State Park and Key Largo National Marine Sanctuary. The number and name for each of the 17 study sites are given at the respective locations.

The Florida reefs have been described by several writers. Louis Agassiz surveyed them in 1851 (L. Agassiz, 1852 and 1880) and discussed their origins. Pourtales (1871) described and illustrated many of the corals. Alexander Agassiz (1883) published a report on the corals of the Dry Tortugas and presented a detailed map. With the founding of the Tortugas Marine Laboratory of the Carnegie Institute, the first studies of the biology of corals were initiated by Vaughan who presented data on the water temperatures of the Florida reef tract (Vaughan , 1918). A general survey of the shallow inshore waters with emphasis on the ecology was made by Stephenson and Stephenson (1950). Voss *et al.* (1969) published a detailed literature and data survey, and map of the newly created Biscayne National Monument, immediately north of the Sanctuary. Hoffmeister (1974) discussed the reef tract and stated that the Florida coral reefs have their finest development to seaward of Key Largo where they are protected by the land mass from the sediment rich waters of Florida Bay. He divided the Florida reefs into two types, (1) outer reefs on the seaward edge of the platform and (2) patch reefs or clusters of irregular coral masses located behind the outer reefs.

Hudson (1981) included Molasses Reef, French Reef, The Elbow, Carysfort Reef, Grecian Rocks and Key Largo Dry Rocks in the "offshore reefs" although strictly speaking the latter two lie within an indentation in the reef line. The remaining reefs of the Sanctuary, White Bank Dry Rocks, Mosquito Bank, Basin Hill Shoals, Turtle Rocks and the numerous small reefs unnamed on National Ocean Survey Chart 11462, are patch reefs. Hudson (loc. cit.) stated that the midshore reefs" of Basin Hill Shoals and White Bank Dry Rocks have greater water clarity than the extreme inshore reefs due to influxes of clear oceanic water from the Straits (Jones, 1963). Jones's study of Margot Fish Shoal is the only published source of water conditions in the northern part of the reef tract.

The geology and sedimentology of the reef tract have been discussed by Ginsburg (1956), Hoffmeister and Multer (1968), Hoffmeister (1974), Shinn (1963); Shinn *et al.* (1981) and Marszalek (1982).

The present reefs are growing on Holocene fossil reefs dating from about 15,000 years ago, and which also form the offshore hardbottom. The inshore hardbottom bordering the Keys is Key Largo Limestone of Pleistocene origin upon which the later fossilized coral rock and sediments lie. Ginsburg (1956) gave the composition of the reef tract sediments as fine grained carbonates and fragments of *Halimeda* coralline algae, corals, foraminifera and mollusk shells. The sediments of the outer platform area tend to be coarse while those of the lower fore reef and inshore form carbonate muds (Marszalek, 1982). The carbonate production of the coral *Diploria labyrinthiformis* was studied by Ghiold and Enos (1982). Shinn (1980) reported on the geologic history of Grecian Rocks, the only detailed study of a coral reef within the Sanctuary.

Studies of the biology of Florida reef corals have been primarily concerned with growth. Vaughan (1915) published results of work at the Dry Tortugas. He gave the growth rate of *Montastraea annularis* as 6 - 7 mm annually. He considered that this was the controlling growth of the reefs as this species formed the basis of the Florida reefs. Hoffmeister and Multer (1964) conducted growth rate studies at Carysfort Reef and found that *M. annularis* grow at a rate of 10.7 mm per year. Hudson (1981) found that this species grew at different rates according to location, 6.3 mm per year on the outer reefs, 8.2 mm per year on the inner reefs and 11.2 mm per year on the midshore reefs. He also found that the growth rate was lowest during the years of uncontrolled dredging and filling along the keys but that it increased when dredging was banned. In contrast with the slow outward growth of *Montastraea annularis,* Shinn (1966) found that *Acropora cervicornis* grew terminally at the rate of 100 mm per year.

The problem of coral reef deterioration or damage due to devastating storms and human impact has been reported by numerous investigators (Voss, 1973; Shinn, 1975; Dustan, 1977a and 1977b; Davis, 1977; Tilmant *et al.*, 1982; Antonius, 1981c; Raymond, 1981). Coral disease has been reviewed by Antonius (1981a and 1981b). Studies to assess damage, death and disease have been made by Antonius (1974), Antonius *et al.* (1978), Dustan *et al.* (1975), Davis (1977, 1982) and Tilmant *et al.* (1982). Hudson *et al.* (1976) have used coral slabbing and sclerochronology for interpreting coral growth versus environmental perturbations.

Studies of the assemblages of organisms of the reef tract are diverse. Among the most useful are Stephenson and Stephenson (1950), Voss and Voss (1955), Ebbs (1966), Kier and Grant (1965) and Voss *et al.* (1969). The last named has an extensive bibliography dealing with works on the Florida reef tract up to 1969. References to works on fishes will be found in the extensive list given by Bannerot and Schmale in the separate report on the fish census.

The present report deals with the coral reefs and the assemblages of fauna and flora found in the reef tract with the exception of fish. The latter are dealt with by Schmale and Bannerot. Their report is appended as a separate study.

2. ACKNOWLEDGMENTS

This study was funded by the Office of Coastal Zone Management, NOAA, under contract NA-79-SAC-00813. Lt. Stephen Jameson assisted in the early stages of the planning. Mr. James Stephenson, Department of Natural Resources, Tallahassee, provided collecting permits for State waters. The Superintendent of the Pennekamp Coral Reef State Park and his staff provided gear storage space at the Park headquarters and assisted the work in many ways. The staff of the Park concession was helpful in too many ways to enumerate.

Dr. Dennis Taylor, RSMAS, planned the field work and methods of analysis but left the university before field work began. Dr. Jon Staiger assisted in the early phases of the field studies. Ronald Toll was in charge of logistics during the first year, followed by Lynne Fieber. Divers on the study included the following: Fred Baddour, Scott Bannerot, Thomas Burns, Peter Bushnell, Meri Cummings, Ian Davis, Jeffrey Erickson, Charles Evans, Lynne Fieber, David Gordon, Mark Gottfried, Charlene Grall, Diane Ledder, Valery Lee, Susan Markley, John Martin, Mark Poli, Robert Riggio, Alice Russel, Edward Rutherford, Michael Schmale, Alan Schneyer, Susan Sogard, Douglas Wilson and Janet Zurschneider. The RSMAS Dive Officer, Stewart McCormick, supervised the deep dives at Molasses Reef. Dr. James Bohnsack supervised the poison stations at Grecian Rocks.

Specimen sorting was supervised by Ronald Toll who also made many of the identifications. The following persons identified or checked identifications of specimens in the laboratory: Dr. F. M. Bayer, USNM, alcyonarians and corals; Dr. James Bohnsack, CIMAS, poison station fishes; Rafael Lemaitre, crabs and shrimp; Dr. Lowell Thomas, ophiuroids; Dr. C. R. Robins, fishes; Dr. Gilbert Voss, ophiuroids and algae; Robert Work, sponges and worms. Catalogue photographs were mainly taken by John Park. Lynne Gilliss and Susan Candela assisted with data compilation.

Grateful thanks are extended to all these persons without whose help the study could not have been carried out.

[Rescue of this work in 2002 was funded through a grant of the South Florida Ecosystem Restoration Prediction and Modeling Program (SFERPM) - a competitive program conducted by the Center for Sponsored Coastal Ocean Research (CSCOR), in association with the South Florida Living Marine Resources Program (SFLMR) - for Coastal and Estuarine Data/Document Archeology and Rescue (CEDAR) for South Florida.]

3. METHODOLOGY

3.1. Field methodology

Seventeen sites were designated to be studied qualitatively and quantitatively within the Sanctuary and Park (Figure 1b). The odd numbered sites were to be worked the first year (1980) and the even numbered sites the second year (1981). One site was to be censused twice for which Grecian Rocks was chosen. Cryptic species of fish and invertebrates were to be collected by use of rotenone at selected coral sites, and reef health and anchor damage were to be assessed. A full fish census based on the Jones and Thompson (1978) method was to be made at all sites.

Field studies were delayed until late spring in 1980 due to stormy weather and turbid waters with low visibility. Work on the odd numbered sites continued through the summer until fall weather prohibited further activities. The even numbered sites were worked during the summer and fall of 1981.

At each site three parallel transects not less than 400 m long were run perpendicular to the reef or shore, each 300 m apart. The transect lines were made of braided nylon and were marked at every 5 m with red tape. Each line was equipped with anchors and buoys. On the outer reefs the transects started in 18 m depth and ran across the reef crest to the back reef in the turtle grass. In patch reefs the transects ran from sand or grass bottom across the reef to sand or grass bottom on the other side.

The first transect at each site was located in relation to a permanent structure on or near the site such as a lighthouse, navigational marker, pipe or stake, and was laid down on a compass course later converted to true course. The second and third transects were made 300 m apart on the same course.

Observations, data collecting and sampling were done by two teams of divers. The first team consisted of the photographer and an assistant who carried a 1-m^2 quadrat frame made of PVC pipe. This was laid down on the transect line at each 5 m with the meter marker in the center of the frame and the quadrat was photographed. The assistant noted on the clipboard the meter marker number and depth, the latter read from calibrated diver's depth gauge.

About 10 m behind the photographic team was the fauna and flora team consisting of an identifier and a bagger. At each marker the identifier wrote down on the clipboard the name of the animal or plant beneath the marker and the marker number. If the organism was unknown, it was collected and bagged with a label containing the number of the site, transect and meter marker. Identification aids carried aboard the boat were Greenberg's (1979 and 1980) diver's fish and coral identification cards, Smith's (1948) coral handbook, Taylor's (1972) algal manual, and Voss's (1980) invertebrate and algal guide.

Bags were collected at intervals by a person in the attending boat where camera transfer and film changes were also done.

Quantitative sampling in the various zones at each site was done by the fauna and flora team. Two 1-m^2 PVC pipe quadrat frames were linked together and one set of frames was laid down on each side of the transect line providing four 1-m^2 frames. Within each frame all of the species were identified and each specimen counted. Where possible all 4-m^2 quadrat sampling was done on the transect at points where the line crossed over the appropriate zone. In sand areas, the sand was removed to a depth of 10 cm, screened through a set of geologist's sieves, and all specimens 1 cm long or longer were retained for identification and counting. Further explanations of methodology are given in Appendix A.

All specimens were preserved in the field in 10% seawater formalin. In the laboratory they were sorted out and where appropriate changed to 70% ethanol or in the case of algae to buffered 5% seawater formalin. As identifications were received, the names were entered in the appropriate site file for transect and meter marker. Voucher specimens were catalogued into the research collections of RSMAS.

Individually selected specimens were photographed and the photographs filed for later compilation of the photographic catalogue to be deposited with NOAA.

Some discrepancies between entries in the transect list and the catalogue specimens were inevitable. Often a quickly moving animal under the marker could not be caught and was entered simply as crab, shrimp, brittle star or other general term. The meter marker was approximately 2-cm broad and offered no problem with the average specimen. When the marker rested upon a small piece of rubble covered with sessile organisms, the piece of rubble was collected and all of the species attached to it were listed. The first species listed was arbitrarily selected as the one species under the marker for analysis purposes.

While the contract called for identification to species of all algae, this was often not possible because of the condition of the specimen, such as time in preservative, maturity of the plant, lack of seasonal fruiting bodies, or insufficient material. This primarily was a concern in small red and blue-green algae and corallines.

Identification of worms, both polychaetes and sipunculids, often proved difficult and many could only be taken to family. Many of the worms were fragmented or so contracted in preservation that critical characters were obscured. Some worms need relaxing and the use of special preservative techniques not possible in general field work, and require the attention of a specialist. Further discussions on survey problems are given in Appendix A.

Coral Health. Two methods of recording coral health were used. The first was by observation of the amount of white area on each coral under the marker as done by Antonius (1974). Observations at each 5-m marker afforded too few data points and this method was dropped. At each 5-m, a photograph was taken of a 1-m^2 area. These photographs provided many more corals on each transect and careful scrutiny by hand lens and screen projection permitted observation of white areas and estimates of percentage of cover. This method was adopted for analysis. Antonius used an "all or nothing" method in which if a coral had 50% or more of its surface bare of tissue and uneroded it was considered to be "dead"; a coral with less than 50% white area was considered to be "live". While this method was used for comparisons with Antonius' 1974 findings, the number of corals with less than 50% white areas as well as the number with no white spots were recorded.

Seagrass health. Seagrass health estimates are subjective at best. In this report only turtle grass, *Thalassia,* is considered. Health of turtle grass is indicated by the general condition of the grass blades. length, width, color, erectness of blades, and amount of *aufwuchs* or sessile growth on the blades, especially filamentous algae. As some of these characters may change seasonally, care must be taken in their use. However, as the grass areas were surveyed in summer and fall, comparisons between sites should be of value. In this report, mature turtle grass beds are those in which only turtle grass was present. Where manatee grass was mixed or occurred in large patches, it was considered that the area was possibly under stress or recovery from turtle grass loss. Areas were considered "lush" when the turtle grass completely covered the bottom and the blades were long and broad.

Anchor and boat damage. No general survey of the reefs was made, thus observations on boat and anchor damage depended upon the observations made by the divers in both the transect and fish census studies. Few indications of damage were seen such as broken coral or gashes made by keels or propeller blades.

Fish census. The fish census was conducted separately from the transect and quadrat work in order to have less disturbance of the fish populations. The methodology required was the space, time technique of Jones and Thompson (1978). Because it does not take bottom type into consideration, the data could not be incorporated into zone descriptions. The full methodology is described in the separate fish census report by Bannerot and Schmale.

Poison stations. A 2.1-m radius cast net with a stretched mesh of 12.5 mm was lowered over the area to be sampled, except at station 4. The net was not used at that station to avoid excessive damage to the corals. Approximately 0.5 L of pure liquid rotenone (without synergistic agents) was applied to the sample area. Attempts were made to collect all specimens that appeared to be affected by the poison. Four SCUBA divers were used for specimen collecting.

Transect profiles. The base lines of the pictorial profiles were drawn from the diver depth gauge data. The organisms illustrated were taken directly from the 35 mm color transparencies shot at each 5 m along the transect line. A key to the symbols used is given in Figure 2.

Metric conversions. Depth readings from diver gauges and lead line were recorded directly in feet. When converted to meters they were rounded to one decimal place as the use of two decimal places infers a precision greater than the field measurements a common error seen in conversion figures.

Statistical analyses. Species diversity was estimated as H' in the Shannon Weaver equation

$$H' = -\sum P_i \log_e P_i \text{ where } P_i \approx \frac{n_i}{n}$$

n_i is the number of individuals of the i^{th} species, N is the total number of individuals in the community.

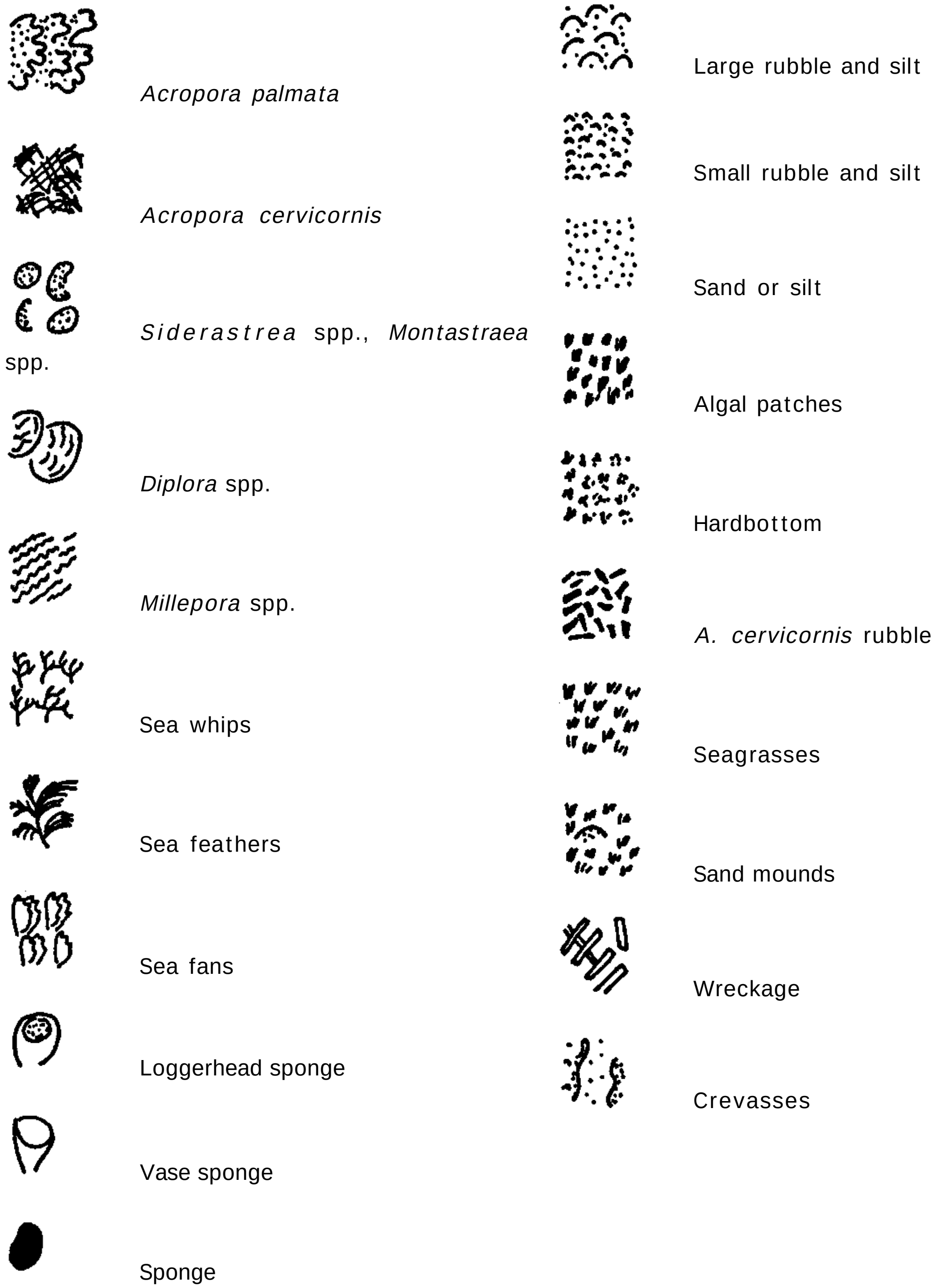

Figure 2. Key to symbols used in pictorial transect profiles.

3.2. Description of the Study Area

The section of the Florida reef tract surveyed in this report is shown in Figures 1a and 1b. It includes the waters of the Pennekamp Coral Reef State Park and the Key Largo Coral Reef Marine Sanctuary. The present study covered only sites within the 18 m isobath indicated in the figure by a dotted line. Table 1, modified from Bannerot and Schmale (this volume), lists the sites by name and number, habitat and type and amount of use. The data on distances, depths and locations are taken from National Ocean Survey Chart 11462.

About two thirds of the combined Sanctuary and Park lies within the 18-m isobath. The area seaward to the 91-m isobath has been studied by Sanctuary personnel (Jameson, 1981). Within the 18-m isobath, water depths of 4.5 to 7 m predominate with numerous hardbottom and coral outcrops several of which are awash at extreme low tide: Molasses Hump, White Bank Dry Rocks, and Key Largo Dry Rocks.

The bottom within the area is very diversified as shown by the habitat map prepared by Marszalek (1982) from aerial surveys. As much as 75% of the bottom may be classified as turtle grass cover which maintains a distinctive faunal and floral community. The second major bottom type is calcareous sands and sediments comprising perhaps another 10% of the bottom. The remaining 15% of the bottom is formed of hardbottom.

A dominant feature of the Sanctuary is the shoal sedimentary bank formation known as White Bank which extends from just inshore of Molasses Reef northeastward terminating at Turtle Rocks near the northeastern extremity of the Sanctuary. It is discussed briefly by Shinn (1980). Many patch reefs are located on White Bank.

Growing on the offshore fossil reef rock are the living coral reefs of the Sanctuary. Marszalek's maps do not distinguish the living coral reefs and their area, but within the 18-m isobath approximately 5% of the bottom may be characterized as living coral reefs, the main subject of this study. When it is considered that the best developed coral reefs of the Florida reef tract are found seaward of Key Largo (Hoffmeister, 1974) and that the Florida reefs are the only shallow water coral reefs in the continental waters of the United States, the importance of the Sanctuary to their protection and preservation becomes clear.

The classification of the Sanctuary reefs is somewhat confused. Hoffmeister (1974), following local usage, divided the reefs into "(1) outer reefs, which form at the seaward edge of the platform", and "(2) patch reefs, which are found behind the outer reefs in the back reef zone". He gave Key Largo Dry Rocks and Carysfort Reef as examples of the first, and Mosquito Bank as an example of the second. Hudson (1981) divided the reefs into: inshore reefs, such as Basin Hill Shoals and Mosquito Bank; midshore reefs, those lying on White Bank; and offshore reefs, those lying seaward of White Bank. Bannerot and Schmale (this volume) use: offshore reefs for Carysfort, the Elbow, French and Molasses reefs; intermediate reefs for White Bank Dry Rocks, Grecian Rocks and Key Largo Dry Rocks; and inshore patch reefs for Basin Hill Shoals, Mosquito Bank, Turtle Rocks and Angelfish Creek. Nonetheless, it is often convenient to speak of the reefs in reference to their location within the Sanctuary as outer, middle and inner reefs.

In the present study Hoffmeister (loc. cit.) is followed. Carysfort Reef, Key Largo Dry Rocks, Grecian Rocks, the Elbow, French Reef and Molasses Reef are considered as outer reefs. Angelfish Creek, Turtle Rocks, Basin Hill Shoals, Mosquito Bank and White Bank Dry Rocks are patch reefs.

Table 1. (Modified from Bannerot and Schmale) List of study sites by number and name with habitat type and approximate extent and type of usage by visitors. Habitat definitions are (1) offshore reef (OR) - a major aggregation of scleractinian corals occurring on a contour approximately 6 km offshore defined by the outermost lighthouses on the Florida reef tract; (2) patch reef (PR) - an aggregation or group of various sized aggregations of scleractinian corals usually at least 2 km inshore of the outer reef line; (3) turtle grass (TG) - an area dominated by turtle grass, *Thalassia testudinum*, bottom; (4) hardbottom (H) - bedrock areas featuring numerous octocorals, various sponges, and encrusting and small head scleractinian corals. The term "diving" includes non-consuming recreational SCUBA and snorkeling, the only consumptive usuage being the taking of lobsters in season. "Fishing" refers only to hook and line fishing, most of which is recreational (spearfishing and fish traps are illegal in both conservation areas). Boat traffic is only considered for turtle grass or hardground sites less than 4.9 m depth where bottom disturbance from wakes and prop turbulence is most noticeable. The extent of the various activities are strictly subjective impressions obtained by one of the authors during 6 years of diving experience in the area and by both authors during the course of the study (no quantitative data such as boat counts were obtained on a regular basis). H = heavy usage, M = moderate usage, L = light usage, 0 = very little or no usage.

				Approx. Extent and Type of Usage		
Site No.	Name	Habitat	Depth Range of Fish Census (m)	Diving	Fishing	Boat Traffic
1	Molasses Reef	OR	3.1 - 12.8	H	M	
2	White Bank Dry Rocks	PR	0.6 - 7.6	M	L	- - -
3	French Reef	OR	4.0 - 13.7	H	M	- - -
4	Mosquito Bank	PR	0.9 - 4.6	L	M to L	- - -
5	Grecian Rocks	OR	0.3 - 9.1	H	L	- - -
6	Key Largo Dry Rocks	OR	0.6 - 10.7	H	L	- - -
7	The Elbow	OR	2.4 - 9.1	H to M	M	- - -
8	Carysfort Reef	OR	4.6 - 15.2	M	M to L	- - -
9	Basin Hill Shoals	PR	0.2 - 2.4	L	L	- - -
10	Turtle Rocks	PR	4.6 - 6.1	L	L	- - -
11	Ocean Reef	TG	3.1 - 3.7	0	0	- - -
12	Turtle Harbor	TG	3.7 - 4.7	0	0	L
13	North Channel	TG/H	2.7 - 4.3	0	0	M
14	South Channel	TG/H	4.0	0	0	H
15	Rock Harbor	TG	2.4 - 3.4	0	0	H to M
16	Point Elizabeth	TG/H	4.0 - 4.6	0	0	L
17	Angelfish Creek	PR	3.1 - 5.8	L	L	- - -

3.3. Outer Reefs

On the basis of their geologic history, the outer reefs are often termed bank reefs (Shinn, 1963) while in their functional aspect they are termed barrier reefs (Ginsburg, 1956). As Ginsburg stated, while they are barrier reefs, they are of little individual extent, have wide, nonreef areas between them and are only somewhat more consolidated within the Sanctuary and northward to Fowey Light.

From northeast to southwest the outer reefs are Carysfort, The Elbow, Key Largo Dry Rocks, Grecian Rocks, French Reef and Molasses Reef. With the exception of Key Largo Dry Rocks, all of the reefs are located on the edge of the bank about 8 - 9 km from shore and are bordered seaward by the Florida Current. The fore-reef slope is rather steep and the 18-m isobath is located within only a few hundred meters of the reef crest.

Below the 19-m isobath, the bottom drops off in terraces of calcareous sands, deep coral reefs, coral rubble, deep hardbottom and finally to the outer platform of calcareous sand extending outward to the edge of the canyon of the Straits of Florida. The deep coral reef lies between about 30 to 40 m depth. This reef is composed predominantly of *Montastraea* and alcyonarians. This area has been surveyed and reported upon by Jameson (1981) working from a submersible.

Carysfort Reef is perhaps the best developed of the outer reefs and is more characteristically Caribbean in its zonation. The fore reef is terraced. There is a crustose coralline algal ridge, an *Acropora* crest, and well-developed back reef (Jones and Thompson, 1978), but it lacks developed spurs and grooves. According to Bannerot and Schmale (this volume), there is an extensive *Acropora cervicornis* thicket at approximately 14 m. The reef is marked by Carysfort Lighthouse.

The Elbow lies on a separate small shoal surrounded, except seaward, by waters not less than 8 m deep, and is several kilometers from the nearest part of White Bank. It has an extensive back reef rubble area, a limited *Acropora* crest and well-developed spurs and grooves with large *Montastraea* heads.

French Reef has been described by Jones and Thompson (1978). The spur and groove system is composed mainly of *Montastraea annularis* rather than *Acropora palmata* and the spurs are often interlaced with cavernous passages.

Molasses Reef has been described by Jones and Thompson (1978) and Shinn (1963). It has an extensive back reef rubble area, a few live *Acropora* colonies but an extensive old *Acropora* spur and groove system with *Montastraea* on the reef slope. The offshore deep reef was not surveyed by Jameson (1981). The fore reef slope levels off onto a sand terrace at about 14 m.

Key Largo Dry Rocks and Grecian Rocks, set back from the edge of the bank by over 1 km, is located in a long break in the outer reefs between the Elbow and Dixie Shoal. The bottom seaward of the reef slope is only about 7 - 9 m deep and composed of calcareous sand.

Grecian Rocks has been well described by Shinn (1963, 1980). It is over 700 m long and 200 m wide. Although located behind the outer reef line, it exhibits well defined spurs and grooves, a terraced reef slope, an *Acropora* crest, reef flat and rubble back reef (Shinn, 1980).

Key Largo Dry Rocks is situated only a little over 1 km to the northeastward. It rises abruptly from the bottom with large fields of *Acropora palmata* and *A. cervicornis* and has a large back reef rubble area.

None of the outer reefs are much more than 1 km long and 5 km wide, with even a lesser extent of living coral.

3.4. Patch Reefs

The named patch reefs within the Sanctuary are Turtle Rocks, Basin Hill Shoals, Mosquito Bank and White Bank Dry Rocks. The patch reef called Angelfish Creek in this study is not named on the chart.

All of the patch reefs consist of patches of corals and coral associates surrounded by turtle grass, and rise from depths of only 3 to 4.5 m. Basin Hill Shoals consists of a series of coral patches extending for a distance of some 4 km. It is the largest series of patch reefs in the Sanctuary. There is no distinct zonation on the patch reefs although some of the larger coral patches have extensive rubble areas, especially in the central portion of the patch.

White Bank Dry Rocks, although located further offshore, is similar to the other patch reefs although somewhat more consolidated. It shares none of the outer reef features despite its more seaward position.

3.5. Turtle Grass and Hardbottom

Six of the sites were inshore of the Sanctuary on seagrass meadows or low hardbottom bars. The locations of the sites were chosen to represent areas of heavy to moderate, or nearly no boat use. Sites at Ocean Reef, Turtle Harbor and Rock Harbor were on turtle grass meadows. Sites at Point Elizabeth, North Channel and South Channel were mixed turtle grass and hardbottom.

The hardbottom at these inshore sites was formed of low, flat rock bars of Key Largo Limestone. Where this limestone is exposed, it supports a fauna of sponges, alcyonarians, and corals as well as rock dwelling algae.

Four of the inshore sites have considerable boat traffic. In increasing order they are (1) Ocean Reef located off the Ocean Reef Club and its marina, (2) North Channel with considerable yacht and commercial traffic out of Largo Sound and Garden Cove Marina, (3) Rock Harbor with boat traffic out of the several marinas in the area and (4) South Channel which bears the traffic from Pennekamp Park Marina and Largo Sound.

The sites at Point Elizabeth and Turtle Harbor were chosen as representing areas with very little boat traffic and which could therefore be used for comparison with areas of heavy use.

4. RESULTS

4.1. Site 1. Molasses Reef

Molasses Reef lies on the outer edge of the reef line approximately 5.5 nautical miles off Key Largo. It is composed largely of coral rubble of which the highest point, "Molasses Hump," is exposed on low spring tides. The reef crest has extensive growths of alcyonarians but few live corals. It appears similar to conditions 50 years ago.

Three transects were made across the reef, all about 600-m long on headings of 308° true (Figure 3). The reference point for the transects is the iron pipe just back of the reef and northeast of the light. Transect 1 ended at the pipe. Transect 2 was parallel to Transect 1 and 300 m west. Transect 3 was 300 m to the east.

Transect 1 (Figure 4.1) was about 625 m long and extended from 16 m depth shoreward to the pipe on the reef flat. The first 60 m was hardbottom with rubble and a thin layer of white sediments. The fauna was primarily low scattered colonies of alcyonarians, sea feathers and sea whips, and occasional small colonies of finger corals, *Porites,* and star corals, *Montastraea*. At about 225 m, the reef face rose upward to about 5 m depth over a distance of about 50 - 75 m. This area was covered with small clumps of elkhorn coral, *Acropora palmata*, sea feathers, and numerous sea fans, *Gorgonia ventalina*. At about 280 m, the reef contour dipped a few meters and then rose to the reef flat at a depth of about 3 - 4 m. From about 300 to 450 m, the bottom was formed of large rubble with silty sand. This rise was covered with sea fans and occasional large bushy sea feathers but in the last 50 m the sea fans and sea feathers were small and poorly developed. The remaining 150 m of the transect was over seagrass beds. A few large vase sponges were seen in the area.

Transect 2 (Figure 4.2) began in 17.5 m depth and was about 525 m long. The bottom for the first 200 m was mainly hard with much rubble and occasional small sand patches. This area was very similar to that in Transect 1 but sponges, alcyonarians and small coral colonies were much more numerous. Vase sponges were conspicuous, scattered sea fans occurred below their usual 7 to 9 m depth, and stinging corals were found in patches. There were occasional small colonies of finger corals, *Porites,* and brain corals, *Meandrina,* and one colony of *Stylaster roseus* was seen. At 200 m, the contour dipped about 3 m and the bottom was clean sand followed by numerous small rubble until the reef crest was reached at about 250 m. The crest of the reef consisted of hardbottom and rubble with numerous sea fans, feathers and clumps of a bushy red alga. At about 310 m, the bottom was covered with small rubble in which were small sea feathers and sea fans. At about 460 m, the bottom flattened out in about 8 in depth and was formed of densely packed stag horn coral, *Acropora cervicornis,* rubble with scattered dwarfed alcyonarians. As there is now very little live staghorn coral on Molasses Reef, this rubble may have come from a more luxuriant growth in earlier times.

Transect 3 (Figure 4.3) began in 16.5 m depth and for the first 75 m was over a rather smooth rubble bottom with a thin veneer of silt. It supported a sparse growth of sponges, alcyonarians and algae. At about 75 m the bottom changed abruptly to a clean grayish white fine sand with only a few scattered small sea whips and an occasional small *Porites*. This continued to about 200 m where a little small rubble appeared, patches of red alga *Galaxaura* and small balls of a green filamentous alga. The bottom trended upward with slightly increasing surface growth until at 425 m, at a depth of about 7 m, a ridge of scattered, poorly developed elkhorn coral, *Acropora palmata,* occurred for about 50 m. From 475 m, shoreward the bottom continued to shoal with rubble and sand and scattered small sea fans, sea feathers and sea whips.

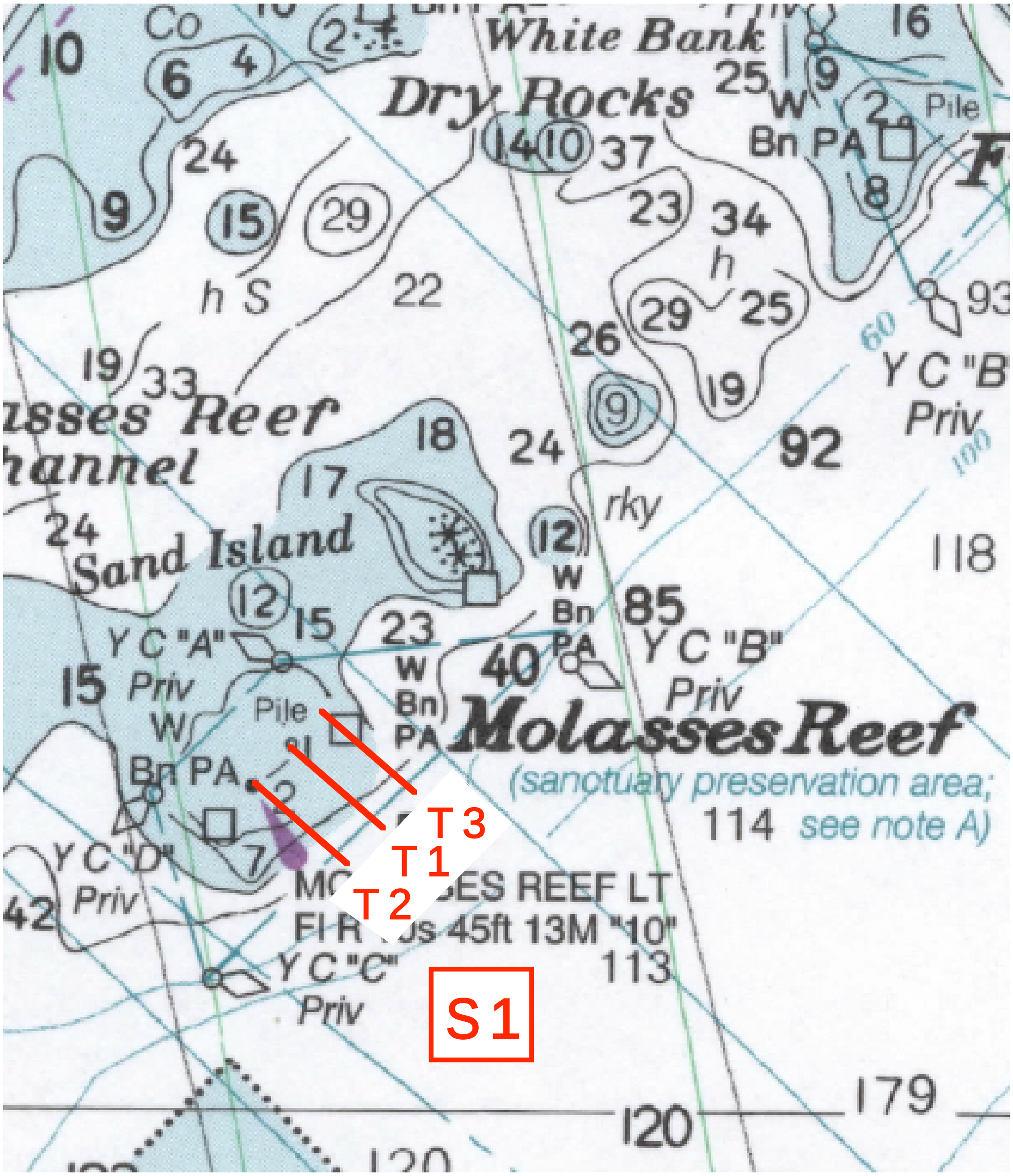

Figure 3. Location of transects. Site 1. Molasses Reef (National Ocean Survey Chart 11462).

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Figure 4. Pictorial transect profiles. Site 1. Molasses Reef.

In general the seaward side of Molasses covered by the transects can be bottom on which are found green and red algae, scattered alcyonarians and vase sponges. A band of elkhorn coral, *Acropora palmata* and sea fans is found on the reef face at about 7 - 9 m depth and across the top of the reef. Although not encountered on the transects, the reef crest also had numbers of the common star coral, *Montastraea annularis,* and other stony corals. Shoreward of this crest is a broad reef flat formed of large rubble and numerous sea fans. Seagrasses grow close to the reef on the shoreward side.

At this site three additional transects were made in 1981 (see Appendix A, site 19) extending from about 19 m depth downward and offshore to a depth of about 30 m. Comparing the profiles with those of Jameson (1981) at French, the Elbow and Carysfort reefs, the area covered was along the upper reef slope shown as a blank area on Jameson's pictorial profiles.

The three Molasses Reef profiles are very similar. Each transect was 60 m long up the slope face. Thus the horizontal distance was somewhat shorter. Within this distance the slope rose approximately 12 m.

The slope is formed of hardbottom, sand and mixed large and small rubble, with many open clear spaces. Growing on the slope were large, scattered colonies of *Montastraea* and other head forming corals, some small patches of *Acropora cervicornis,* sponges of which the most prominent were large *Xestospongia muta* and *Agelas* sp., numerous large sea feathers and fans, and patches of green, brown and red algae.

It is probable that at the base of this slope at about 30 m depth, the bottom flattened out in a sand terrace before turning downward again in the deep reef zone.

4.2. Site 2. White Bank Dry Rocks

White Bank Dry Rocks consists of a cluster of patch reefs and slightly elevated areas of hardbottom surrounded by an extensive area of turtle grass meadow. It lies well back from the outer reef margin, but because of its low profile it hardly warrants being termed a true lagoon patch reef.

Because of its highly irregular formations and clustering, transects across White Banks do not show profiles that parallel each other as on a single reef entity. Three 400-m transects (Figure 5) were run shoreward from the outer edge of the bank on headings of about 298° true.

Transect 1 was the northeasternmost (Figure 6.1). It started at a depth of 9.5 m and for the first 165 m shoaled to about 8 m depth. The first 165 m was rather smooth and consisted of turtle grass beds. In some areas these were dense. In others the plants were sparse with areas of silty sand. Small amounts of manatee grass are present as well as scattered plants of the calcareous alga, *Halimeda incrassata,* and the shaving brush alga, *Penicillus capitatus*. There were few sponges. From 165 m to 253 m, the bottom shoaled to a depth of about 3 m. From the turtle grass area to the top of the rise, the bottom consisted of cemented rubble, loose rubble, and sand. This section was dominated by various alcyonarians, mainly sea feathers, *Pseudopterogorgia*, sea whips such as *Muriceopsis*, and corals, *Siderastrea*. At the top of the reef in 3 - 4 m, the gorgonian zone was reached. This is characterized by numerous colonies of sea fans, *Gorgonia ventalina,* patches of staghorn coral, *Acropora cervicornis,* stinging coral, *Millepora,* and the brown alga, *Stypopodium zonale*.

At about 335 m, the depth increased slightly and the bottom was again covered with turtle grass for about 40 m. The transect ended in about 25 m on hardbottom formed of rock, small rubble, small colonies of the starlet coral *Siderastrea*, sponges, and sea whips.

Transect 2 (Figure 6.2) began in 5.4 m depth on the offshore edge of a well developed patch reef that rose to a depth of about 3 m across the top. The first 25 m was composed of patches of staghorn coral *Acropora cervicornis*, sea whips, and sea fans. This continued for 125 m with occasional large heads of common star coral *Montastraea annularis*, finger corals *Porites,* and starlet coral *Siderastrea siderea,* stinging corals, sea feathers and sponges.

At about 125 m and for the next 35 m, the transect crossed a patch of large common star coral, *Montastraea annularis,* forming a patch reef. Beyond this point the transect crossed over a thick turtle grass bed with manatee grass, the calcareous alga, *Halimeda*, sea biscuits and occasional mollusks. At about 350 m another patch of low hardbottom and rubble occurred with low colonies of staghorn coral *Acropora cervicornis*, *Pseudopterogorgia*, *Gorgonia* and corky sea fingers *Briareum asbestinum*. The transect ended in turtle grass near the 400 m marker.

Transect 3, the southwestern transect, started in 8.5 m on a small area of hardbottom in the midst of a turtle grass bed (Figure 6.3). It contained a few sponges and small sea whips. The meadow extended for about 145 m where the bottom rose to a depth of 3 m which was maintained for the remainder of the transect. The top of the reef was composed of large, extensive patches of staghorn coral *Acropora cervicornis,* sea whips, and occasional large heads of the common star coral *Montastraea annularis,* and starlet coral *Siderastrea* siderea. At about 175 m sea fans became conspicuous as usual at this depth and exposure. The bottom was rocky, hard, with cemented and loose coral rubble and scattered sand patches.

The reef ended at about 375 m in the usual turtle and manatee grass meadow.

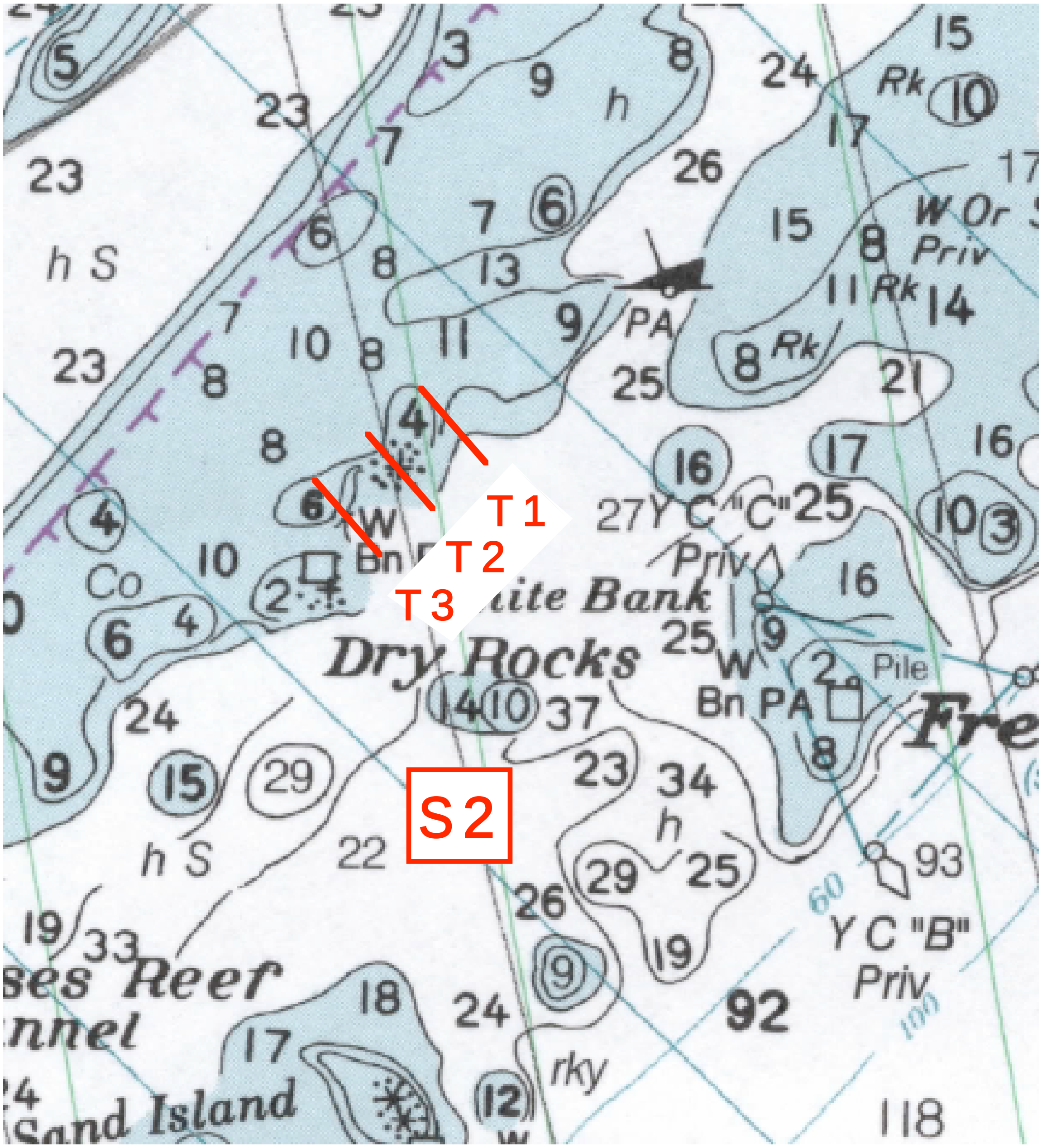

Figure 5. Location of transects. Site 2. White Bank Dry Rocks (National Ocean Survey Chart 11462).

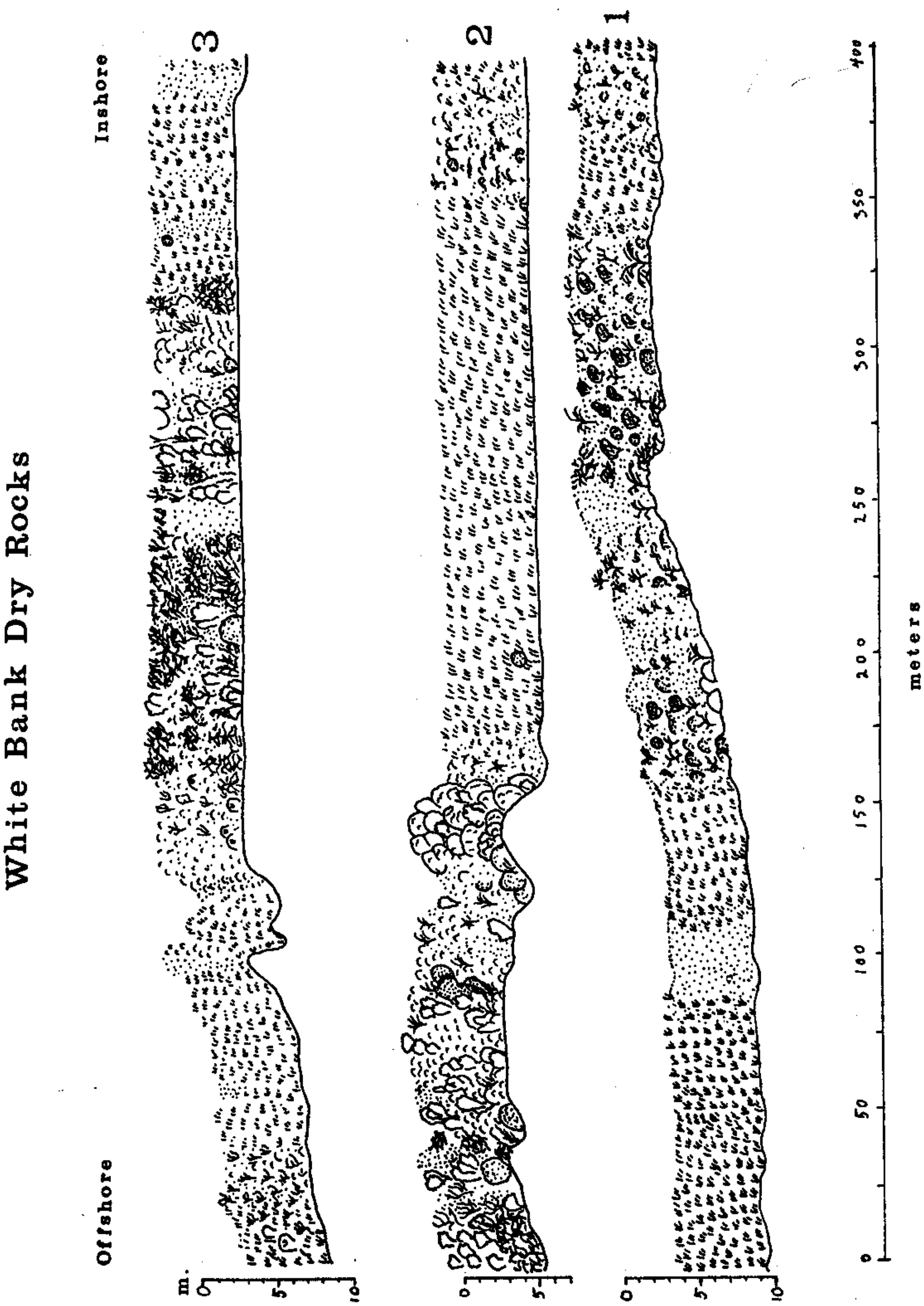

Figure 6. Pictorial transect profiles. Site 2. White Bank Dry Rocks.

4.3. Site 3. French Reef

French Reef lies 5.7 nautical miles directly offshore of the south entrance to Largo Sound. It is on the edge of the drop-off into the Straits of Florida and is bathed by the edge of the Florida Current. Despite its offshore position, French Reef has little live coral growth and, like Molasses, is primarily formed of coral rubble on an old coral reef base.

Three transects, one of over 700 m, were run at this site (Figure 7). The base line transect, Transect 1, was run on a heading of 308° true and at 495 m passed immediately by the piling or stake on the reef flat shown on the chart. Transect 2 was run parallel to Transect 1, 300 m to the southwest, while Transect 3 was 300 m to the northeast. It is difficult to relate the three transects. Transects 1 and 2 have similar profiles for about the first 250 m. The profile for 3 is very different and one could consider that the offshore end of Transect 3 might be compared with the area at about 100 m on the other two. The difference is probably due to the small size of French Reef.

Transect 1 (Figure 8.1) began in 18.5 m depth on a hardbottom with star corals, *Montastraea,* sponges, small alcyonarians, and algae. This broken, partially-rubble bottom with sea feathers, sea whips, tube sponges and corallines slowly shoaled to 14 m depth on a ridge 75 m from the start. Here the bottom dropped sharply away for about 3 m and then shoaled again to 7 m depth to a rather narrow ridge. The bottom from the first ridge to the second, was sediment-covered flat rock with scattered sponges, stinging coral and small sea whips and sea fans. A few scattered heads of starlet corals, *Siderastrea,* and finger corals, *Porites,* were seen. A few small patches of staghorn coral, *Acropora cervicornis,* were noted. Loggerhead sponges were common. The bottom up the slope was smooth rock with some rubble most overlaid with white calcareous sand.

At 180 m, the crest of the second ridge rose to within 7 m of the surface. It was covered by large sea fans, *Gorgonia ventalina,* and patches of elkhorn coral *Acropora palmata,* and large heads of common brain coral *Diploria strigosa.* The ridge dropped away by 4 m to a white sand bottom with scattered patches of *Agaricia, Porites* and stinging coral, and some rubble with bushy red algae.

At about 215 m, another irregular ridge occurred that was covered with sea feathers and small coral heads. It was topped at 250 m by another area of elkhorn coral *Acropora palmata*. This area was followed by a wide expanse of calcareous sands that shoaled slowly to rubble bottom with alcyonarians and occasional sponges, followed by other areas of sand. The crest of the reef was reached at about 425 m, and for the next 100 m there was rubble, scattered sea feathers and numerous sea fans. About 50 m beyond the stake, the bottom changed to small rubble, few scattered and stunted sea whips and small patches of algae. Most of the rubble in this area was formed of old sections of elkhorn coral, *A. palmata*.

Transect 2 (Figure 8.2) began in 16.8 m depth on hardbottom overlaid by calcareous sand and old coral rubble. The first 60 m was covered by heads of *Montastraea annularis,* tube sponges and sea feathers. At about 60 m the bottom fell away to open sand and rubble. The bottom then shoaled slowly to about 7 m depth at 175 m distance. The bottom changed to rubble with patches of red and green algae, a few small coral heads, occasional sponges and small whips. At about 175 m the second ridge was formed of rubble with some sea feathers and patches of algae, especially long streamers of Gulf weed, *Sargassum*. The bottom then changed to small rubble, dipped downward 4 m depth and then rose again. The raised area at about 215 m was the reef crest, and from 235 to 300 m it was covered with sea feathers, sea whips and sea fans on a flat rubble bottom. At about 300 m, the alcyonarians thinned out, and the bottom was flat with small coral heads, occasional small stunted sea whips, and patches of red and green algae.

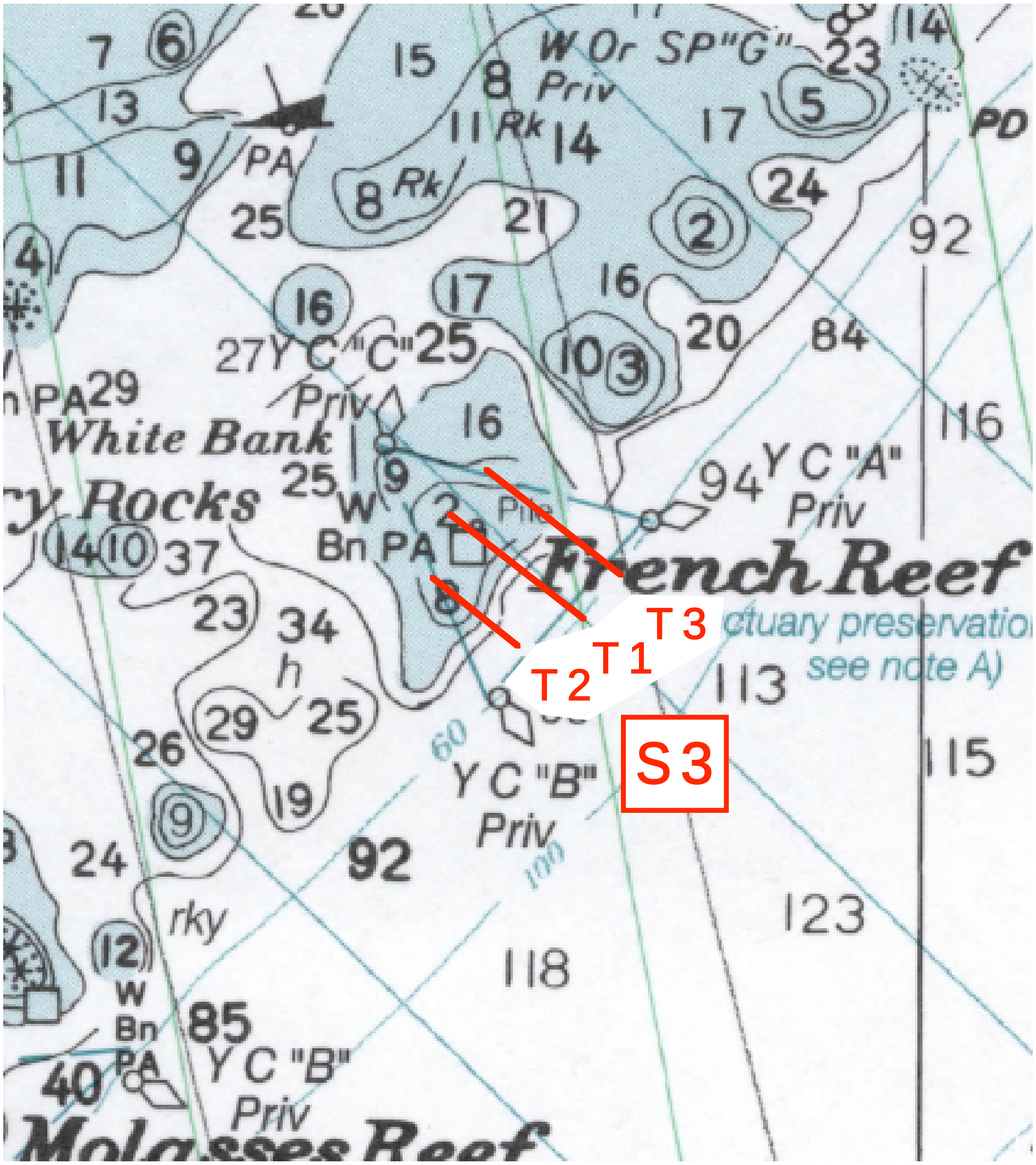

Figure 7. Location of transects. Site 3. French Reef (National Ocean Survey Chart 11462).

Figure 8. Pictorial transect profiles. Site 3. French Reef (cont. on next page with an overlap in case the figure needs to be reassembled). [Continued on following page.]

Figure 8. Pictorial transect profiles. Site 3. French Reef (cont.).

Transect 3 (Figure 8.3) began in 15 m depth on hardbottom. The first 95 m was flat, covered with rubble, scattered coral heads of starlet corals, *Siderastrea,* sea feathers and Gulf weed, *Sargassum.* At about 60 - 65 m, the bottom changed to large rocky areas with large coral heads and large bushy sea whips. This continued to the base and up the walls of the rise at 85 m. On top of the rise for the next 500 m the bottom was nearly flat, shoaling slowly from 12 to 4 m depth. Throughout this area the bottom was hard rock overlaid by calcareous sediments and small rubble. A few small patches of staghorn coral, *Acropora cervicornis,* occurred at about 100 - 125 m. Beyond this, the only corals were small heads of *Favia*, *Porites* and *Siderastrea,* a few small scattered sea feathers and sea whips, sea fans and scattered sponges.

At 625 m, the bottom rose again to between 1 - 3 m depth and for the first 50 m numbers of sea fans, *Gorgonia ventalina,* were noted. Beyond this the bottom became filled with fine small rubble and slowly tapered off into seagrasses.

The three transects each started at about 18 m depth on hardbottom with *Montastraea,* sponges, alcyonarians and algae. As the bottom to seaward shelves downward, the hardbottom gives way to a terrace covered with calcareous sand. At about 28 m, the Deep Coral Reef begins and extends downward to about 45 m where the lithothamnion cobble zone occurs. Jameson (1981) stated that the deep reef is continuous with the shallow reef but neither his pictorial profile nor depths agree and show the two reefs separated by a broad area of bare sand. The reef face contour is much more irregular than is indicated in Jameson's Figure 13.

4.4. Site 4. Mosquito Bank

Mosquito Bank is located directly offshore of the town of Key Largo in the middle of the bank southeast of the south entrance to Largo Sound. It is marked by a lighted beacon "35." On the east is a 6 m deep, white sand channel separating White Bank from the shallow inshore bank covered by seagrass.

Three 400-m transects were run on a heading of about 303° true across the bank and 300 m apart. Transect 1 was the northeastern, Transect 2 the middle and Transect 3 the southwestern one (Figure 9).

Transect 1 (Figure 10.1) started in 3.7 m depth in seagrass. At about 75 m, the bottom shoaled to 1.8 m depth on a hardbottom ridge or bar occupied by scattered starlet coral, *Siderastrea,* finger coral, *Porites,* stinging coral, sea feathers, sea whips and sponges. At 110"m, the bottom dropped off to 3.7 m depth in beds of turtle grass and manatee grass. These continued to the end of the transect. The fauna and flora were typical of seagrass habitats.

Transect 2 (Figure 10.2) started in 2.7 m depth on a ridge of hardbottom among rubble, sea feathers and sea whips. At 25 m, the bottom deepened to around 4 m in seagrass for 175 or so meters. At 235 m, another low hardbottom bar was crossed. It was covered by starlet coral, *Siderastrea*, brain coral, *Colpophyllia,* and sea feathers and sea fans. At about 270, m the bottom was again covered by seagrass and remained so to the end of the transect.

Transect 3 (Figure 10.3) also began on a bar in 3.4 m depth. The first 5 m was over sand and rubble with sea feathers and whips. From 6 m to 210 m, the bottom was covered by seagrasses and their associated fauna. At 210 m, another bar was crossed. This had starlet coral, *Siderastrea,* star coral, *Dichocoenia,* and finger coral, *Porites,* stinging coral, sea feathers and sea whips, various sponges and red and green algae. At 250 m, the transect crossed over seagrass meadows and continued so to its end.

Unfortunately, part of the film of both transects 2 and 3 was exposed and photos are unavailable for the inshore parts of both transects.

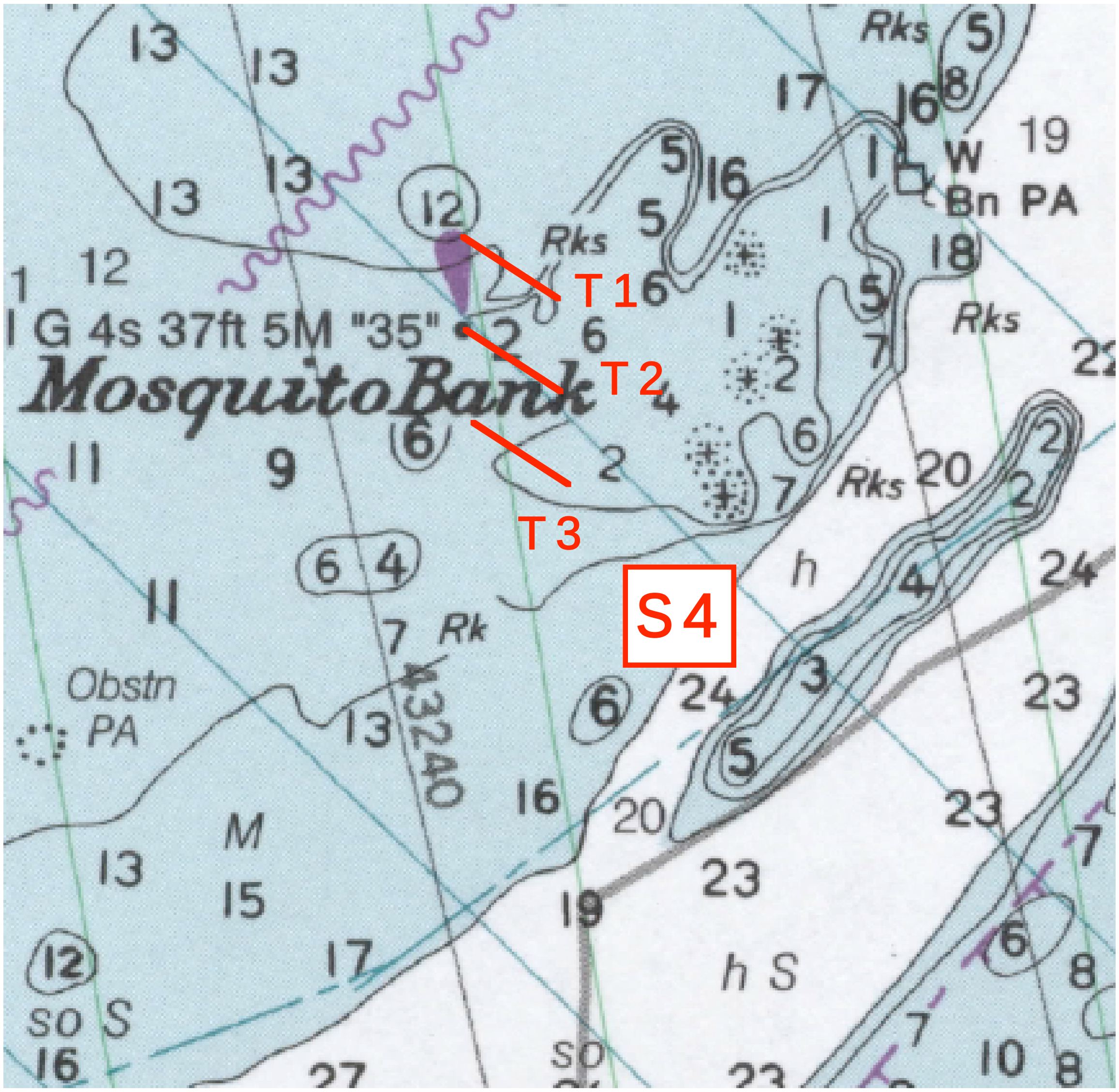

Figure 9. Location of transects. Site 4. Mosquito Bank (National Ocean Survey Chart 11462).

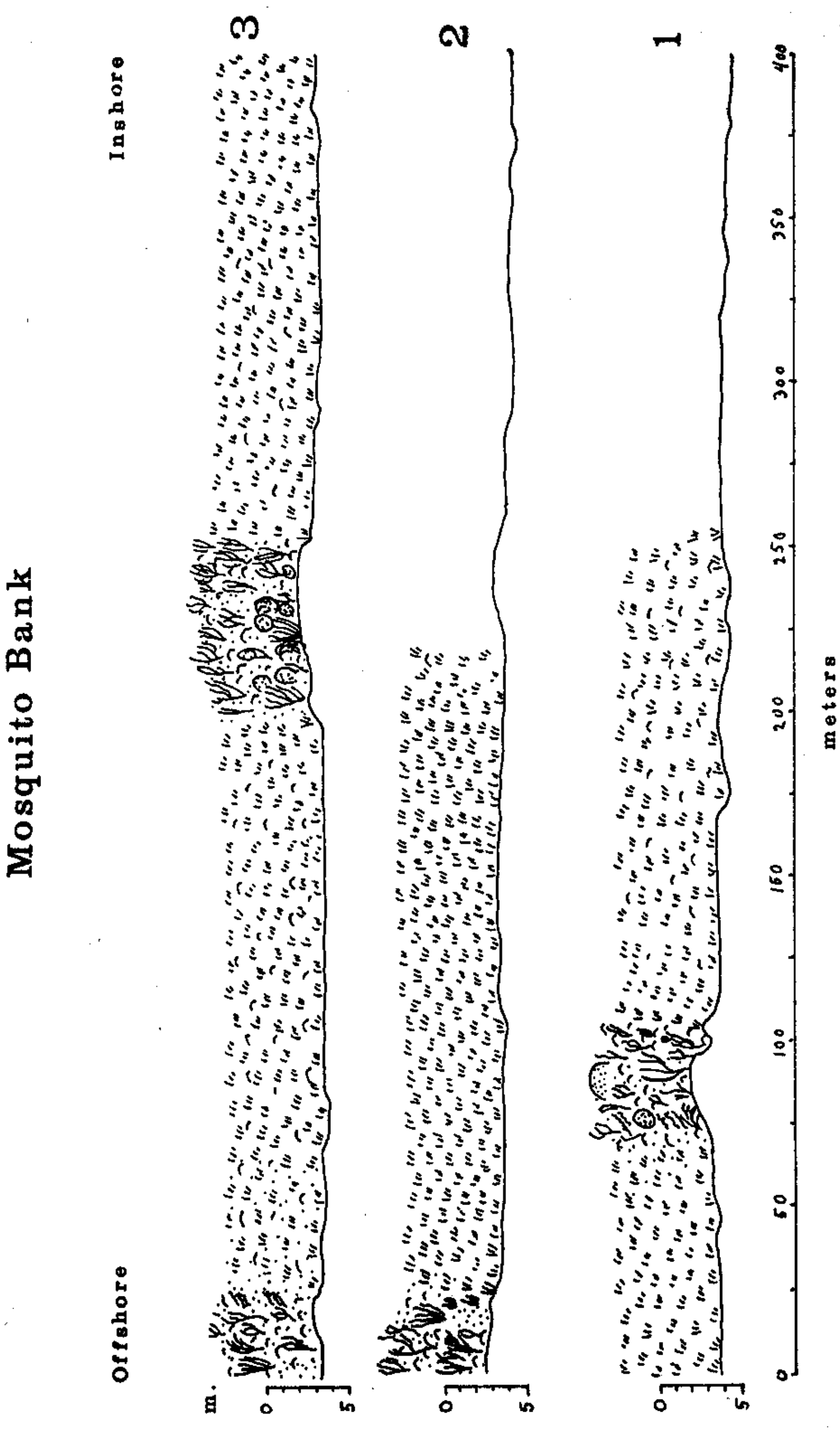

Figure 10. Pictorial transect profiles. Site 4. Mosquito Bank.

4.5. Site 5. Grecian Rocks

Grecian Rocks is a small cluster of patch reef located somewhat inshore of the outer reef line. It is bordered by grass meadows on the shoreward side but to seaward the bottom drops off onto clear silty sand or calcareous mud. A privately maintained buoy WOR "E" is anchored just inside of the reef.

Three 400-m transects were run on a heading of 308° true, 200 m apart and parallel to each other (Figure 11). Transect 1, the middle one, was run on a line with the buoy and the microwave tower. Transect 2 was southwest. Transect 3 was northeast of Transect 1.

Transect 1 (Figure 12.1) began in 10 m depth on smooth clean silty sand with occasional small bits of rubble and little mats of algae. With little change in depth this bottom continued for the first 125 m. Large rubble then began to appear along with scattered, straggly sea whips and small coral heads. The bottom shoaled, and at a depth of about 4 m, sea fans appeared along with colonies of stinging coral. At about 175 m, coral heads were common but at 180 m these gave way to large masses of elkhorn coral, *Acropora palmata*, at a depth of about 1 m. *Acropora palmata* was distributed in large clumps or sparsely for the next 120 m with occasional breaks of sand or rubble, finally rising to within 0.5 m depth of the surface. At about 310 m, the corals ended in scattered turtle grass, first in rubble and then in deep sandy mud.

Transect 2 (Figure 12.2) began in 9.5 m depth on a clear sand bottom with only small patches of matted algae and occasional green algae. At about 100 m, the bottom changed with a few scattered alcyonarians on large rubble. At 125 m, the bottom shoaled and at 6 m depth the first sea fans appeared along with patches of stinging coral. Only a few scattered *Acropora palmata* and *Porites* with sea feathers and sea whips occurred until about 235 m at a depth of 1.1 m when large areas of *Acropora palmata* appeared and continued to about 325 m where the corals ended abruptly, the bottom dropped off to about 2.5 m depth, and the transect ended over seagrass beds with several patches of nearly pure stands of *Syringodium*. Almost no *Acropora cervicornis* was seen on this transect.

Transect 3 (Figure 12.3) began in 10.5 m depth on a small patch of hardbottom and rubble with a few coral heads and sea whips. The bottom then leveled off at about 11.5 m depth and except for some scattered turtle grass at about 100 m continued on smooth sandy silt to about 175 m where the bottom rose in a series of steps. At 180 m, a considerable patch of *Acropora cervicornis* appeared along with a few sea fans, a small patch of *A. palmata* and some coral heads. This was followed by a few meters of open sand after which the bottom again shoaled. At about 6 m depth numerous sea fans appeared along with scattered stinging coral. At 265 m and a depth of 4 m, a large patch of *A. palmata* formed the second crest. The bottom then fell away to sand and then shoaled onto the reef crest proper at about 3 m depth. For the next 50 m, the reef was covered by a dense stand of *Acropora cervicornis* with a few large *Montastraea* heads. The last 50 m of the transect was over seagrass beds.

The zonation shown on the profiles (Figure 12) correspond roughly to that shown by Shinn (1980, Figure 2) of Grecian Rocks: an offshore rubble zone, a low terraced *Millepora* and *Montastraea* zone, a second terrace for the *Acropora* zone, the reef flat and back reef. Shinn showed a strong spur and groove system on the seaward reef face not shown in the present profiles. Otherwise the two studies show similar features including the rich *Acropora* stand in the reef flat.

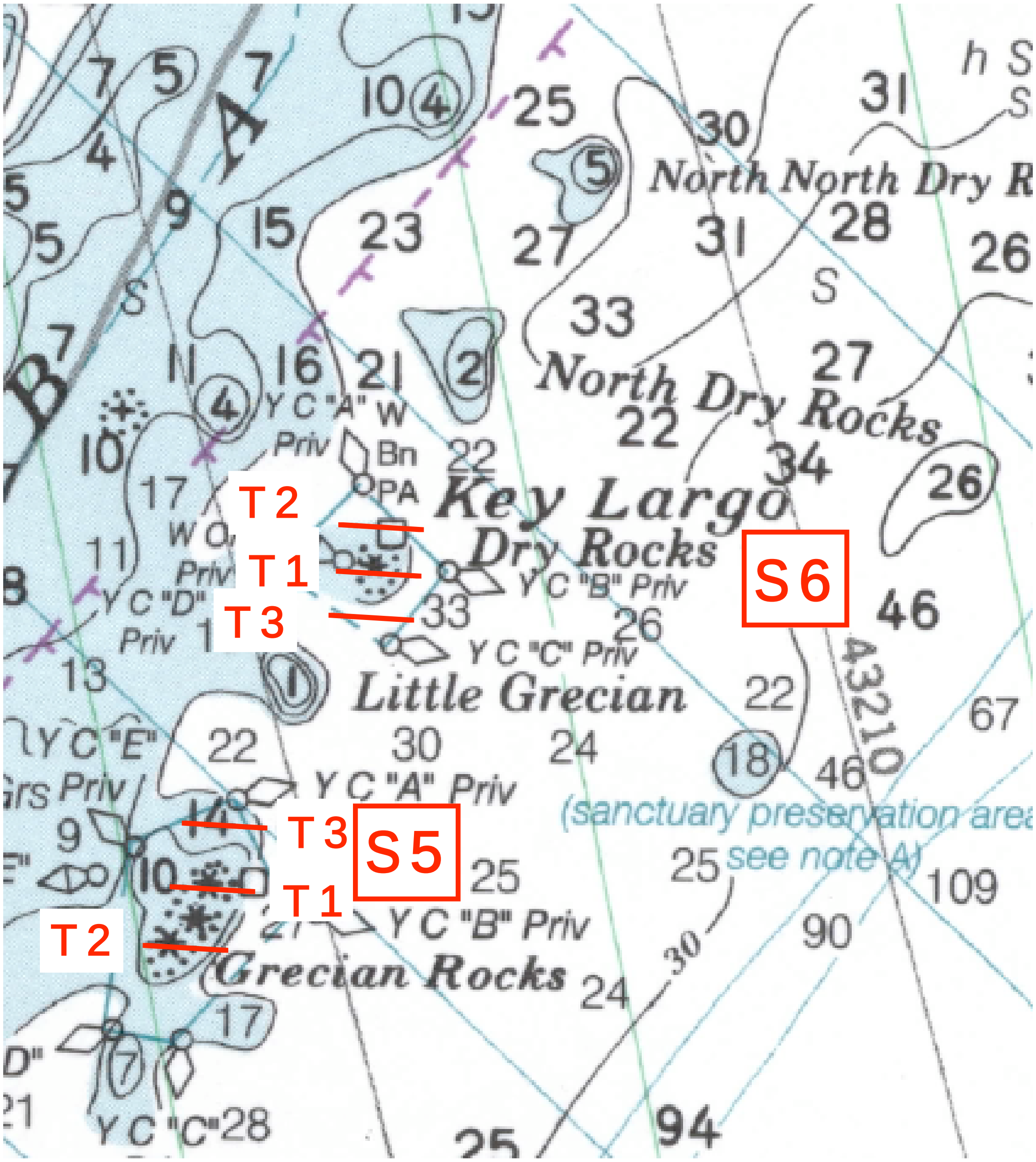

Figure 11. Location of transects. Site 5 - 6. Grecian Rocks and Key Largo Dry Rocks (National Ocean Survey Chart 11462).

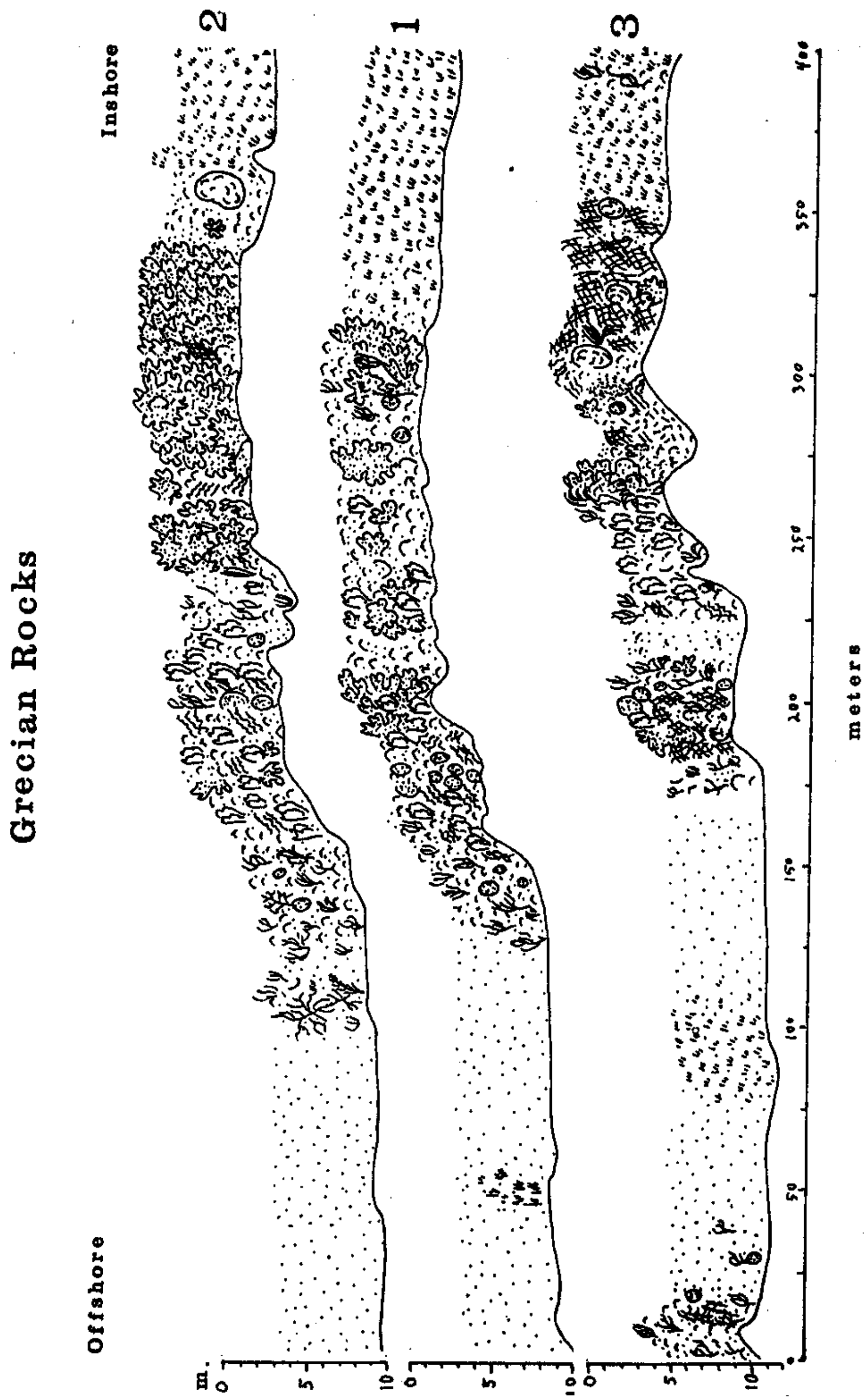

Figure 12. Pictorial transect profiles. Site 5. Grecian Rocks.

4.6. Site 6. Key Largo Dry Rocks

Largo Dry Rocks has one of the most extensive coral growths within the Sanctuary and Park area. While many forces were acting upon it during the period from the 1940s to its integration into the Park, the reef has withstood them well: hurricanes, coral collectors, reef fish collectors, observation tower builders, and many others.

The north central area is formed of jumble of old reef and large coral rubble honeycombed with passages and open spaces. Some of the old rock bares out at low tide, formerly marked by a stake. South of this is a broad expanse of elkhorn coral, *Acropora palmata*, and staghorn coral, *A. cervicornis,* probably the best in the Park. Offshore, the reef is bounded by clear sand bottom at a depth of about 11 m. Inshore, the seagrass beds extend shoreward in an almost unbroken expanse.

Three 400-m transects were run across the reef on a heading of about 278 -298° true (Figure 11). Transect 1 was run past the Dry Rocks buoy "D." Transect 2 was 300 m to the northeastward and Transect 3 was 300 m to the southwestward of Transect 1.

Transect 1 (Figure 13.1) began in 10.7 m depth on deep, clear, silty sand or coral mud which extended for about 60 m. The bottom contained some rubble and small patches of algae. The bottom rose to within 4 m of the surface and on its top were a few sea fans and sea whips. At 75 m, the bottom fell away to white sand at 7.6 m depth, but immediately started to rise, with large brain coral heads, *Colpophyllia natans,* sea whips and rubble. At 110 m, *Acropora palmata* began to appear and covered the bottom as it shoaled to 1.5 m depth at 130 m. The reef was nearly flat for the next 125 m, the entire top covered with *Acropora palmata* with large patches of *A. cervicornis*. Occasional rubble with sea feathers, sea fans and sea whips, was interspersed. The tops of the coral formed a flat expanse that lay just a few centimeters from the surface, controlled apparently by sea level at low Spring tides. At 265 m, the inner edge of the reef dropped off abruptly to seagrasses that extended to the end of the transect.

Transect 2 (Figure 13.2) began in 10.4 m depth on a sandy turtle grass area that extended for 250 m, varying from sand patches to dense seagrass. At 250 m, the bottom shoaled to about 6.5 m depth and a small area about 100 m wide had a moderate to lush growth of *Acropora cervicornis* interspersed with sea whips and an occasional sea fan. A small rubble area led into seagrass which extended to the end of the transect.

Transect 3 (Figure 13.3) began in 9.1 m depth on the seaward slope of a small rise. The bottom was covered with large rubble and silt with small clumps of green algae. The bottom rose and leveled off at 6.1 m depth where some large patches of *A. cervicornis* occurred for about 35 m. These ended in the middle of the rise on sand bottom. The bottom then fell away at 60 m distance to a depth of 9 m for only a short distance and then rose to level off at 7.6 m depth on sandy, silty bottom. This region extended for 200 m on bare sand with only occasional scattered patches of turtle grass and small clumps of algal mats. At about 310 m, the bottom again rose slightly to 6.1 m depth where another 30 m patch of *Acropora cervicornis* and a few sea fans were found on the seaward slope. At 350 m, the bottom changed to seagrasses which extended to the end of the transect.

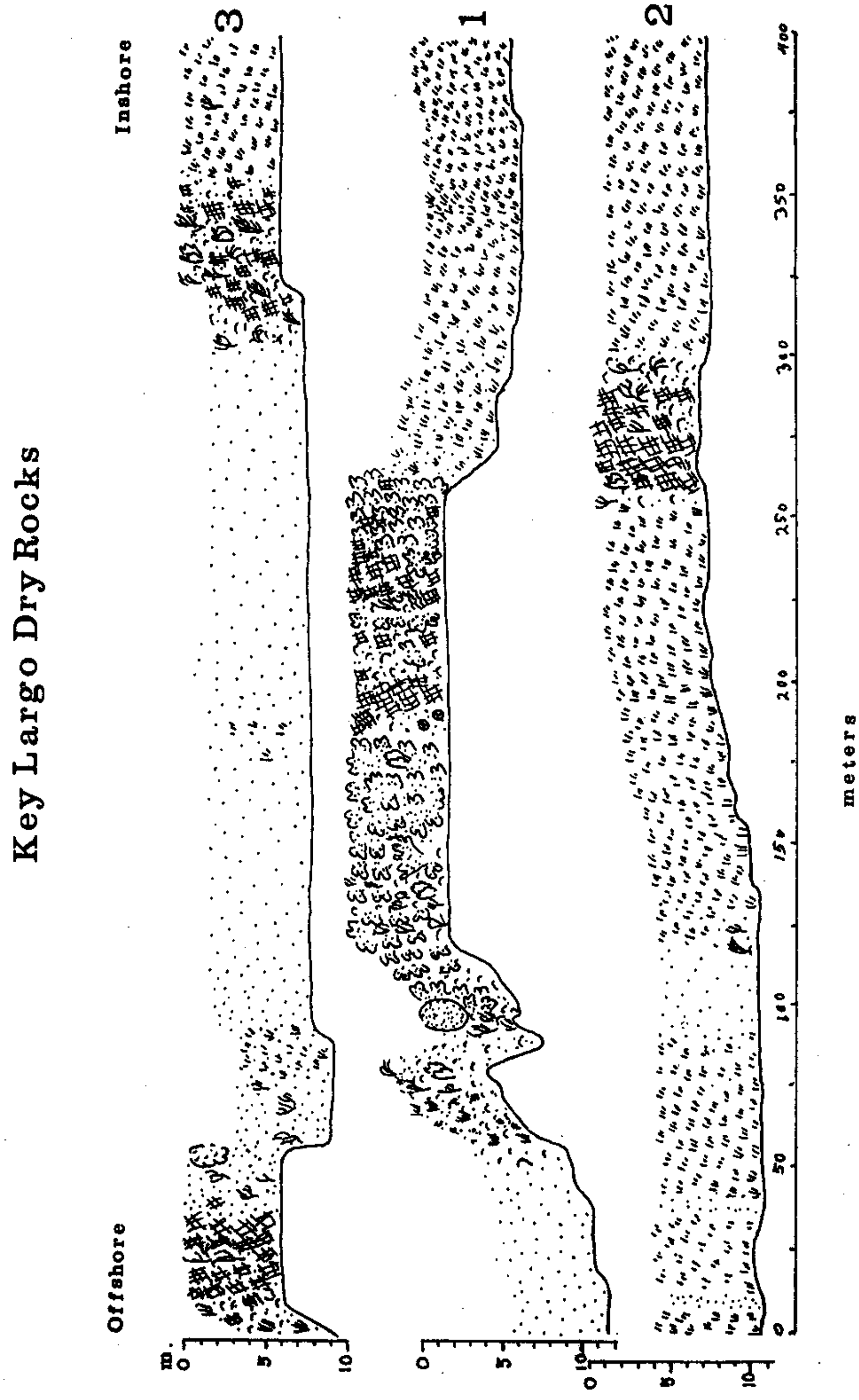

Figure 13. Pictorial transect profiles. Site 6. Key Largo Dry Rocks.

4.7. Site 7. The Elbow

The reef known as the Elbow is located directly offshore of Garden Cove on the outer edge of the reef line. It is unusual in that it lies apart from the shallow bank and is surrounded to the north, west and south by waters at least 10 m deep and to the eastward by an abrupt drop-off to over 30 m. It is mainly composed of old coral rubble piled atop the old reef base on which some corals have become established. There is an old wreck on the reef now indicated by parts of the hull, boilers and engine.

Three transects (Figure 14) were run across the reef. Transect 1 was made on a heading of 278° true and passed alongside of the light, crossing over the wreck at approximately 430 m from the start. Transect 2 was parallel to Transect 1 but 300 m to the southwest. Transect 3 was 300 m to the northeast.

Transect 1 (Figure 15.1) began in 18.3 m depth on hardbottom with a thin covering of white sediments. The flora consisted mostly of green algae such as *Dictyota, Dilophus, Enteromorpha*, and filamentous greens, brown algae, *Pocockiella*, various red algae and corallines. Alcyonarians such as sea feathers and sea whips were mostly low but some grew to 0.7 to 1 m high. Sponges, mostly vase and tube sponges, were scattered. There were a few small patches of staghorn coral as well as scattered heads of *Siderastrea*, *Porites*, and others. Hardbottom extended for about 250 m where a series of ridges bore colonies of large bushy alcyonarians. Shoreward of the ridges the bottom dropped to about 10 m depth and was sandy with a little rubble and an occasional sea whip. At 425 m, the transect crossed over the timbers of the wreck lying on a small ridge. At approximately 480 m, the reef crest was reached with a small area of elkhorn coral in 3.7 m depth. Shoreward of the *Acropora,* the bottom dropped to about 5.5 to 6.0 m depth and was covered by rubble of which the inner part was made up of rodlike rubble formed by dead *Acropora cervicornis*. The transect ended in seagrass beds.

Transect 2 began in 16.5 m depth on hardbottom (Figure 15.2). This shoaled steadily with only minor small ridges for about 350 m. The hardbottom was very rich, covered with algae, sponges, alcyonarians, corals, and other sessile life, but with no *Acropora* except for a small patch of *A. cervicornis* near the start. At about 325 m at a depth of 6 m, the sea fan zone began and extended to the end of the transect at 550 m. Despite its extent, there was no *Acropora* on the reef top and very little stinging coral. The transect ended just short of the seagrass beds.

Transect 3 (Figure 15.3) began in 13.7 m depth on hardbottom with rubble and sediments. This transect missed the reef top and ran for 400 m in a series of low ridges and sand areas. The bottom was sparsely covered with algae and occasional small alcyonarians, sponges and few little coral heads.

The deep reef survey (Jameson, 1981, Figure 14) depicted a sand/soft (horny?) coral zone lying between the shallow reef and the deep reef. This is undoubtedly a continuation of the sand covered hardbottom described above. This zone characteristically is found between ridges on the fore reef slope but is not indicated in the somewhat diagrammatic figure given by Jameson. Seaward, the deep reef extends down to about 40 m where it gives way to corralline algae and leafy algae. Jameson remarked that at both French Reef and the Elbow "the deep reef extends to 39.6 m (130 feet) but the majority of the reef formation is found at depths less than 36.6 m (120 feet)." While this is true at the Elbow, the 36.6 m contour is found approximately in the middle of the deep reef zone at French Reef.

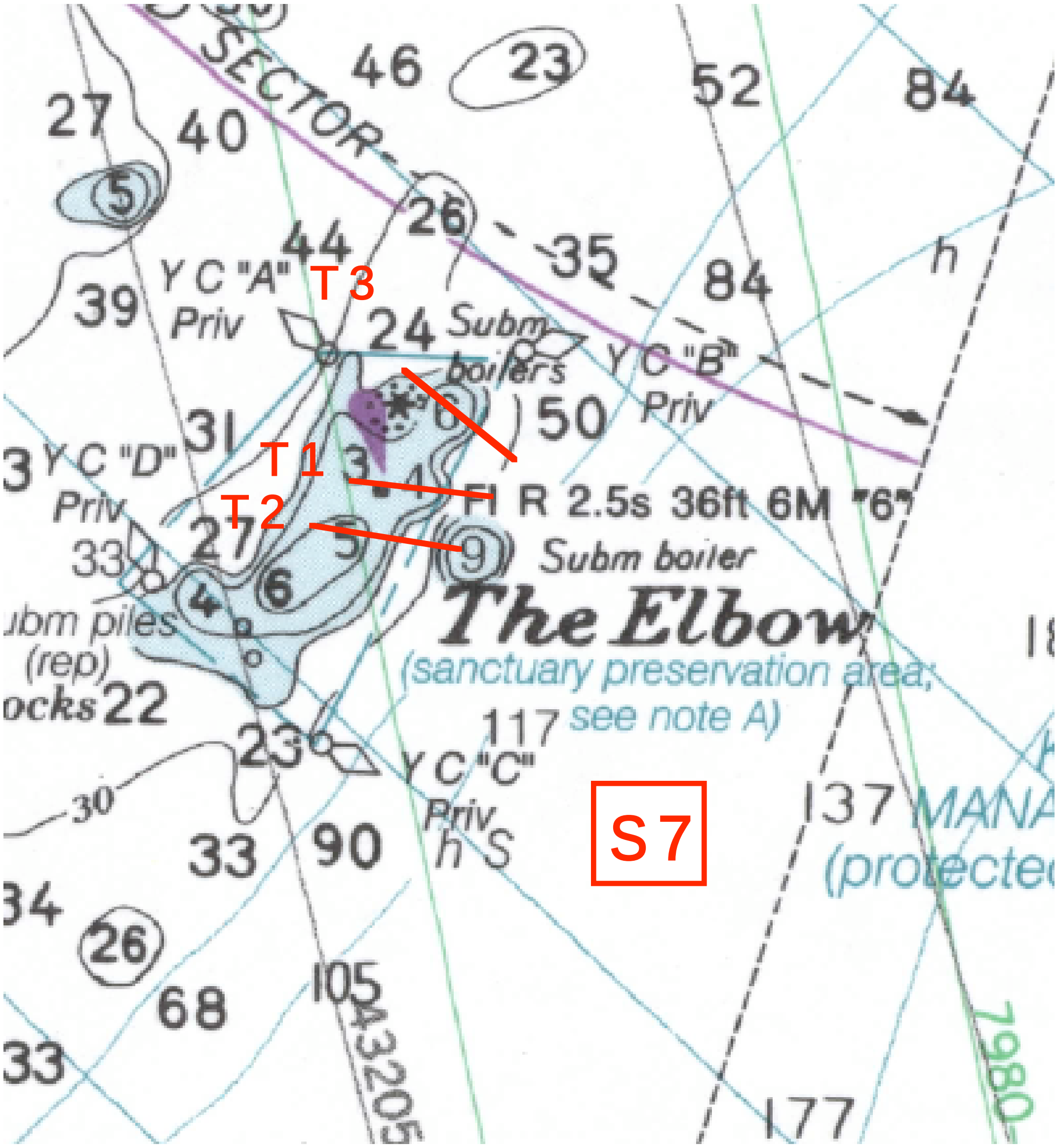

Figure 14. Location of transects. Site 7. The Elbow (National Ocean Survey Chart 11462)..

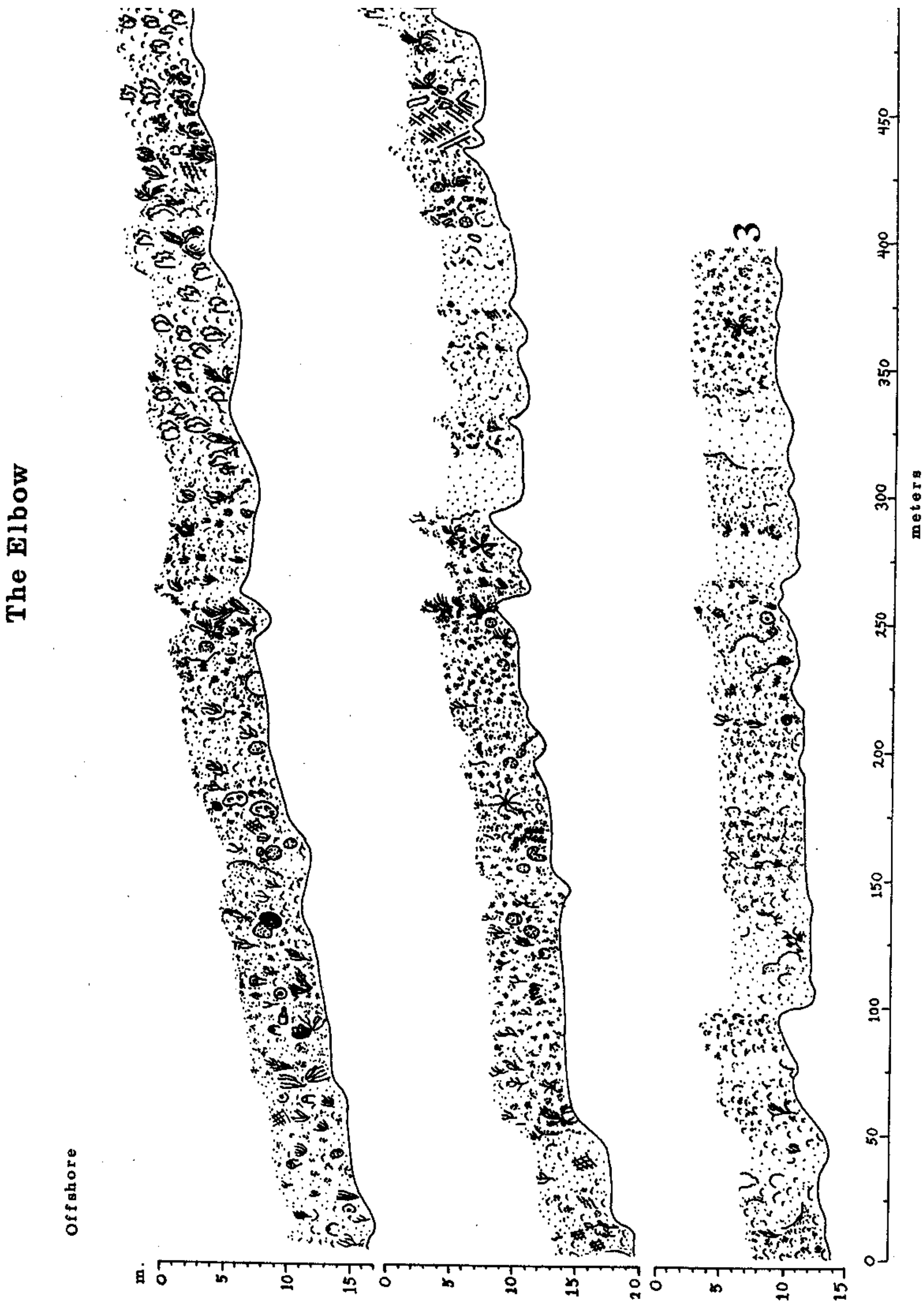

Figure 15. Pictorial transect profiles. Site 7. The Elbow (cont. on next page with an overlap in case the figure needs to be reassembled). [Continued on following page.]

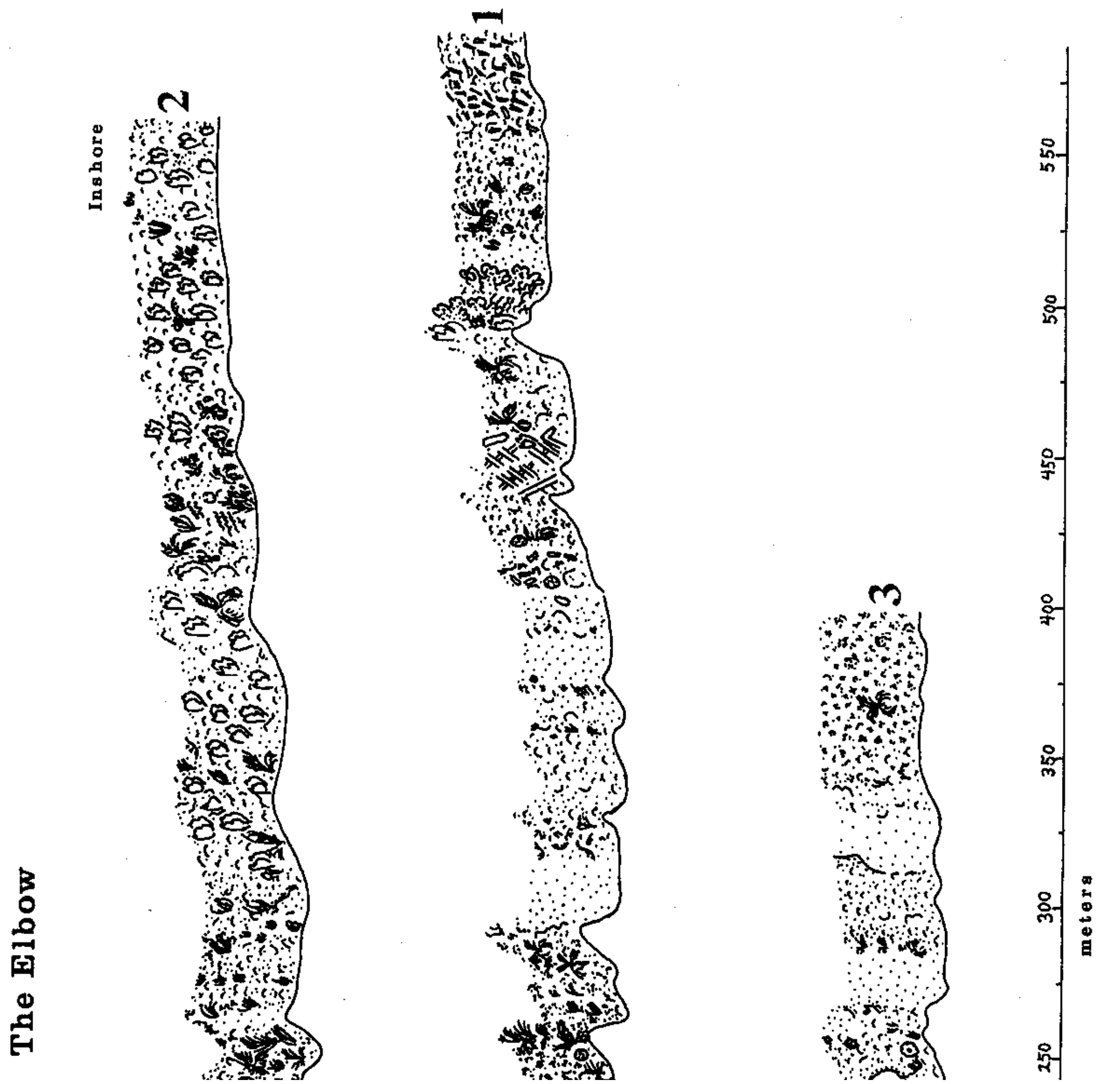

Figure 15. Pictorial transect profiles. Site 8. The Elbow (cont.).

4.8. Site 8. Carysfort Reef

Carysfort Reef is located on the outer edge of the bank at the edge of the drop off into the Straits and is swept by the oceanic waters of the Florida Current. It is marked by Carysfort Light, formerly with a keeper and assistants, but now untended. The reef proper is less than 600 m long although the shallow rocky bank on which it is located is about three quarters of a nautical mile in length.

Transect 1 was 785 m long. It was run on a heading of 293° true on Carysfort Light which it passed at about the 665 m mark. Transect 2 was 300 m to the northeast while Transect 3, only 200 m long, was 300 m to the southwest (Figure 16).

Transect 1 (Figure 17.1) started on hard, silt, covered bottom in 16.8 m depth. The bottom shoaled slowly to about 8.5 m depth at 235 m across a rock ridge and then fell away to 16.8 m depth before again ascending. From the start to approximately 300 m the bottom was rocky with small rubble covered by a thin layer of white silt. Viewed from above in the camera shots, the bottom had a mottled or "salt and pepper" appearance, but from the bottom it had growths of red and green algae and small sea whips that gave it a "shaggy" look. The fauna and flora were composed mostly of green algae such as *Halimeda*, *Dictyota,* and *Dilophus* as well as filamentous greens and occasional reds. Sponges, alcyonarians such as sea whips, and corals were scattered about among the algae.

At about 300 m, the bottom became a narrow trough and was typically covered by bare white silty sand. At about 365 m, the bottom rose toward the reef crest. The bottom was hard with small to large coral rubble, and with alcyonarians, mostly sea whips, but some sea feathers, sponges, stinging coral, a few coral heads and scattered small patches of *Acropora cervicornis*. At about 460 m, the first sea fans, *Gorgonia ventalina,* were seen and at 480 m, the transect crossed a small patch of *Acropora palmata.* From there to 560 m was a rich sea fan zone which gave way for about 40 m to extensive beds of stinging coral. At approximately 600 m and at a depth of 2.1 m, an extensive area of *Acropora palmata* 80 m wide, broke to the surface opposite the Light. Immediately inshore the back reef of rubble and sand blended into the seagrass meadows.

Transect 2 (Figure 17.2) began in 17.1 m depth on hardbottom covered by a thin layer of silt and some rubble, the area corresponding to the first part of Transect 1. The bottom slope and coverage were similar to Transect 1 except that the dip shoreward of the first ridge was longer and flatter with an expanse of bare sand nearly 150 m across. At 400 m, the bottom began to shoal and was characterized by a conspicuous sea feather and sea whip zone followed at 475 m in 6 m depth by the sea fan zone that continued to 560 m. Here a small stand of elkhorn coral was followed by a rather broad area covered predominantly by stinging coral. The transect ended in small rubble thinly coated by white sediments with occasional small individual sea fans and sea whips. This was followed by seagrass meadows.

These two transects were very similar and clearly show the basic zonations of the outer reef tracts: (1) a deep hardbottom zone shoaling into (2) a rubble, sea feather and sea whip zone, giving way (3) to the sea fan zone usually starting at 67 m depth and extending across the reef top, interrupted (4) on some reefs by a broad *Acropora* zone. This zone ended (5) in the back reef area formed of coral rubble and small sea whips and sea fans, terminating (6) in the thin sediment seagrass beds.

Transect 3 was only about 200 m long (Figure 17.3). It started at a depth of 21.9 m on sandy bottom that must lay back of an offshore ridge. The bottom shoaled rapidly and steeply on a hardbottom zone to 5 m depth where the sea fan zone began. This zone continued across the

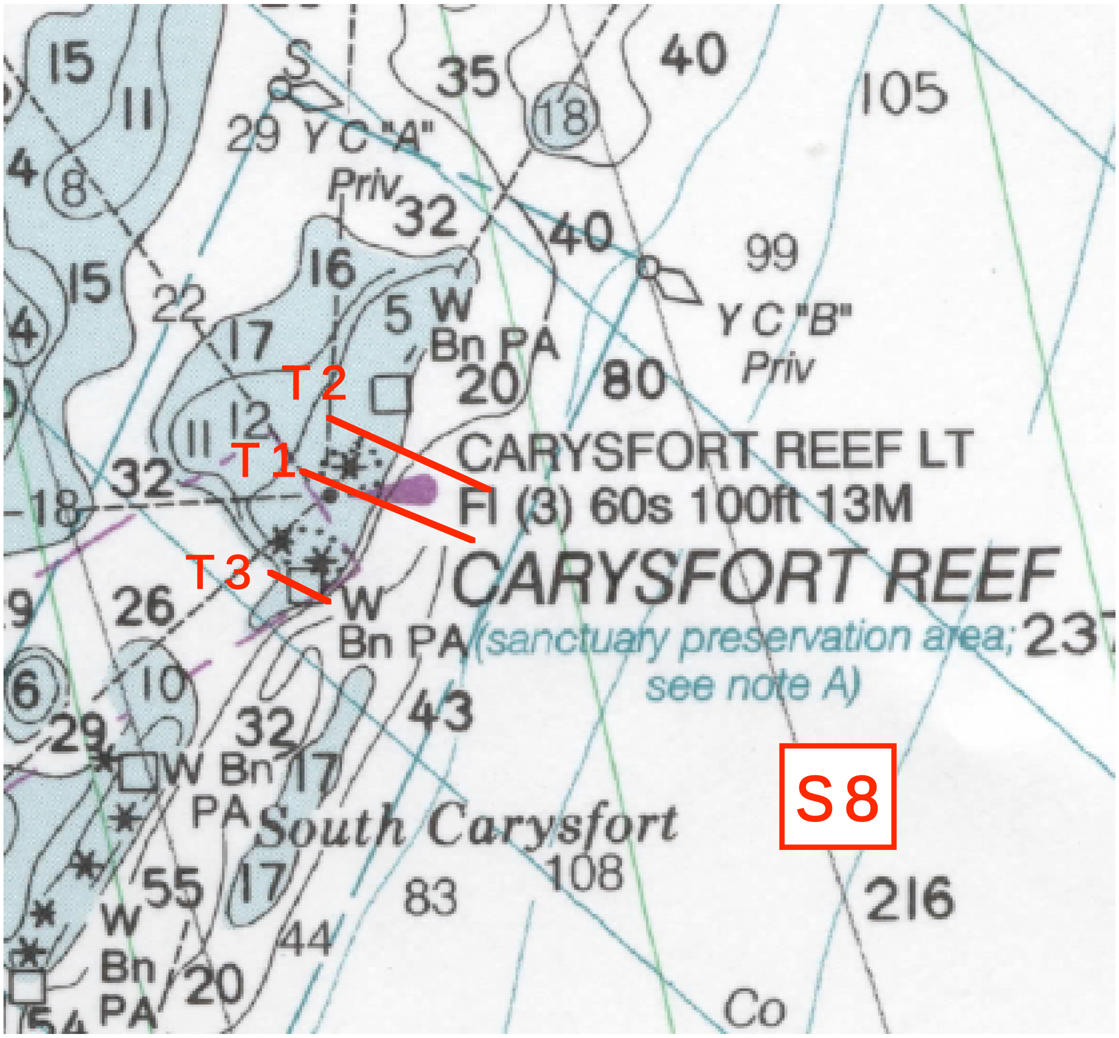

Figure 16. Location of transects. Site 8. Carysfort Reef (National Ocean Survey Chart 11462).

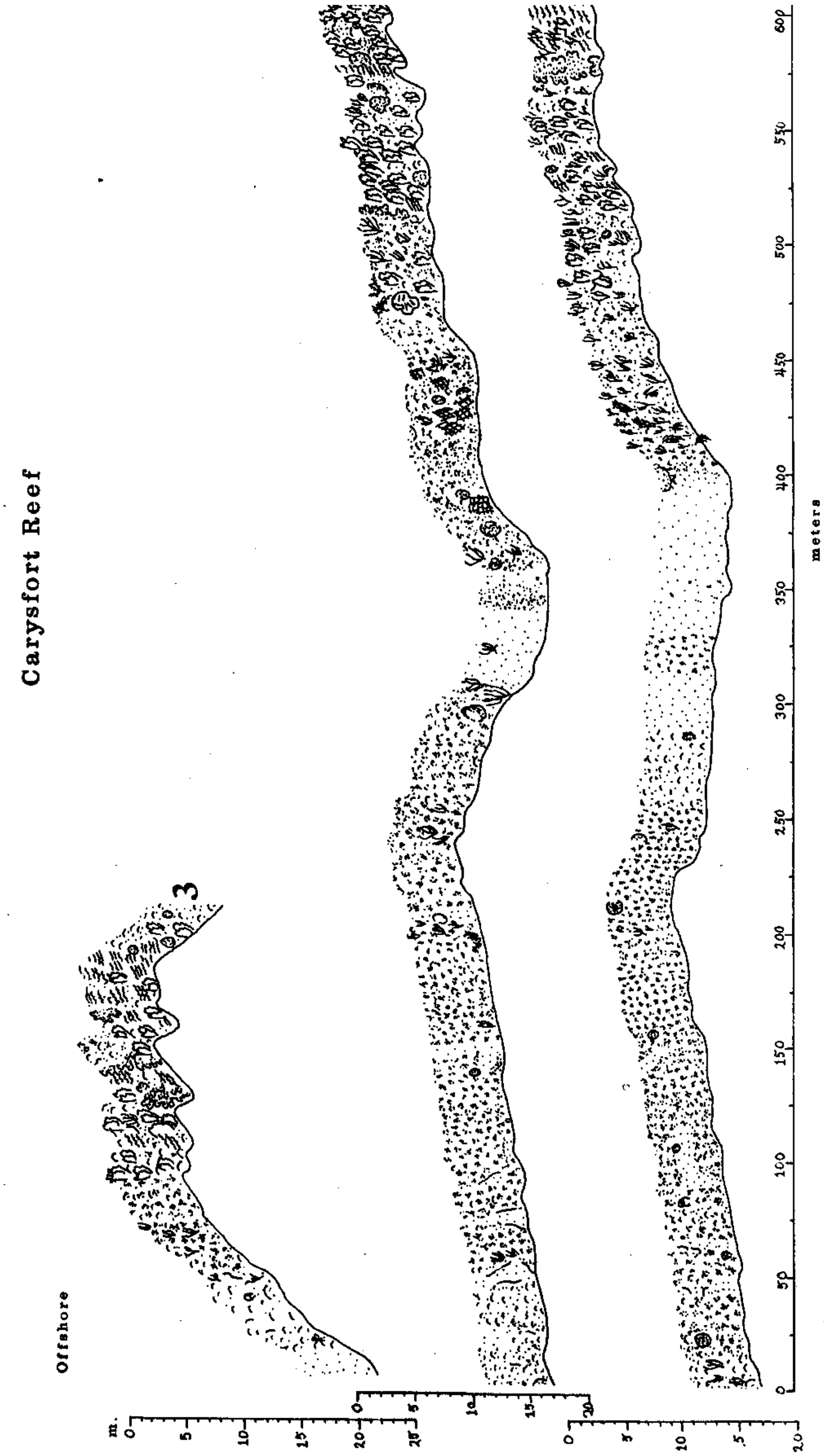

Figure 17. Pictorial transect profiles. Site 8. Carysfort Reef (cont. on next page with an overlap in case the figure needs to be reassembled). [Continued on following page.]

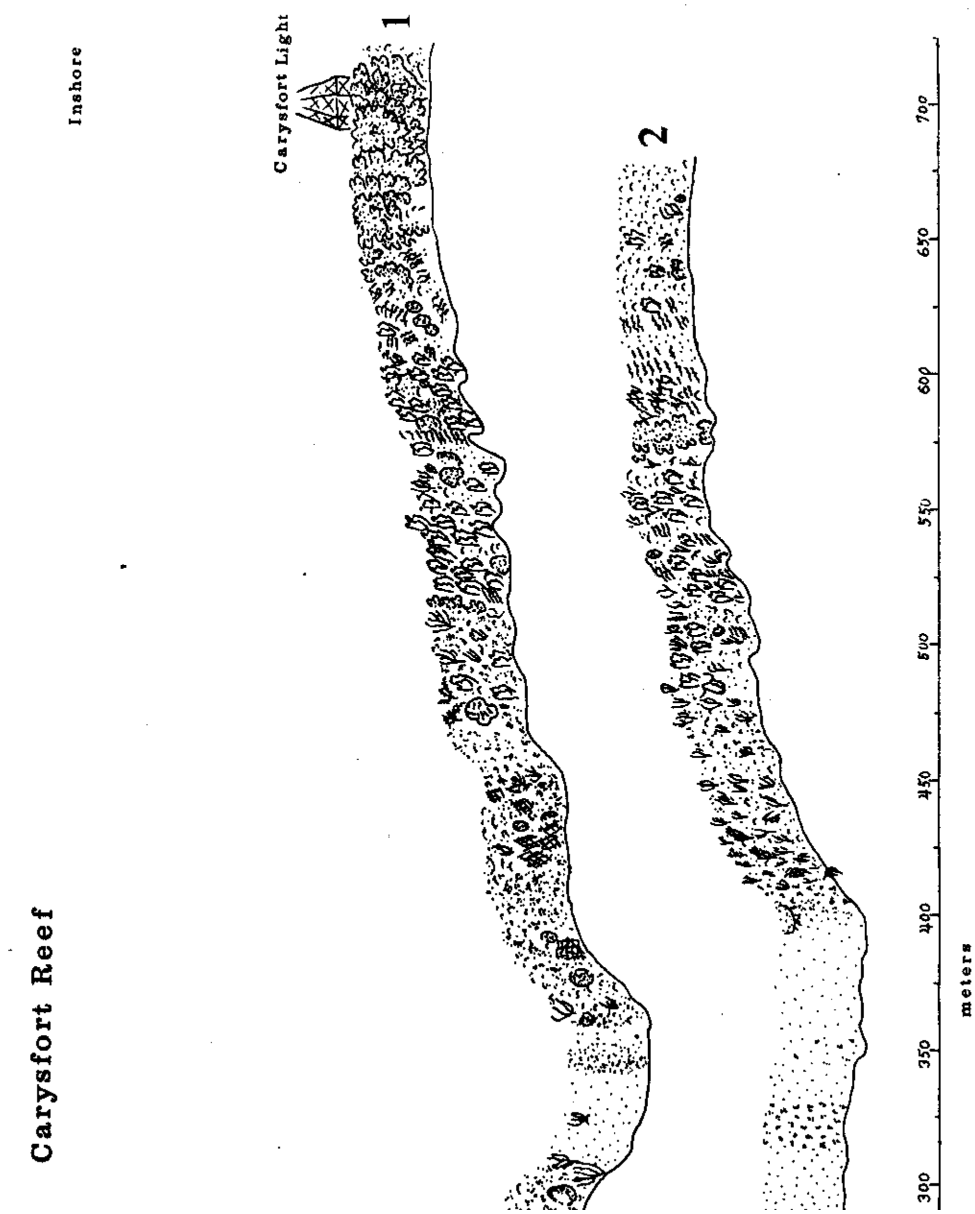

Figure 17. Pictorial transect profiles. Site 8. Carysfort Reef (cont.)

shoal reef top and down the inshore side to the end of the transect. The reef crest contained large beds of stinging coral with only limited areas of elkhorn coral. This transect ran across the southwest end of the reef where the profile showed that it dropped off into the deeper water separating Carysfort Reef from the main bank of the Hawk Channel.

Bannerot and Schmale (this volume) report an extensive thicket of *Acropora cervicornis* at approximately 14 m depth off of Carysfort Reef, within the purview of this report. Jameson (1981) also reported that the deep reef off South Carysfort, in about 26 - 34 m depth was "also unique in that the common shallow reef staghorn coral, *Acropora cervicornis,* is present." However, it is not shown in his Figure 15. The deep reef off Carysfort is not as wide as at the other reefs, the slope is less but there is a stronger terracing of the "Lithothamnion cobble zone."

4.9. Site 9. Basin Hill Shoals

Basin Hill Shoals is an area of small patch reefs and shallow hardbottom bars located slightly south of a line between Point Elizabeth and Carysfort Reef. It is approximately halfway from shore to the edge of the outer reef. It is surrounded by turtle grass meadows at depths from about 3 to 5 m.

Three 400-m transects (Figure 18) were run on headings of 288° true across the patch reef area. Transect 1 was started at 4.3 m depth and ran shoreward, ending at day marker BH19. Transect 2 was run on the same heading and parallel to Transect 1, 300 m to the southwest. Transect 3 was parallel to 1 and the same distance to the northeast.

Transect 1 (Figure 19.1) passed over turtle grass for the first 90 m. The grass was lush, with long, broad blades. There were scattered sand mounds. Some *Syringodium* was present. At about 90 m the transect passed over a small patch reef composed of the common star coral, *Montastraea annularis,* the starlet coral, *Siderastrea siderea*, sponges and sea whips on rubble partly covered by silt. The reef was about 25 m across followed by about 25 m of turtle grass. At about 135 m another small patch reef about 15 m wide was crossed over. This consisted of large coral heads with small alcyonarians. Another 70 m of turtle grass ended with another patch reef about 20 m wide consisting of *Montastraea* and alcyonarians. This was followed by an expanse of turtle grass about 25 m across and a fourth patch reef. The latter was 25 m wide and composed of large heads of *Montastraea* with alcyonarians and sponges on silt-covered hardbottom. From this point on, the bottom was almost entirely covered by turtle grass except for patches of alcyonarians at 275 and 300 m. The grass beds extended to day marker BH19 at the end of the transect.

Transect 2 (Figure 19.2) began at a depth of 6.0 m on silty mud with a sparse growth of *Thalassia* and numerous sand mounds. Moving shoreward, the turtle grass increased in spread and density, with longer and wider blades. Sand mounds averaged 3 - 6/m^2. No macroorganisms were found except for a few scattered loggerhead sponges, *Spheciospongia vesparia,* a few isolated alcyonarians, worms and the tiger lucina, *Codakia*. In some areas there were a few *Syringodium* patches scattered among the turtle grass.

At about 330 m, the transect crossed a narrow hardbottom bar covered by bare sand, about 20 m wide. A few large heads of the common brain coral, *Diploria strigosa*, bushy alcyonarians and sponges were seen. The inner edge of the bar had small colonies of either *Porites* or *Siderastrea*, all in apparent good health.

Transect 3 began in 5.2 m in turtle grass beds (Figure 19.3). These extended shoreward for about 250 m, often mixed with manatee grass, *Syringodium,* which occasionally grew in thick patches or predominated over the turtle grass. At 250 m, a patch reef occurred, formed mainly of *Montastraea annularis*, sea feathers, sea whips, and sponges. This patch was about 20 m wide. Turtle grass and manatee grass were common and their beds extended from the inner edge of the reef to the end of the transect, accompanied by few scattered sponges and the usual grass meadow calcareous algae.

Bannerot and Schmale (this volume) report an extensive thicket of *Acropora cervicornis* at approximately 14 m depth off of Carysfort Reef, within the purview of this report. Jameson (1981) also reported that the deep reef off South Carysfort, in about 26 - 34 m depth was "also unique in that the common shallow reef staghorn coral, *Acropora cervicornis* is present." However, it is not shown in his Figure 15. The deep reef off Carysfort is not as wide as at the other reefs, the slope is less but there is a stronger terracing of the "Lithothamnion cobble zone."

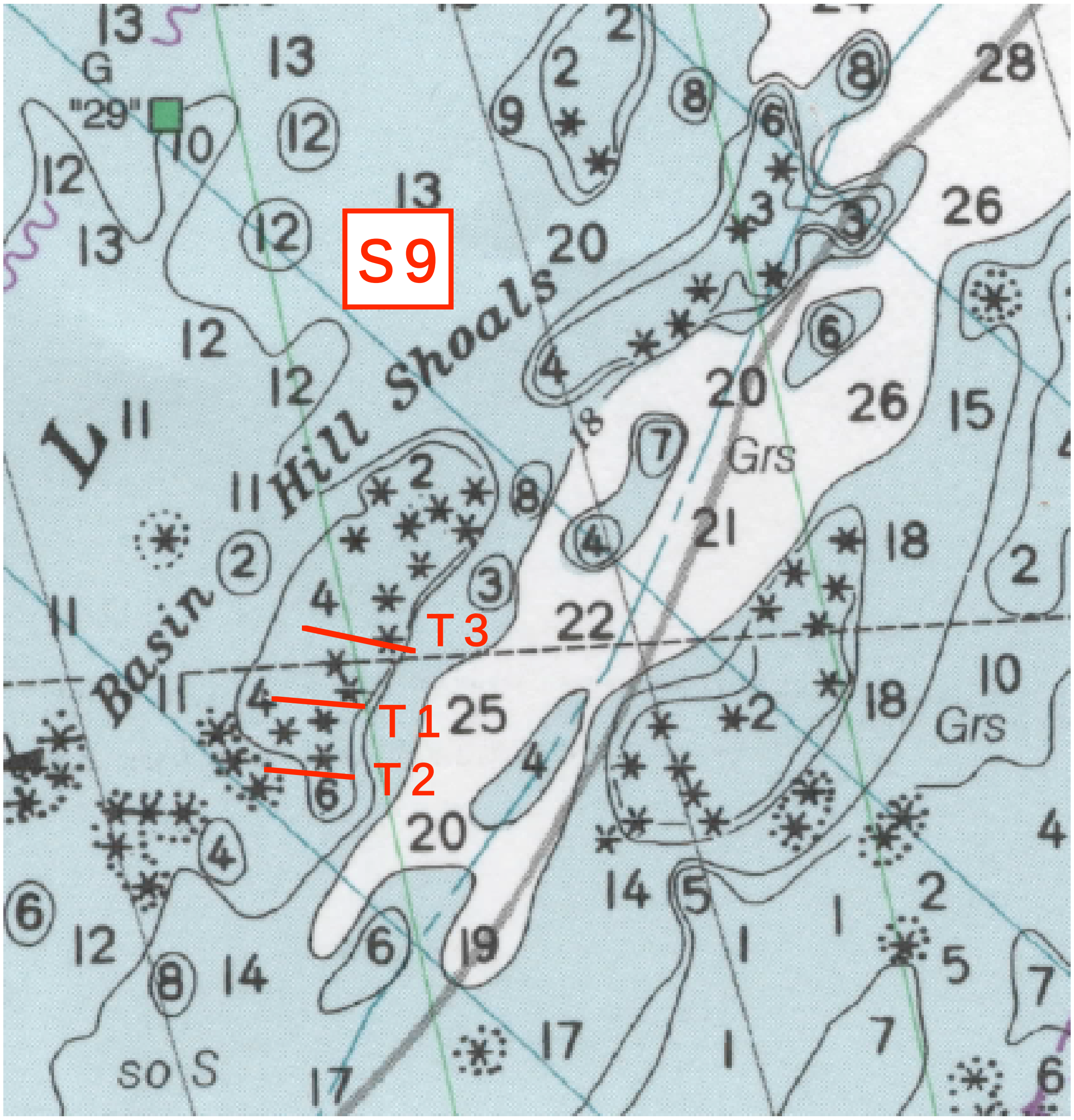

Figure 18. Location of transects. Site 9. Basin Hill Shoals (National Ocean Survey Chart 11462).

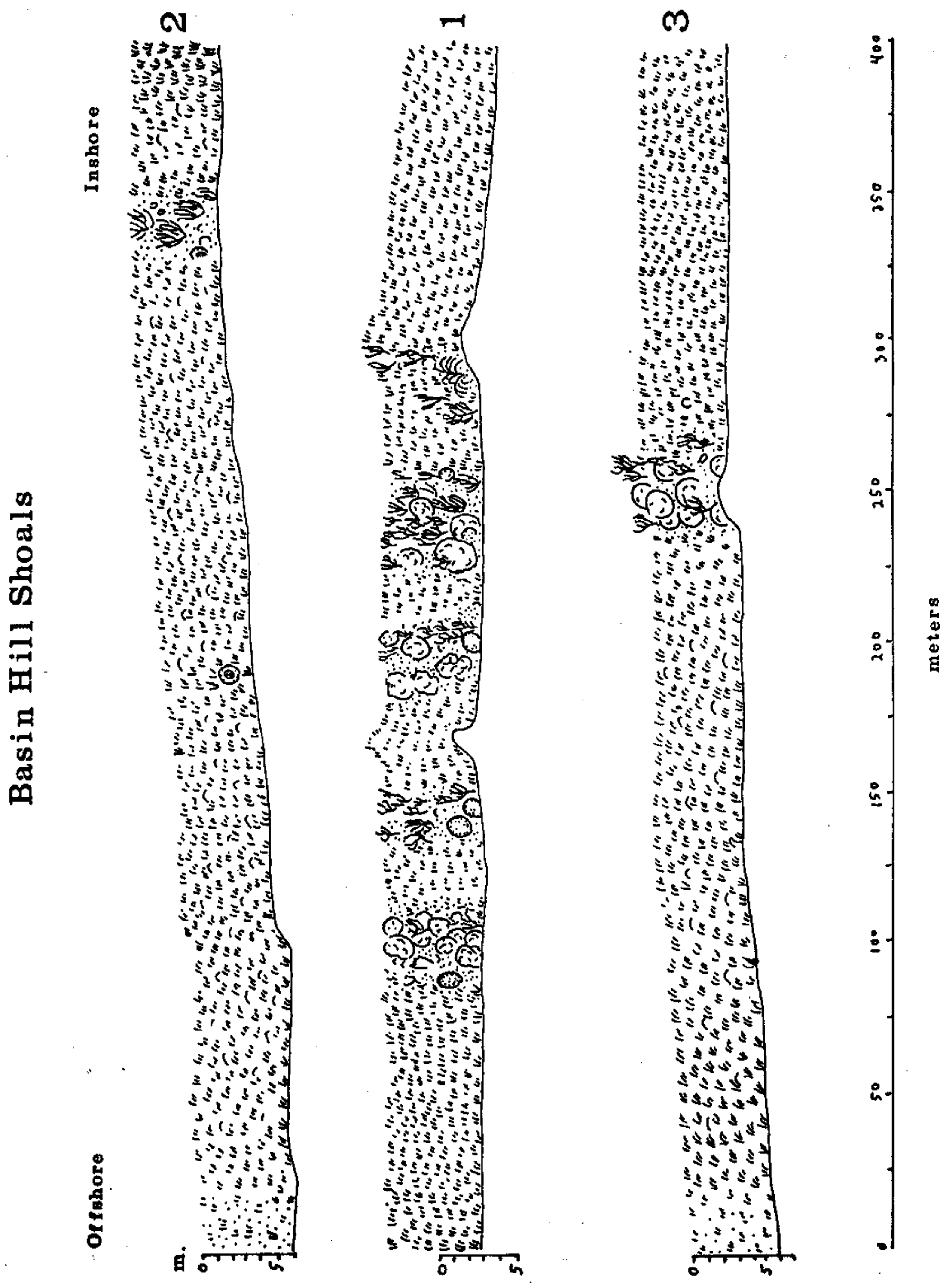

Figure 19. Pictorial transect profiles. Site 9. Basin Hill Shoals.

4.10. Site 10. Turtle Rocks

Turtle Rocks is located offshore of the Ocean Reef Club on a point of shoals forming the eastern side of Turtle Rocks Anchorage. It is surrounded on all sides except the south by depths of 10 m or more. It is unprotected from the east and the waters of the Florida Current.

Three 400-m transects (Figure 20) were run parallel to each other and 300 m apart. Transect 1 was run on a heading of 238° true almost due east of marker "6." Transect 2 and 3 were progressively farther north.

While this area is called Turtle Rocks, it does not contain true patch reefs and the National Ocean Survey chart 11462 shows no coral patches at this location.

Transect 1 began in 3.0 m depth (Figure 21.1) on hardbottom covered with white calcareous sands or silt. This bar covered about 55 m. Corals consisted only of a few small colonies of *Porites*. The other fauna consisted of stinging corals, the alcyonarians *Pseudopterogorgia americana* and *Plexaurella mammosa,* a few low sea whips, the sponge *Iotrochota birotulata* and various corallines. The main part of the transect was over seagrass beds, much of which was sparse and somewhat muddy. At 300 m a little hardbottom was encountered with a few low sea whips. The last 40 - 50 m was sandy with sparse grasses and an occasional vase sponge.

Transect 2 began in 6 - 8 m depth (Figure 21.2). The bottom gradually shoaled until at 65 m it leveled out at about 4.6 m depth for the rest of the transect. For the first 25 - 30 m the bottom was rocky overlain with a thin layer of calcareous sand in which were a few scattered alcyonarians, mainly sea whips. The rest of the transect was over seagrasses growing thickly or thinned out in sand patches. A few small colonies of *Porites,* scattered sponges and the usual grass associates made up the grass beds formed of turtle and manatee grasses.

Transect 3 (Figure 21.3) began in 3.0 m depth on hardbottom and shoaled in 25 m to a depth of 1.8 m which was continued for 125 m across a shoal hardbottom bar. The bar was rock overlain by a thin layer of calcareous sand and silt. Growth on the bar consisted of alcyonarians, scattered patches of *Acropora palmata* and *A. cervicornis*, *Porites, Siderastrea* and *Montastraea* growing on flat rock and coral rubble. The rest of the transect was over beds of turtle and manatee grasses with their associated algae and invertebrates.

While the transects were not very productive in quantity and diversity, both the grass and coral quadrats were very rich.

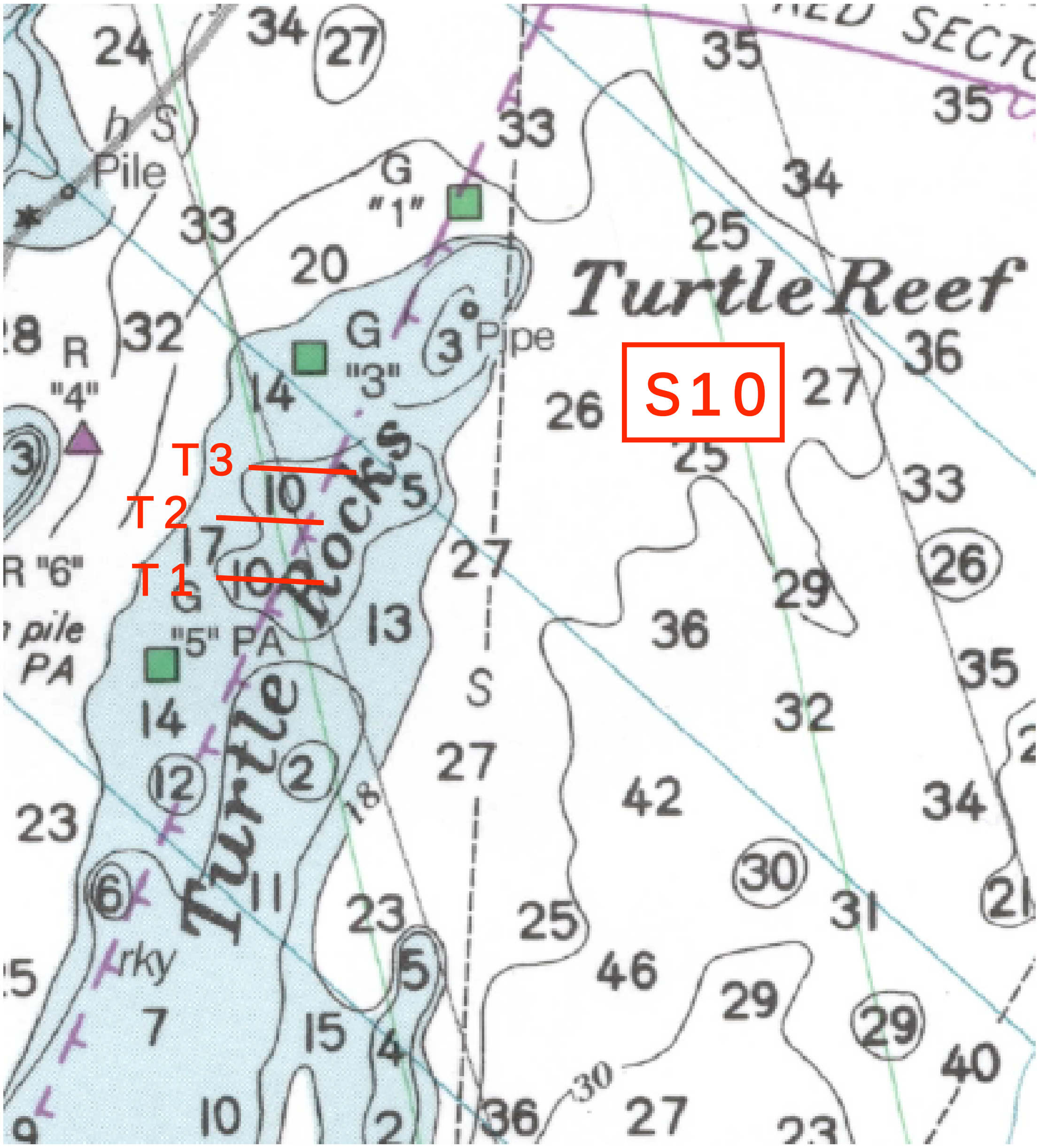

Figure 20. Location of transects. Site 10. Turtle Rocks (National Ocean Survey Chart 11462).

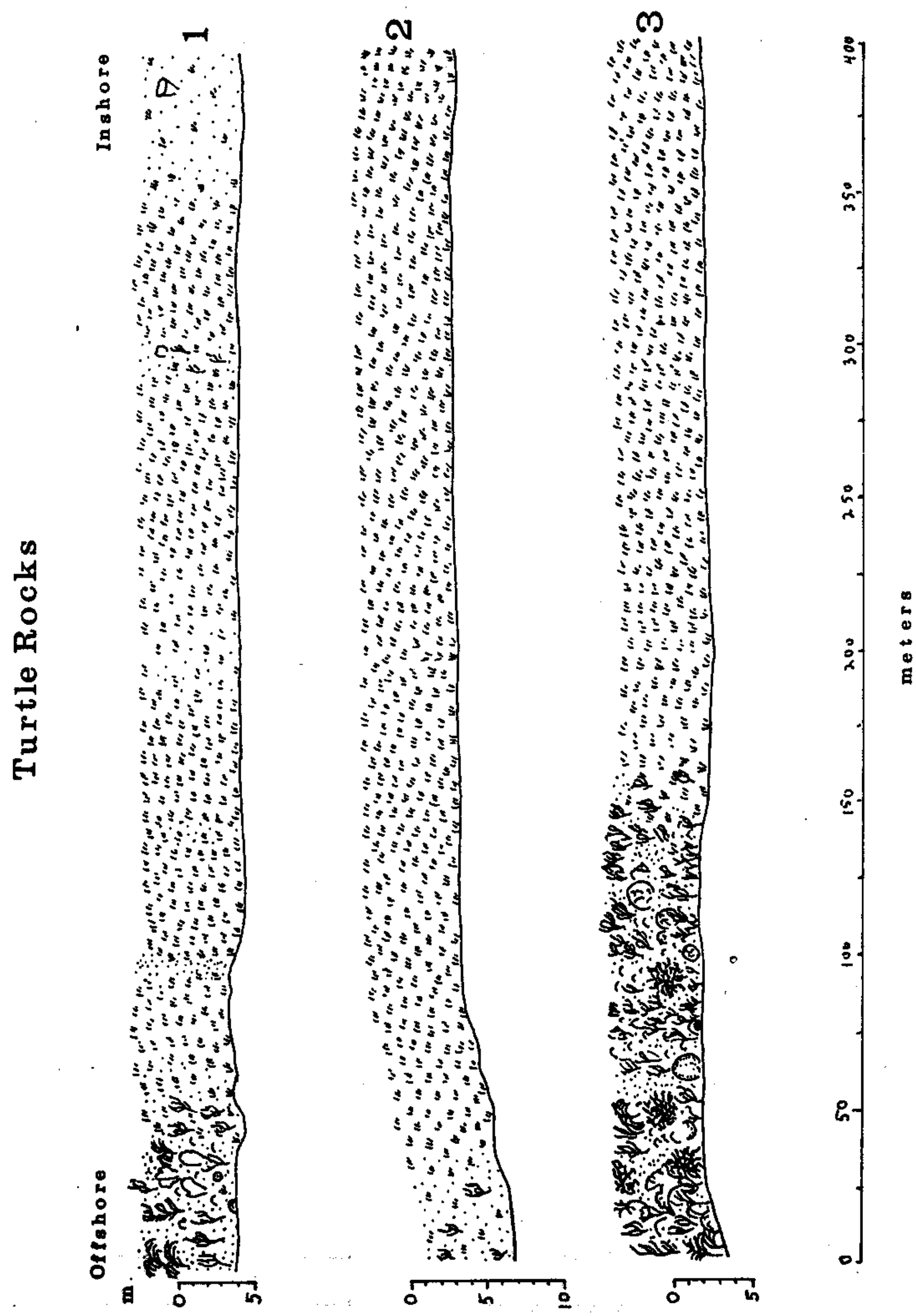

Figure 21. Pictorial transect profiles. Site 10. Turtle Rocks.

4.11. Site 11. Ocean Reef

This site lies just offshore of the Ocean Reef Club at the north end of Key Largo. Three 400-m transects (Figure 22) were made at a nearly constant depth of 4 m. Transect 1 was run on a heading of 288° true and ended 500 m from navigation marker "2," bearing 288° true. Transect 2 was parallel to Transect 1 and 300 m to the northeast. Transect 3 was 300 m to the southwest of Transect 1.

The entire area (Figure 23) was covered by an almost pure stand of *Thalassia* within which no *Syringodium* was seen. This seems to indicate that this was a mature, unstressed *Thalassia* meadow. The grass blades were long and wide and appeared healthy. The entire area was closely peppered with sand mounds often averaging 3 - $4/m^2$.

Algae were not plentiful and were nearly restricted to *Halimeda monile*, *H. tuna* and *H. incrassata*, shaving brush alga, *Penicillus capitatus,* and *Rhipocephalus phoenix.* Few sponges were seen. Those present were the green sponge, *Haliclona viridis,* chicken-liver sponge, *Chondrilla nucula,* and an unidentified demospongiid. One sea whip, *Plexaura lamourouxi*, represented the coelenterates.

Seven species of mollusks were noted. Of these, the tiger lucina, *Codakia orbicularis,* must be considered common. Other invertebrates were a single starfish and some ascidians.

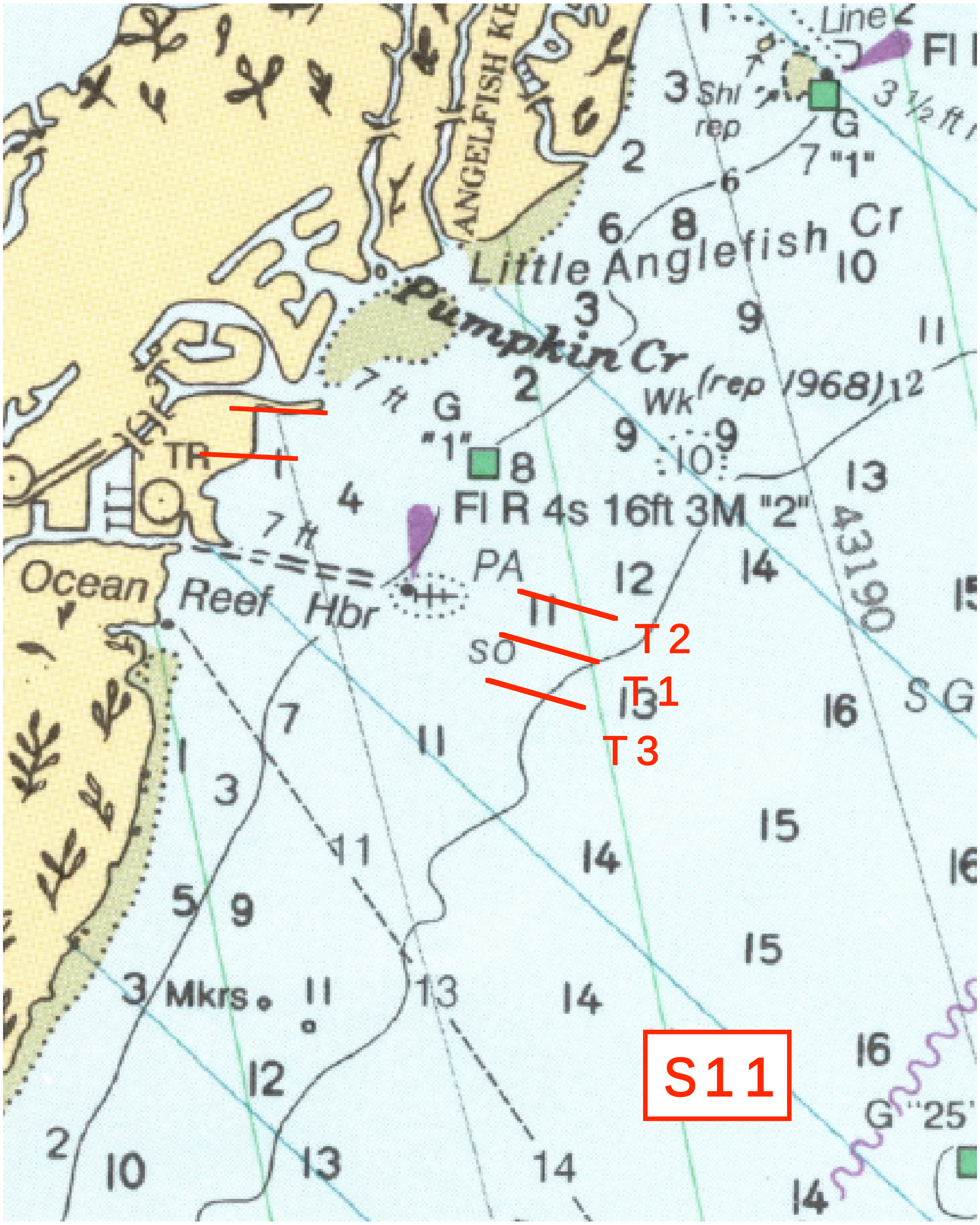

Figure 22. Location of transects. Site 11. Ocean Reef (National Ocean Survey Chart 11462).

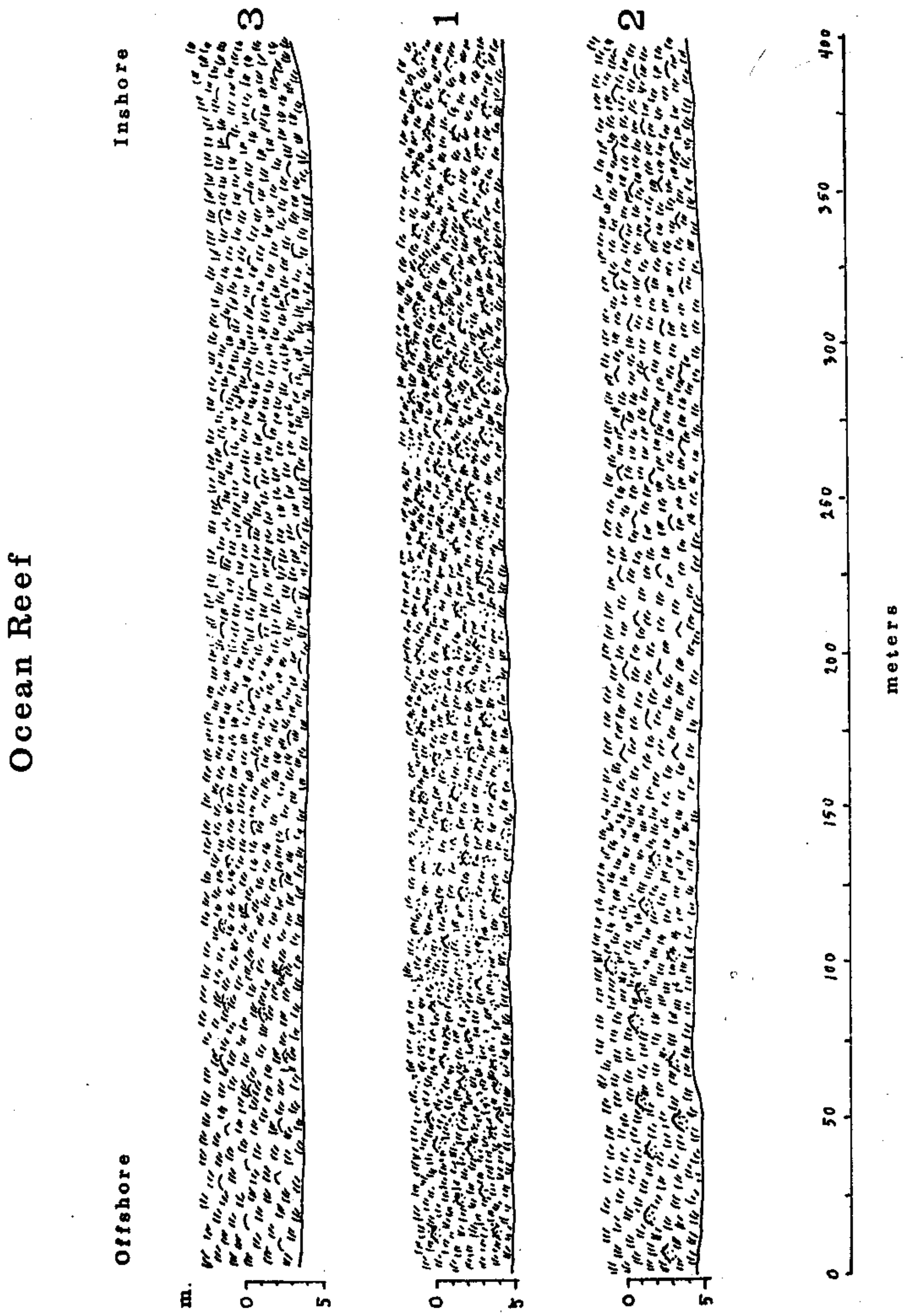

Figure 23. Pictorial transect profiles. Site 11. Ocean Reef.

4.12. Site 12. Turtle Harbor

Three transects (Figure 24), each 400 m long, were made north or shoreward of Turtle Harbor Anchorage in from 4.5 - 6.6 m depth. The transect profiles were nearly flat. Transect 1 was started about 100 m inshore of navigation marker "27" on a range with Carysfort Light and was run on a heading of 318° true. Transect 2 was parallel to Transect 1 and 300 m southwest; Transect 3 was also parallel and 300 m to the northeast.

The Turtle Harbor site consisted of a lush turtle grass meadow (Figure 25). The blades were long, wide, and appeared healthy. There was very little admixture of other species of plants, these being mainly *Penicillus*, *Halimeda, Udotea* and *Avrainvillea*, all nearly obscured by the grass blades. Very little *Syringodium* was present.

One large loggerhead sponge, *Spheciospongia vesparia*, was recorded near the beginning of Transect 3.

A few tube worms were attached to the grass blades and one medusa worm, *Loimia,* was recorded. There were very few sand mounds in the area except near the inshore end of Transect 3.

Transect 3 was somewhat more open because of the sand mounds and most of the algae noted were found on this transect as well as the mollusks, *Codakia orbicularis*, *Laevicardium laevigatum* and *Linga pensylvanica*.

A single holothurian, *Actinopyga agassizi,* and two sea urchins, *Lytechinus variegatus,* accounted for all of the echinoderms seen.

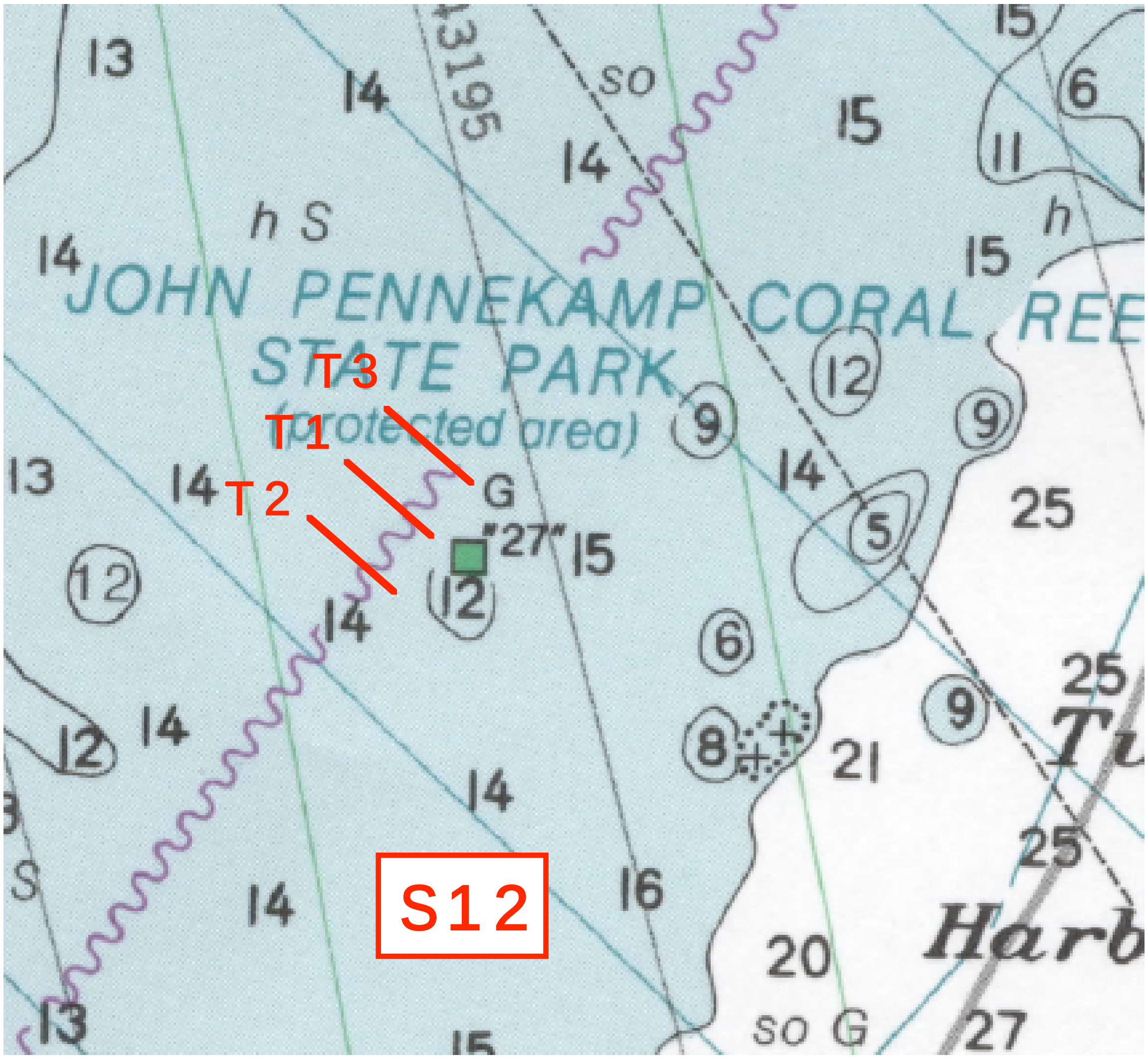

Figure 24. Location of transects. Site 12. Turtle Harbor (National Ocean Survey Chart 11462).

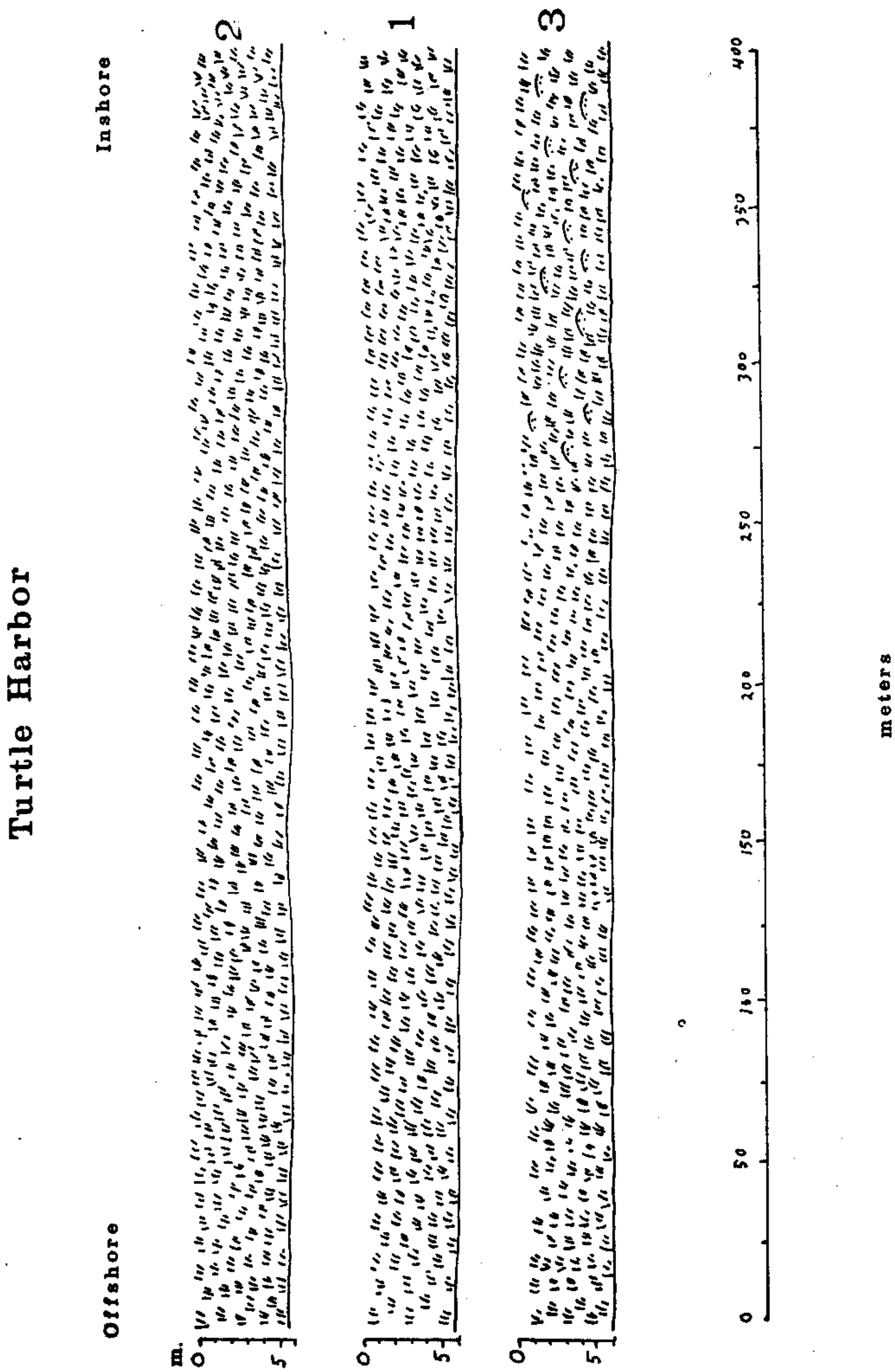

Figure 25. Pictorial transect profiles. Site 12. Turtle Harbor.

4.13. Site 13. North Channel

This site (Figure 26) lies off Garden Cove, the northern entrance to Largo Sound. Three transects were run, each 400 m long. Transect 1 began at the base of marker "32" and was run shoreward toward the wreck on a bearing of 278° true. Transect 2 was run parallel to Transect 1, 300 m to the southwest and Transect 3, a similar distance to the northeast. The depths varied from about 4.6 m at the offshore end to little more than 1.5 m depth as the transects passed over a rocky bar (Figure 27). The bar is covered with a thin layer of white silty sand too thin to permit the growth of turtle grass, but offering firm attachment for a wide assortment of inshore hardbottom algae and invertebrates.

The turtle grass beds offshore had the usual grass bed associates such as the algae *Halimeda incrassata*, *H. monile*, mermaid's wine glass, *Acetabularia crenulata*, mermaid's fan, *Udotea* flabellum, *Avrainvillea nigricans,* shaving brush, *Penicillus*, *Rhipocephalus* and others. Sponges were represented by *Aplysina cauliformis,* green sponge, *Haliclona viridis, Ircinia felix*, chicken liver sponge, *Chondrilla nucula,* and several others. Grass bed corals were represented by the rose coral, *Manicina areolata*, small finger coral, *Porites divaricata,* and clubbed finger coral, *E. porites.* Sand mounds were present.

As the transects preceded shoreward, the turtle grass thinned out and the bottom changed to an underlying hard rock covered over by a thin layer of silt and sand, not deep enough for turtle grass rhizomes to develop. Wherever the rock or small stones were uncovered, various green algae such as *Penicillus, Acetabularia, Dasycladus, Rhipocephalus, Anadyomene, Udotea Caulerpa*, *Halimeda* and others, and various reds such as *Gracilaria, Laurencia*, and *Colpomenia* partially covered the bottom. At this site only, the filamentous green alga *Enteromorpha* was common, noted throughout the hardbottom area. This alga is often considered as an indicator of various types of pollution or environmental stress.

Most notable of the algae was the brown Gulf weed, *Sargassum pteropleuron*, that grows profusely on top of the rock bar. In 1948, this sargassum grew so densely here and at South Channel that at low tide it formed a golden band along the sea surface and motor boats had difficulty getting through it because it fouled their propellers (Voss, 1948).

Sponges noted were two species of *Ircinia, Aplysina cauliformis,* several species of *Spongia* and *Niphates digitatus*. Vase sponges and loggerheads were seen in the photographic survey.

Only small inshore species of corals were present, *Siderastrea siderea*, *Porites furcata* and the stinging coral, *Millepora alcicornis,* but alcyonarians were numerous: *Pseudoplexaura flagellosa, Pseudopterogorgia acerosa*, and the sea whip, *Pterogorgia anceps*.

Few mollusks were seen, among which were *Glycymeris, Chione* and *Arca*.

Several species of polychaetes were found. Both amphinomids and sabellids were among the rocks. The golden tube worm, *Cistenides gouldi,* the star feather worm, *Pomatostegus stellata,* and a *Marphysa* were identified.

A few ophiuroids were seen and *Ophionereis squamata* was collected. The common sea biscuit *Clypeaster rosaceus,* occurred frequently.

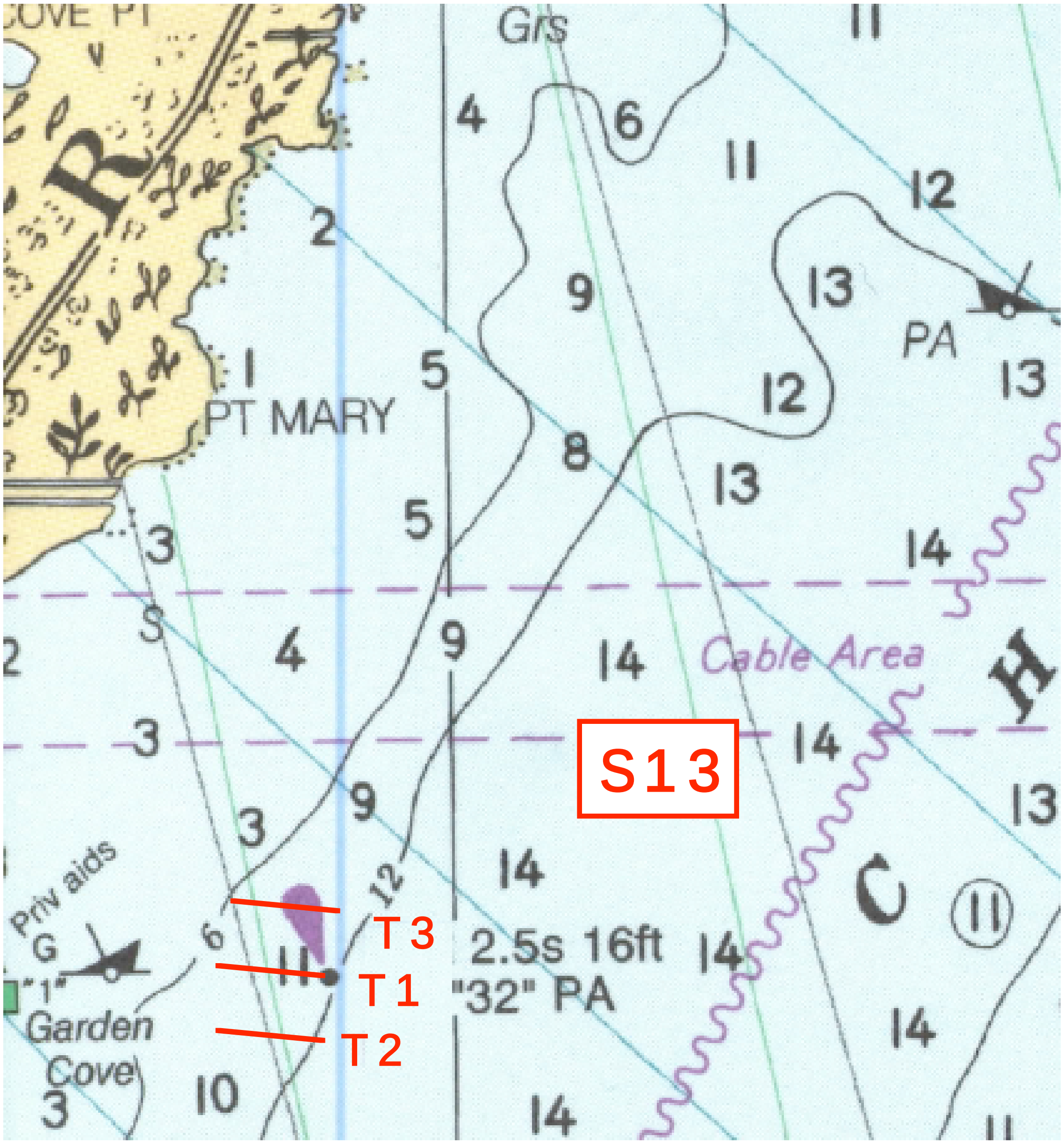

Figure 26. Location of transects. Site 13. North Channel (National Ocean Survey Chart 11462).

Figure 27. Pictorial transect profiles. Site 13. North Channel.

Regrettably, the survey was not notified of the new development of Port Bougainville, then being constructed inshore of the site. Park officials have stated that the proposed channel for the marina is west of the marker between it and the wreck in deep mud and turtle grass meadows. Transect 2 lies closest to this area. If Port Bougainville becomes active, transects should be made over the proposed traffic area to monitor changes to the turtle grass. The present survey should show changes if boat traffic follows the marked channel now in use.

4.14. Site 14. South Channel

Three 400-m transects (Figure 28) were made off the South Channel to Largo Sound. Transect 1 started at navigation marker "2" and ran shoreward on a heading of 328° true. Transects 2 and 3 were spaced 300 m apart proceeding northeastward from and parallel to Transect 1. The general depth was 4 m (Figure 29). This area is used by boats coming out of Rock Harbor and Largo Sound as well as marinas along the shore. It offers deeper water for boats entering and leaving Largo Sound than is found at North Channel leading out of Garden Cove.

Near marker "2", the bottom was generally covered with turtle grass, fairly lush seaward of the marker but shorter leaved and more scattered as the sand layer above the underlying rock became thinner. The grasses were interspersed with *Halimeda,* various sponges, and with occasional mollusks, *Codakia* and *Astraea*.

At around 50 to 100 m, the *Thalassia* beds gave way to the flora and fauna associated with hardbottom overlaid by a thin superficial layer of sediments. This hardbottom rock bar is a part of the same bottom encountered at North Channel but is deeper.

The bottom from this point shoreward for over 300 m showed little variation in life. The bottom was nearly covered with patches of low, matted, filamentous algae, both greens and reds. Throughout the area the bottom was peppered with small upright plants of *Penicillus*, *Dasycladus*, *Batophora*, *Rhipocephalus*, and *Halimeda* and the fanlike *Udotea*, and *Avrainvillea*. Because of their upright growth pattern they frequently resembled miniature forests. Among these algae were single plants or patches of larger red algae, the prickly appearing *Acanthophora* and the knobby *Laurencia*. The latter sometimes breaks loose from its holdfast and forms floating mats on the bottom.

Sponges were not numerous. They consisted mainly of *Ircinia campana* and *I. strobilina, Haliclona viridis* and its associate the white sponge, *Geodia gibberosa*, *Aplysina cauliformis*, *Niphates*, the little blue heavenly sponge, *Dysidea etheria,* and occasional large loggerheads, *Spheciospongia vesparia*.

The corals encountered were all small. The starlet corals, *Siderastrea radians* and *S. siderea,* were perhaps the most common along with small heads of the star coral, *Favia fragum,* and pillars of the lobed star coral, *Solenaster hyades*. One of the most characteristic components of the bar was the alcyonarians. The large sea feathers were very scattered but the angular sea whip, *Pterogorgia anceps*, and certain others were prominent.

More mollusks were found here than in the other inshore locations. Nine species were listed in the quadrats of which the commonest was *Arca zebra* with *Astraea tecta* next. In the grass beds, *Codakia orbicularis* was noted along with the turtle grass denizen *Modulus modulus*.

The variegated urchin, *Lytechinus variegatus,* was moderately common and two ophiurans, *Ophioderma rubicundum* and the little striped *Ophiothrix oerstedii,* were found in rocky crevices.

This site is subject to medium to heavy boating activity, but this may not be responsible for the apparently poor health of the region as indicated by the condition of the turtle grass and the appearance of the hardbottom. The amount of filamentous algae present may have been a reflection of the long, warm summer. Certain algae bloom in late summer in this region and large areas of Largo Sound often used to be draped with filamentous algae near the end of the summer (Voss, personal observations). The present area should be monitored to determine if the condition noted is a long term or a seasonal change.

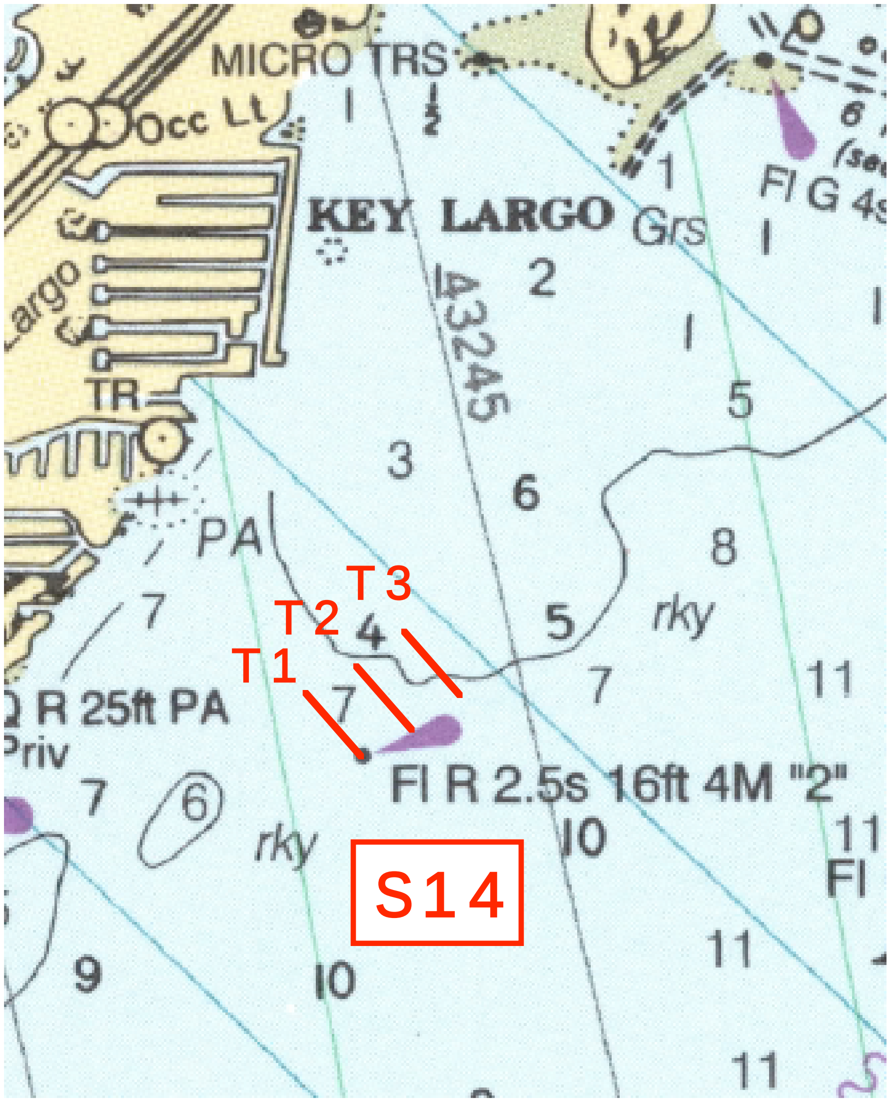

Figure 28. Location of transects. Site 14. South Channel (National Ocean Survey Chart 11462).

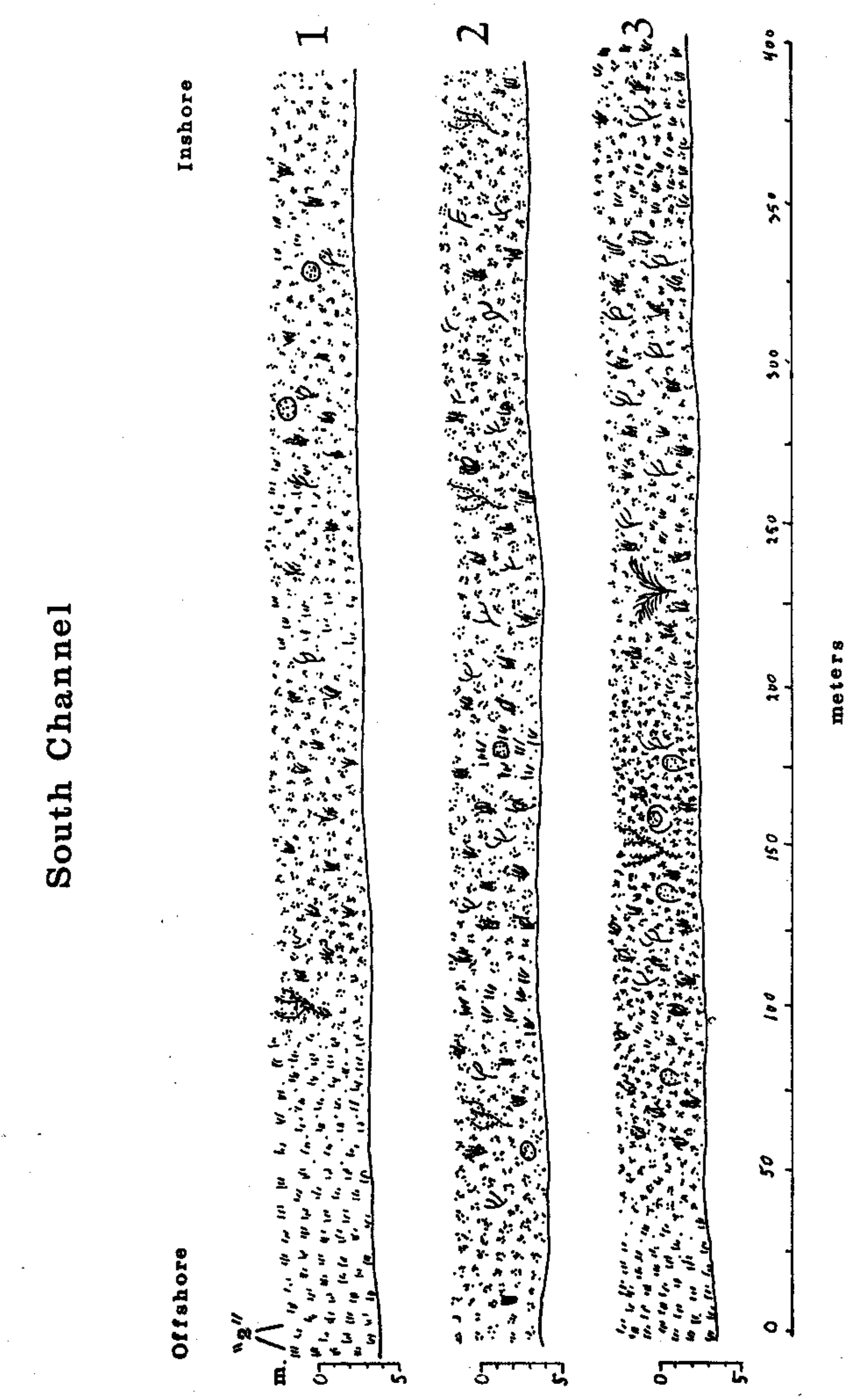

Figure 29. Pictorial transect profiles. Site 14. South Channel.

4.15. Site 15. Rock Harbor

Three 400-m transects (Figure 30) were run offshore of Rock Harbor immediately east of Rodriguez Key on a heading of 278° true. The depth was nearly constant at between 2.7 - 4 m (Figure 31). The bottom was silty sand covered by a growth of *Thalassia* with a small mixture of *Syringodium*. The bottom was thickly spotted with sand mounds about 15 cm in diameter, probably made by a callianassid shrimp. The mounds showed in nearly every picture from the photographic survey.

Small plants of *Halimeda incrassata* were scattered throughout the transects with an occasional *H. opuntia triloba* and *H. monile*. Other green algae were *Penicillus capitatus, P. dumetosus*, *P. lamourouxi*, *P. pyriformis*, *Acetabularia crenulata*, *Udotea flabellum*, *Rhipocephalus phoenix*, *Avrainvillea nigricans*, *Dictyosphaeria cavernosa, D. vanbosseae* and the red alga *Gracilaria* sp.

Few sponges were seen and no large loggerheads. The chicken liver sponge, *Chondrilla nucula,* was sparse. *Haliclona compressa, H. viridis, Ircinia strobilina*, and *I. felix* were found on the transects as well as *Aplysina cauliformis* and a species of *Tethya*. *Lissodendoryx sigmata* was seen only once.

The corals were all characteristic of turtle grass beds. They included *Porites divaricata, P. furcata* and the tube coral, *Cladocora arbuscula*. One *Manicina areolata,* the rose coral, was noted in the quadrats.

While this area should have been suitable for the occurrence of bivalve mollusks, none were noted. Gastropods were present such as *Astraea tecta, A. phoebia, Tegula fasciata* and *Calliostoma jujubinum*.

Echinoderms were represented by the sea urchin *Lytechinus variegatus*, an ophiuroid, *Ophioderma brevispinum,* and a sea cucumber, *Astichopus multifidus*. A tunicate, *Didemnum candidum*, was noted.

Because of the silty water, visibility was greatly reduced and therefore the photographic survey was poor.

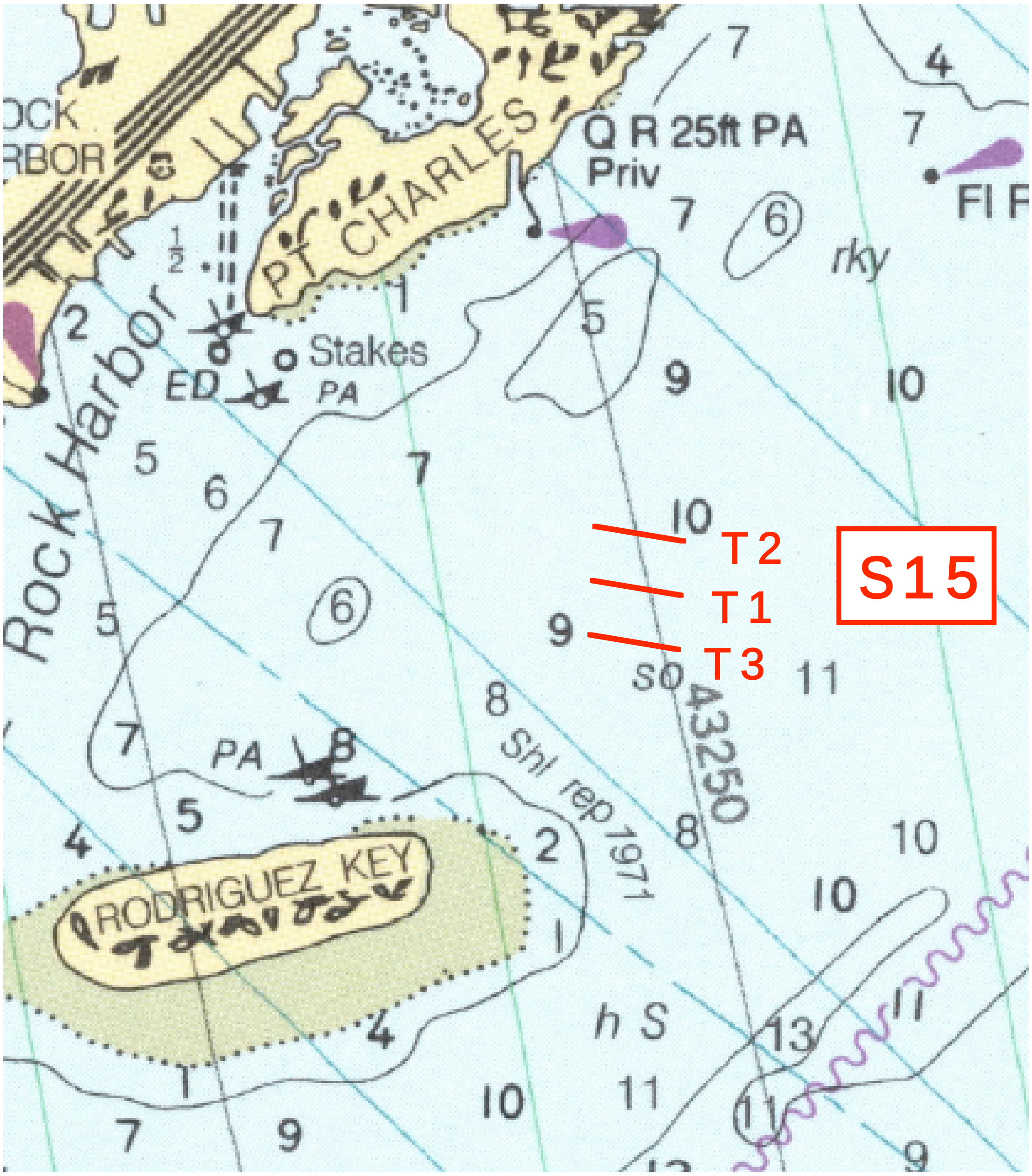

Figure 30. Location of transects. Site 15. Rock Harbor (National Ocean Survey Chart 11462).

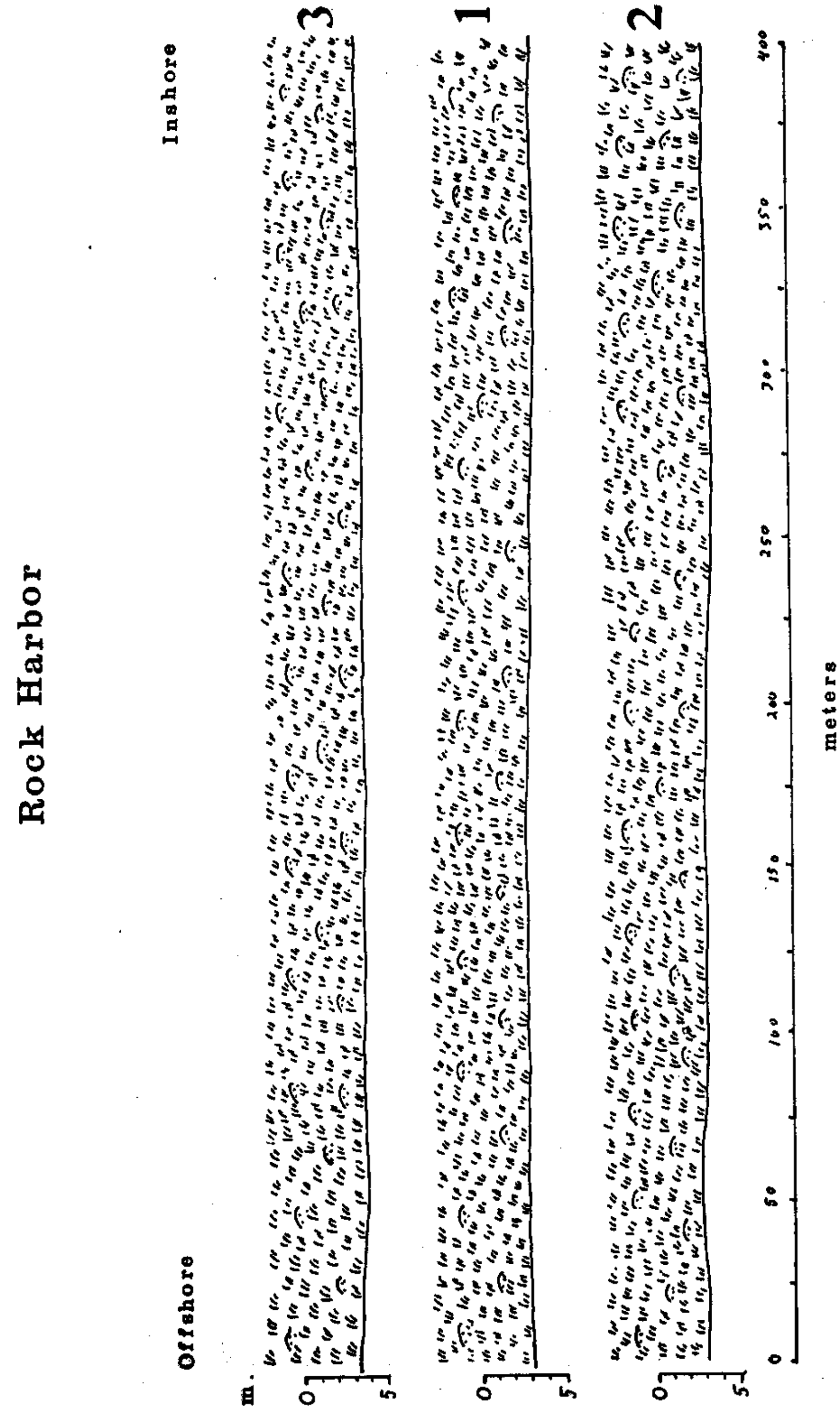

Figure 31. Pictorial transect profiles. Site 15. Rock Harbor.

4.16. Site 16. Point Elizabeth

Three 400-transects were run just offshore of Point Elizabeth (Figure 32) in about 4 m depth. The bottom was deep silty mud/sand covered by a rather lush growth of *Thalassia* (Figure 33). The bottom was pockmarked with sand mounds about 15 cm in diameter made by a callianassid shrimp of which none were seen or captured. These mounds averaged 2 - 3 in each square meter as can be seen in the survey pictures.

Scattered throughout the area were small plants of *Halimeda* of which *H. opuntia triloba* was most common, followed by *H. tuna* and *H. incrassata*. *Penicillus capitatus* was also common.

Because of the deep silt substrate few sponges occurred. Those present were mainly species of *Haliclona* and *Callyspongia fallax*. Surprisingly, no *Chondrilla nucula*, the chicken liver sponge, were noted. Worms were *Eunice unifrons*, terebellids and sabellids.

By far the most numerous large invertebrate was the bivalve mollusk *Codakia orbicularis* which was noted numerous times on all three transects. It was accompanied by four other bivalves, the common *Chione cancellata, Diplodonta punctata, Linga pensylvanica*, and *Anadara notabilis.* The gastropods *Strombus raninus, Calliostoma jujubinum, Astraea phoebia* and *Modulus modulus*, as well as a single octopod, *Octopus joubini*, were also seen.

Several unidentified holothurians and a single *Lytechinus variegatus* were listed.

More species of large organisms than those mentioned above may have been present but did not show in the photographs because of the poor visibility in the silt-ladened and murky water.

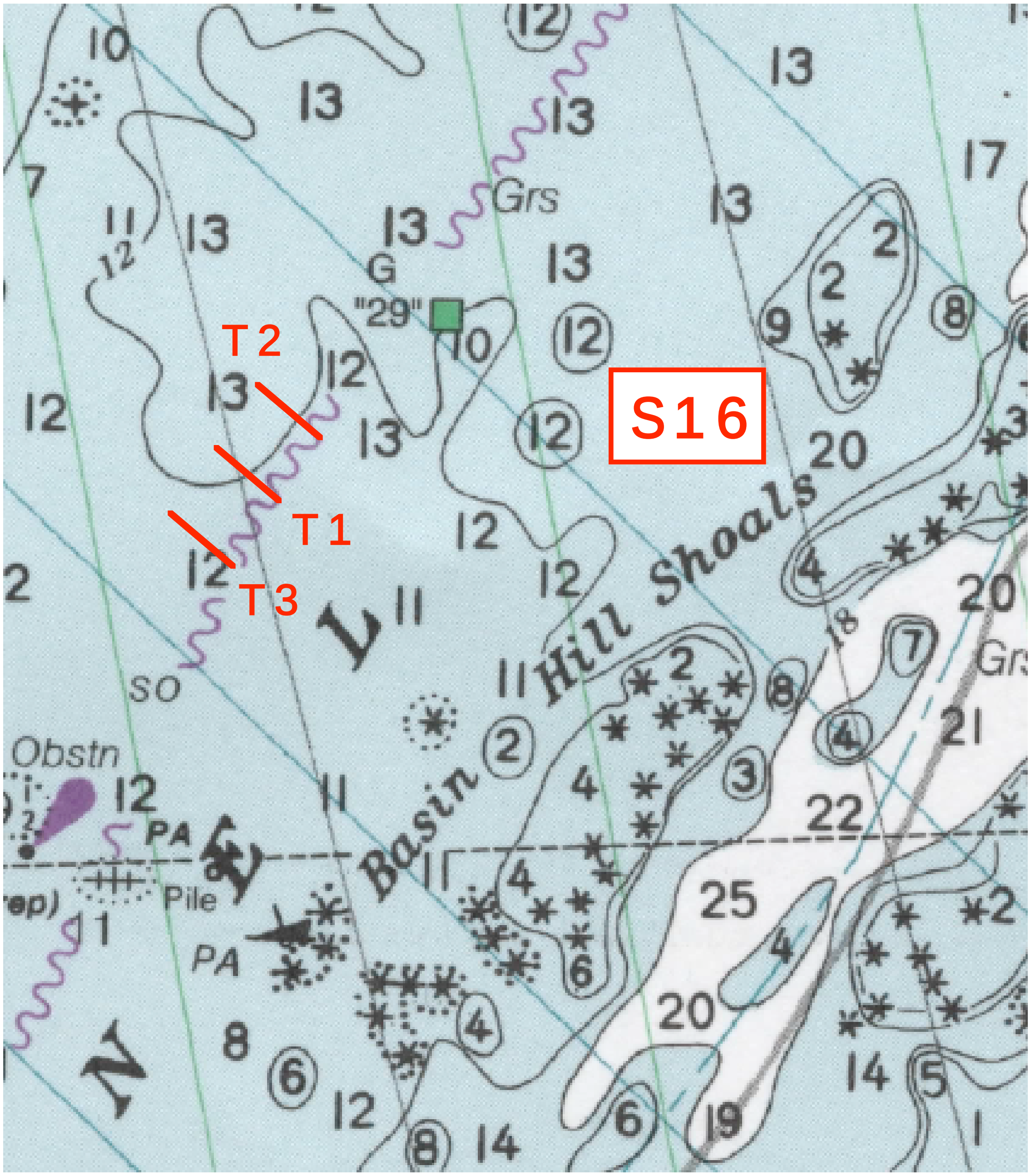

Figure 32. Location of transects. Site 16. Point Elizabeth (National Ocean Survey Chart 11462).

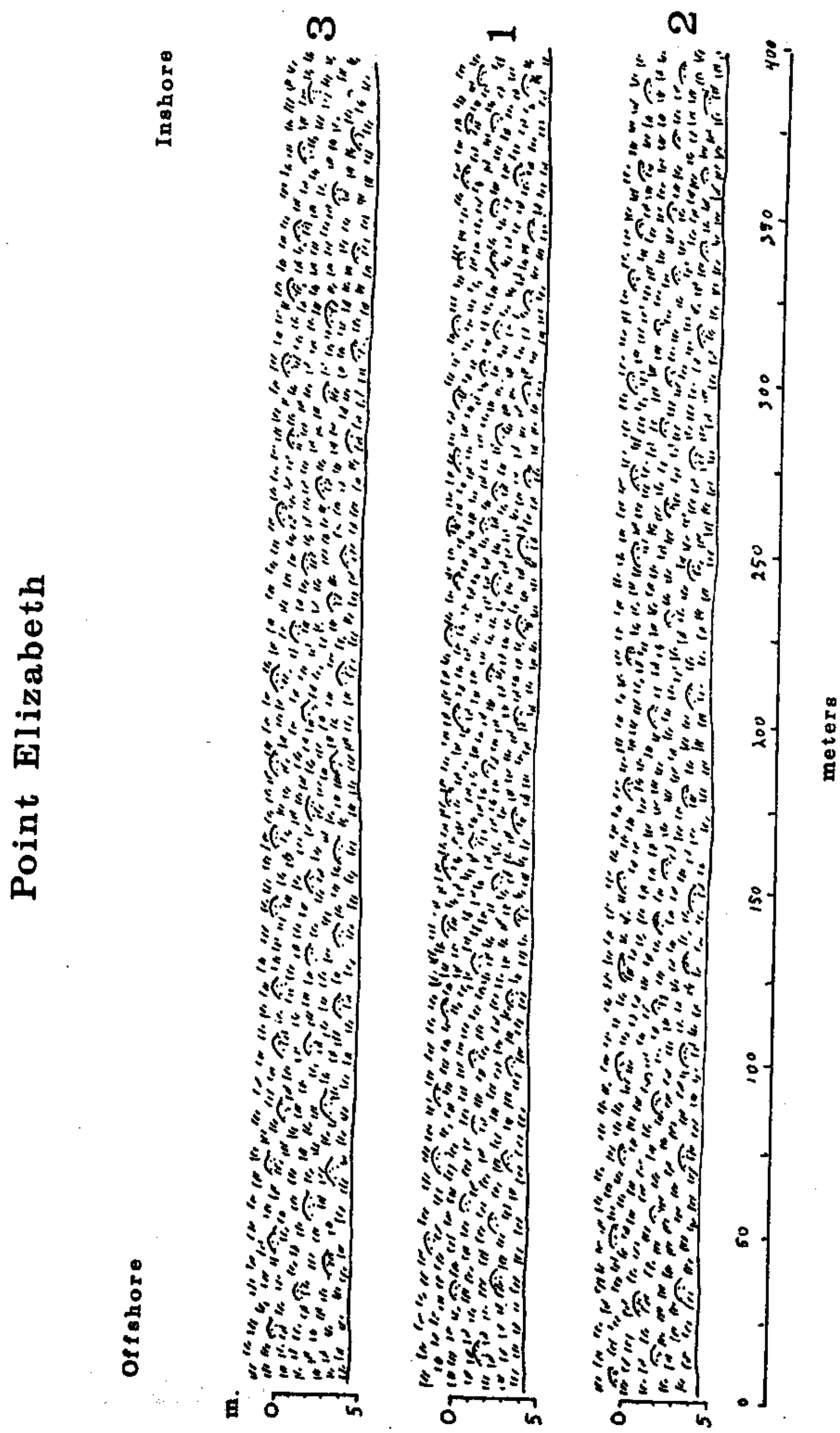

Figure 33. Pictorial transect profiles. Site 16. Point Elizabeth.

4.17. Site 17. Angelfish Creek

The Angelfish Creek site (Figure 34) is located offshore of Angelfish Creek between navigation marker "2" and the entrance to the creek. It is in a seagrass area and little variation was found over the area surveyed.

Three 400-m transects were run at the site. Transect 1 started at navigation marker "2" and was run inshore on a heading of about 278° true toward marker "PA" at the creek entrance. Transect 2 was run northeast of marker "2". Transect 3 was southwest.

Transect 1 varied in depth from 3 to 7 m. Transects 2 and 3 were on level bottom and maintained a depth of 6 m throughout.

All of the transects (Figure 35) ran over lush seagrass meadows with no hardbottom except for the last 10 m of Transect 1 which ended in a hardbottom area inhabited by sea feathers, sea whips, and some *Siderastrea*.

The grass appeared very healthy. There were considerable areas in which *Syringodium* formed a large percentage of the cover but *Thalassia* dominated most of the bottom.

The last 100 m of Transect 2 does not show in the pictorial profiles as the film for this area was accidentally exposed.

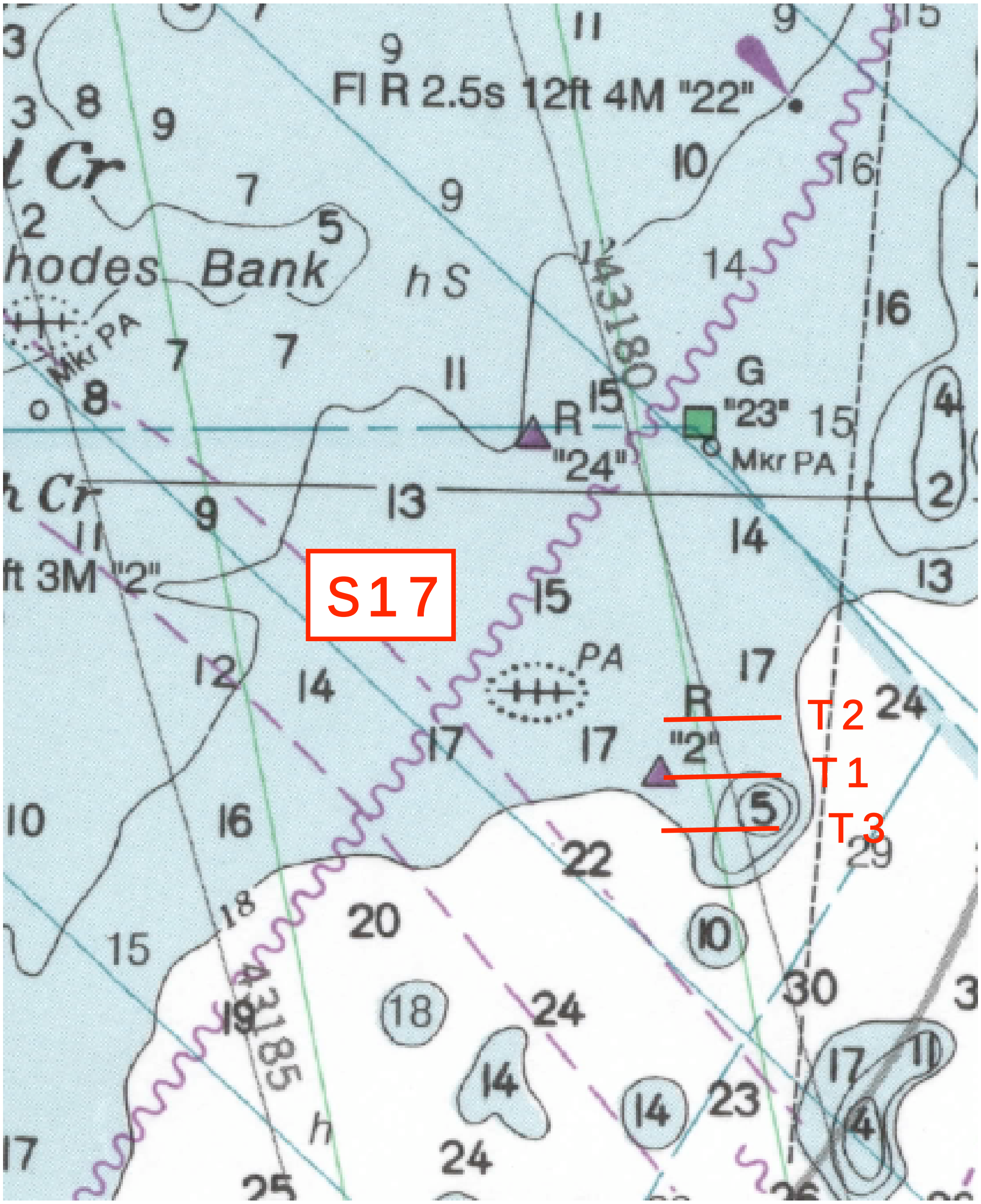

Figure 34. Location of transects. Site 17. Angelfish Creek (National Ocean Survey Chart 11462).

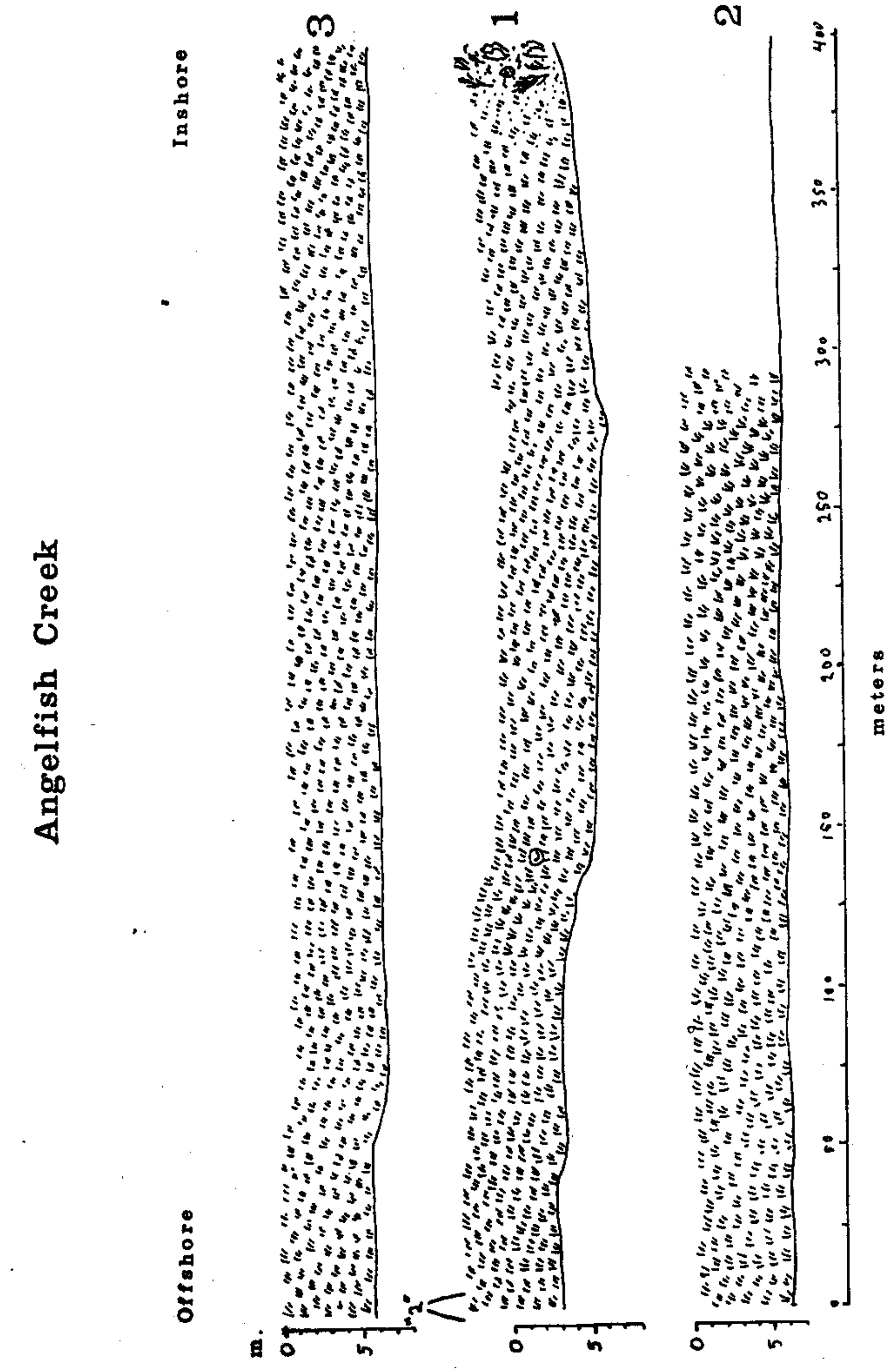

Figure 35. Pictorial transect profiles. Site 17. Angelfish Creek.

5. REEF STRUCTURE AND ZONATION

In this and the following sections, the terms Outer Reefs and Patch Reefs are used as defined in the section Description of the Study Area.

5.1. Outer Reefs

The structure and zonation of the outer reefs conform to a general pattern that varies in some features from reef to reef. All of the reefs are built upward from a Holocene fossil reef that underlies much of the edge of the reef tract platform. Where the fossil reef projects above the carbonate sediments, living corals became established and grew upward. The present live corals are growing upon a base of old dead corals and coral rubble.

Spurs and grooves are found on the upper fore reef slope of most of the outer reefs with the notable exception of Carysfort Reef (Jones and Thompson, 1978). Shinn has investigated spur and groove formation in the Keys (Shinn, 1981; Shinn *et al.*, 1981). According to him, the spurs are formed of old fossil *Acropora palmata* or reef rubble on which living coral is now growing. The spurs in the upper part of the reef bear A. *palmata* or *Millepora,* while lower on the slope the spurs are formed of *Montastraea*. The area between the spurs is filled with loose shifting sand preventing the growth of corals in the grooves. Shinn considered that spurs and grooves in living coral reefs are constructional, not erosional, in origin.

A constant feature of all of the outer reefs is the presence of terracing. This begins offshore with a broad, flat sand terrace that may be several nautical miles wide, extending from the foot of the reef slope to the edge of the drop off into the Straits of Florida canyon. Its upper limit lies at about 70 m depth. Here a strong slope leads upward to the second terrace composed (Jameson, 1981) of lithothamnion cobble. From the cobble zone the reef slope again rises at a depth of 35 to 45 m as the Deep Coral Reef. This reef, rising to about 25 m depth forms a ridge behind which lies another sand terrace that extends upward to within the depths covered by the present study. Unfortunately, Jameson's profiles (1981, Figures 13 - 15) are very diagrammatic and no definite locations for the profiles are given other than "The Elbow," "French Reef," and "South Carysfort Reef", so that direct comparisons with the profiles of the shallow reefs are difficult.

Shoreward of the Deep Coral Reef is another broad terrace of calcareous sands extending to near the base of the upper reef slope or face. This sand terrace rises to a depth of about 15 - 18 m depth. Above this a nearly constant feature is a series of small terraces or ridges and valleys lying parallel to the reef axis. The seaward slopes and the tops of the ridges are formed of hardbottom and low, cemented or partially cemented rubble. These slopes and ridges have an average elevation of about 2.5 to 4 m. The surface is covered with corals, mainly *Montastraea,* sponges, alcyonarians, and other characteristic hardbottom life. Behind and shoreward of these ridges lie valleys of nearly bare calcareous, shifting sands. The valleys may have a width of only 10 - 15 m to as much as a hundred meters, At Molasses Reef, the ridges and valleys are low and narrow, but they are high and wide at French Reef.

After about three or four of the alternating ridges and valleys, the reef crest is reached at about 7 - 8 m depth. The lower part is often marked by large *Montastraea,* but these are displaced above by *Acropora palmata* and *Gorgonia ventalina*. Behind the crest is the reef flat. The reef ends in the back reef with coral rubble blending into the seagrass meadows.

Zones, as can be seen from the above description, are often difficult to delimit. At Grecian Rocks, Shinn (1980) showed 5 zones proceeding from seaward toward the Hawk Channel: (1) Rubble Zone, (2) *Millepora*/*Montastraea*. Zone, (3) *Acropora* Zone, (4) Reef Flat, and (5) Back Reef.

At Key Largo Dry Rocks, however, in one area the zones are (1) Rubble Zone, (2) *Millepora* Zone, (3) *Acropora* Zone, (4) Reef Flat, while in another section it is (1) Rubble, (2) *Acropora* with no reef flat in the customary sense of large coral rubble, alcyonarians, a few corals and sponges.

If the zones are followed from the outer platform in 80 - 90 m shoreward, they might be listed as (1) Sand Zone, (2) Lithothamnion cobble Zone, (3) Deep coral Reef, (4) Sand Zone, (5) Ridge and Valley Zone, (6) Rubble Zone, (7) *Millepora/Montastraea* Zone, (8) *Acropora* Zone, (9) Reef Flat, and (10) Back Reef.

Apparently the basal Holocene reef formation dictates much of the zonation in the upper 18 m of the reef, while the terrace ridges and the Deep Coral Reef are old shorelines of the Pleistocene period.

With the many bottom differences described above, it is difficult to give a single zonational pattern that will fit all of the outer reefs of the Sanctuary or even all sections of a single reef. Reef structure reflects the diversity and defies attempts to depict order in them.

5.2. Patch Reefs

Patch reefs in the Sanctuary are numerous and range from only a few meters in diameter to a few nearly 100 m across. They may be single reefs growing on rock outcrops surrounded by turtle grass or a series of reefs such as at Mosquito Bank.

Regardless of their size and position, the patch reefs show a greater general similarity than was found in the outer reefs. Small patch reefs are usually formed of clusters of primarily *Montastraea annularis* rising abruptly from the surrounding seagrass meadows. The base of the reef is surrounded by a narrow band or "halo" of bare sand. If the patch reef has coral rubble in the center, alcyonarians, primarily sea feathers and sea fans, will be growing on it. Some small patch reefs have almost no coral rubble. In large patch reefs, the large *Montastraea* and other head-forming corals grow mainly around the perimeter of the patch and the center of the reef will be formed of scattered *Montastraea*, patches of *Acropora palmata* and *A. cervicornis* with masses of sea fans, sea feathers and sea whips. In very large patch reefs the center of the reef might be termed a reef flat. Due to their location on the banks, patch reefs show little difference in coral growth or zonation from inshore to offshore or vice versa unless one side or the other borders on a channel with deeper water which alters and increases coral growth.

Zonation in patch reefs, where it occurs, typically would be (1) *Montastraea*/coral Zone, (2) Rubble Zone, (3) *Montastraea*/coral Zone. In some patch reefs only a coral zone is evident.

Patch reefs, being built up by large boulder type corals growing one atop the other, often have a honeycomb to cavernous interior. At Abaco in the Bahamas, Storr (1964) found that the entire center of many patch reefs were hollow and that by prizing away some of the coral heads he could swim or crawl into the central cavern and, in some cases even stand upright inside the reef. While such extremes of solution of the central part of patch reefs have not been found in the Florida reefs, the honeycombing and solution is sufficient for the reef to form a living tenement house for swarms of fish which are not seen outside of the reef. Poisoning of small patch reefs at Margot Fish Shoal north of the Sanctuary revealed this large population of fishes supported inside the reef (Voss and Bayer, 1968).

6. DISCUSSION

6.1. Sanctuary and Park Habitats

In the preceding section the zones across the outer reefs and patch reefs were described: rubble, *Millepora, Millepora*/*Montastraea, Acropora* reef flat and back reef. In describing the general habitats within the confines of the Sanctuary and Park covered by this study, five large habitats may be seen: coral-sea fan, rubble, hardbottom, sand and seagrass meadows. Inshore of the study area another might be listed as a coral/coralline habitat. This is found along much of the intertidal and shallow waters bordering the seaward side of the keys and is composed of low growths of *Porites furcata* and a mixture of coralline algae such as *Jania*, *Amphiroa* and *Goniolithon* along with various species of the calcareous alga *Halimeda*. It is not discussed further here but is worth future study.

The five habitats are distinct and easily recognized, wherever they occur. In various areas, however, their borders may be ill-defined. For example, the rhizomes and blades of turtle grass may invade the edges of the reef flat rubble, there may be patches of sand scattered within both seagrass and rubble, and small patches of corals and sea fans may be found within the rubble. Nonetheless, the habitats remain distinct with these minor exceptions.

In most of the habitats, one or more species are dominant. The seagrass habitat is formed primarily of the turtle grass, *Thalassia testudinum* and manatee grass, *Syringodium filiforme*. Characteristic organisms grow attached to their blades and the whole warrants being called the turtle grass community as Thorson (1957) has done for the level sea-bottom communities. Following the Thorson system, the coral-sea fan habitat could similarly, because of its dominance, be termed, the coral-sea fan community. No such general community designations coincide with the hardbottom, rubble and sand habitats where a number of different communities may be found in each habitat.

It had been the intention, in this survey, to document, if possible, a number of the communities in the study area. It was soon realized, however, that transect surveys, even if species were documented at 1-m intervals, would not yield community data except for large organisms, i.e. alcyonarian community, coral community and grass community. For community designation, numerous repetitive quantitative sampling stations are required to establish the relationships between the species both by numbers and biological connections. Recurrent Groups Analysis as applied by Bayer *et al.* (1970) for Panamanian waters could not be validly applied from the present data.

In the habitat accounts that follow, the descriptions are based mainly upon data from the present study with supplementary information drawn from other published and unpublished sources. Unpublished sources are from data sheets and field notes kept by Voss from over 35 years of field studies within the Sanctuary and adjacent waters.

6.1.1. Coral-Sea Fan Habitat

Three types of coral reefs are found within the boundaries of the Sanctuary: (1) deep coral reefs, not included in this study; (2) outer (barrier) reefs Molasses, French, the Elbow, Grecian Rocks, Key Largo Dry Rocks and Carysfort Reef; and (3) patch reefs Mosquito Bank, Basin Hill Shoals, White Bank Dry Rocks and Angelfish. With the exception of the deep coral reefs, all of the others lie in comparatively shallow water with major coral growth on the reefs occurring from approximately 10 m to the surface. The live coral area probably occupies no more than about 5 per cent of the total area of the Sanctuary and Park.

The live coral community is not a rich aggregation. When quadrats are made directly in pure stands of living coral few invertebrates and algae are found. The live coral quadrats in this study were made in mixed bottom of live coral and rubble so that both coral associated organisms as well as some rubble fauna and flora are included.

The coral-sea fan zone and habitat is typical of the shallow coral reefs of the Florida Keys and the Caribbean. It comprises most of the reef crest and extends into the reef flat on the outer reefs. It may comprise the entire reef in patch reefs.

6.1.2. Outer Reefs

On the outer reefs from about 9 to 7 m depth, the elkhorn coral, *Acropora palmata,* the staghorn coral, *A. cervicornis,* and the sea fan, *Gorgonia ventalina,* first appear together as the large dominant species. The staghorn coral is often absent on the reef face but has a wider depth range than the elkhorn coral, being recorded from the deep coral reef (Jameson, 1981). On the reef crest all three are usually present. Besides these three large, conspicuous species, the abundance of others is unnoticeable to the casual observer. In the smooth, cemented rock of the reef crest, heavily shadowed by these three species, a few other organisms occur. Lettuce coral, *Agaricia agaricia*, may be found growing at the base of *Acropora palmata* or under ledges or in crevices. It is particularly abundant at Carysfort Reef (Voss, 1949). The hardbottom under the corals is scoured by wave surges. Large, wave-battered old conchs, *Strombus gigas* and *S. samba,* and the vase shell, *Vasum muricatum*, often occur between the coral bases. The long spined black sea urchin, *Diadema antillarum,* is present, sometimes an the open bottom in calm weather but more often partially protected by crevices and overhanging coral.

The corals are "hosts" to a number of organisms. Several polychaete worms such as the star featherworm *Pomatostegus stellatus* and the horned featherworm, *Spirobranchus giganteus,* form calcareous tubes on or in living coral, especially head corals. Another polychaete, the green bristle worm, *Hermodice carunculata,* and the bearded worm, *Amphinome jamaicensis,* are found under dead coral slabs during the day but at night feed on the living coral polyps. Several small crabs form galls on the two species of *Acropora.* The coral snail, *Coralliophila abbreviata,* feeds on the polyps of *Acropora* and is particularly common on *A. palmata* from which over 114 specimens were collected from elkhorn coral in one patch on Carysfort Reef (Voss, 1948). Parrotfishes feed upon the coral polyps and their teeth marks are often seen on corals that have been grazed.

Sea fans are host to very small delicate gastropods *Simnia* spp. which often escape notice because of their camouflage coloration. Both sea fans and sea feathers also may have another gastropod which feeds on them, the brightly colored flamingo tongue, *Cyphoma,* of which there are several species on the outer reef. During calm weather they may be found anywhere on the alcyonarian, but during heavy wave action they descend to the base of the host. The grass shrimp, *Tozeuma carolinensis,* green colored when on grass, lives on the purple sea plume, *Pseudopterogorgia* acerosa; it is deep purple and not often seen unless the sea plume is brushed against (Voss, 1957).

Most of the free living invertebrate life of the coral-sea fan habitat is found during the day beneath old dead coral slabs. When these are turned over, the under surface may be coated with coralline algae or *Homotrema rubrum* and attached mollusk egg cases, sponges and tunicates, an occasional cowrie, *Cypraea* spp.; various small crabs, snakeskinned brittle stars, *Ophioderma* spp. and the comet star, *Linckia guildingi,* may be found below. A common gastropod is the miniature triton-trumpet, *Pisania pusio*. Many other species of invertebrates are known from the habitat.

Some of the most spectacular animals are the reef fishes many of which are illustrated in full color by Randall (1968). The fish census by Bannerot and Schmale (this volume) lists the fishes of the outer reefs, but does not designate the habitats. While certain fish species such as the French Angel, the blue parrotfish, Queen parrotfish, the Reef butterfly fish, Rock Beauty and Queen trigger fish may be conspicuous by their bright colors, the ten most common fish in order on the outer reefs are: the surgeonfish, *Acanthurus bahianus*, the blue head, *Thalassoma bifasciatus,* the French grunt, *Haemulon flavolineatum*, the yellowtail snapper, *Ocyurus chrysurus*, damselfish, *Pomacentrus partitus*, yellowhead wrasse, *Halichoerus garnoti*, redband parrotfish, *Sparisoma aurofrenatus*, the sergeant major, *Abudefduf saxatilis*, and the blue tang, *Acanthurus coeruleus*. All of them are found in the coral-sea fan habitat but wander about over the whole reef.

6.1.3. Patch Reef

In the patch reef coral-sea fan habitat shifts of the organisms occur primarily associated with the different types of corals and the association of the corals with the reef matrix. In the outer reefs the rubble habitat lies either below the coral habitat or behind it on the reef flat; patch reef corals grow around and on top of the rubble matrix. The major corals of the patch reefs are *Montastraea annularis* and *cavernosa*, *Porites* spp., *Diploria clivosa*, *Eusmilia* spp., and others to a lesser degree. Most of the corals are of the head or boulder type. The massive specimens on the outer perimeter of a patch reef may rise several meters from the surrounding bottom. The top of the reef may be large rubble with growths of sea fans and sea feathers or may be corals growing on top of the rubble with alcyonarians growing between them.

Few invertebrates other than coelenterates are visible on a patch reef in the coral-sea fan habitat. These few are mainly muricid gastropods, polychaete featherworms, especially *Pomatostegus* and *Spirobranchus* which may be very common, the sea fan and sea feather associates listed in the outer reefs and the boring bivalve mollusk *Lithophaga* spp.

In the patch reefs much of the life of the reef lives within the reef (Voss and Bayer, 1968) in contrast to on top or outside as in the outer reefs, thus a much more complex assemblage of organisms occurs. During this study it was not possible to collect and itemize the fauna of the patch reefs inhabiting the inside structure because it would have required extensive poisoning which was not permitted because of potential adverse public reaction. Poisoning would have produced species and numbers of caridean shrimps, fishes (both day and night feeders), many mollusks including cephalopods, and other animals that respire by means of gills. The lack of poisoning is regrettable because the only patch reef in the Florida Keys ever adequately sampled by poisoning was done at Margot Fish Shoal in 1962 (Voss and Bayer, 1968). No further data for comparison are available.

The ten most common species of fish in the patch reefs, taken by Bannerot and Schmale are, in order: white grunt, *Haemulon plumieri*, stoplight parrotfish, *Sparisoma viride,* yellow tail snapper, *Ocyurus chrysurus*, bluehead, *Thalassoma bifasciatus*, yellow damselfish, *Pomacentrus planifrons*, blue tang, *Acanthurus coeruleus*, French grunt, *Haemulon flavolineatum*, redband parrotfish, *Sparisoma aurofrenatum*, cocoa damselfish, *Pomacentrus variabilis*, and the bicolor damselfish, *Pomacentrus partitus*. Six of the ten species are also among the commonest fish of the outer reefs.

In order to compare the species diversity of the outer and patch reefs on a simple number-of-species-present basis, Table 2 was compiled from the live coral 4-m^2 quadrats. It is interesting to note that of the 140 species associated with the live coral habitat, 34 or 24%

Table 2. Number of species recorded from live coral quadrats. Shared species are common to both outer and patch reefs Outer reef species are from outer reef quadrats only. Patch reef species are from patch reef quadrats only. Figures in parens represent total number of species in each of the categories.

Category	Outer Reefs[Δ]						Patch Reefs[◊]				
	1	3	5	6	7	8	2	4	9	10	17
Number of species (140)											
Number of species by station	37	31	19	37	37	41	28	54	32	48	55
Shared species (63)	25	19	19	26	31	31	25	30	26	37	41
Percent shared species (%)	68	61	100	70	84	76	89	56	81	77	75
Outer reef species (34)	12	12	-	11	6	10	-	-	-	-	-
Percent outer reef species (%)	32	39	0	30	16	24	0	0	0	0	0
Patch reef species (43)	-	-	-	-	-	-	3	24	6	11	14
Percent patch reef species (%)	0	0	0	0	0	0	11	44	19	23	25

[Δ] Outer reefs - 1. Molasses; 3. French; 5. Grecian Rocks; 6. Key Largo Dry Rocks; 7. Elbow; 8. Carysfort.

[◊] Patch Reefs - 2. White Bank Dry Rocks; 4. Mosquito Bank; 9. Basin Hill Shoals; 10. Turtle Rocks; 17. Angelfish Creek.

are from the outer reefs, 43 or 31% are from the patch reefs, while 63 or 45% are common to both. Grecian Rocks with by far the smallest number of associates had only 19 species, of which 2 were shared with the outer reefs and two with the patch reefs. The low number of species at Grecian Rocks is probably another reflection of the poor health of that reef, possibly due to over use and the effects of the coral kill reported by Shinn in 1978 (Shinn, 1980).

6.1.4. Rubble Habitat

The rubble habitat around the reefs varies in size and extent with each individual reef. It also varies with bottom contour and substrate composition. Rubble expanses are found from the fore reef downward to beyond the scope of the survey. The nature of the rubble varies with depth and position. In the deeper waters of the fore reef, the rubble is half buried or imbedded in calcareous sands and silts and in this condition, often lying on top of the rock bottom, should be included in the hardbottom zone. The rubble and hardbottom area excluding the living corals occupies about 10% of the total area of the Sanctuary and Park.

Rubble bottom is considered to be the larger rubble forming much of the top of such reefs as Molasses and French, and the reef flat to near its termination in sand or grass. The rubble area on top of the reef is one of the richest in numbers of species in the whole reef system if the rubble is large, loose, and not buried in sand. Much of this rubble is formed of loose slabs of live *Acropora palmata* recently broken off of mature colonies, dead slabs covered over with algal mats and old coral rock, all lying on top of smaller older rubble. These form large but protected areas for a multitude of animals both free living and sessile. Many of the fragments of rubble are cemented together by coralline algae such as lithothamnids, calcareous deposits, algal mats and alcyonarian spicules. Near the back reef the rubble becomes smaller, formed either of old branches of *Acropora palmata* or the rodlike branches of *A. cervicornis* and is buried in the sediments.

At Molasses, French, and the north end of Key Largo Dry Rocks, the rubble zone is extensively developed. At Key Largo Dry Rocks, it appears that the reef may be largely hollow under the rubble cap as is the case in many high elevation patch reefs (Storr, 1964). This condition affords a great deal of living space within the reef proper, aside from just the surface fauna and flora and that coating the underside of the rocks. Rubble bottom was only found at seven sites: French, Molasses, Carysfort, the Elbow, Key Largo Dry Rocks, Grecian Rocks and White Bank Dry Rocks.

The plotless line transect method gives little indication of the rich rubble life and the survey does not represent it. To find and describe the fauna associated with the rubble, the old coral slabs and rock must be turned over, revealing both the attached life on the underside of the slabs and the free, crawling animals that instantly try to escape into the rubble beneath. To assess this fauna in its entirety is very difficult and was not done in this study. The life described below is taken from previous studies and compilations by Voss.

Viewed from above, the rubble shows little indication of active life. The surface of the rock is covered by several types of low encrusting coralline algae, mainly lithothamnids, splotches of the red foram, *Homotrema rubrum,* and the circular discs of *Melobesia,* largely obscured by a low thick coating of various algae, principally *Bostrychia, Dictyota, Padina, Pocockiella*, *Stypopodium* and *Turbinaria*. A number of sponges are prominent, but species vary greatly from reef to reef probably in response to unknown ecological factors. Perhaps the most prominent animals are the coelenterates, especially the sea fans, *Gorgonia ventalina,* and the sea whips and feathers, particularly species of *Pseudopterogorgia*, *Plexaura, Eunicea* and *Muriceopsis*. These are not confined to rubble, but may be found on almost any hardbottom. The corals of this zone are generally small, consisting of *Diploria, Favia*, *Porites, Siderastrea, Dichocoenia*, *Acropora cervicornis* and others. Species of *Millepora* are common.

The main life is found beneath the rocks and old coral slabs: encrusting sponges, solitary and encrusting tunicates, egg capsules of many diverse forms of invertebrates, and various small, gliding forms of mollusks. In crevices are the red and yellow tentacles of the file shells, *Lima*, and beneath the edge of the rocks the pale orange or red keyhole limpets *Diodora,* the blotched and warty *Pleurobranchus*, and everywhere the long sharp spines of the long-spined black sea urchin, *Diadema antillarum*, and its less dangerous cousin the slate-pencil urchin, *Eucidaris tribuloides*. Occasionally, on turning a slab, the sticky, wormlike sea cucumber *Euapta lappa* drifts upward in the surge, streaming its sticky, white exudate.

Crustaceans are everywhere. *Dromia erythropus,* the sponge crab, crawls about holding a fitted sponge on its carapace by means of its specially modified posterior legs. Portunid, xanthid, grapsold and majid crabs abound, the most characteristic of the outer reef rubble being the beautiful coral crab, *Carpilius corallinus,* the deeply sculptured or hairy xanthids *Actaea acantha, Glyptoxanthus erosus, Leptodius floridanus, Heteractaea ceratopus*, the flattened, swift moving *Plagusia depressa* and *Percnon gibbesi,* and the spider crabs *Mithrax spinosissimus* and *M. sculptus*. There are numerous others, many of which are very difficult to collect.

One of the commonest animals in the rubble zone, but not encountered by the survey, is the orange to dark purple comet star, *Linckia guildingi*. It is often broken up by the surge and a perfect one is rarely seen. It is typically found with only one arm intact with the buds of the other four growing out from its base. Very similar but seldom broken is the orangish *Ophidiaster guildingi*. Common brittle stars are the slimy brittle stars, *Ophiocoma echinata* and *O. wendti,* and various species of the snake-skinned brittle stars, *Ophioderma* spp.

Small solitary tunicates are common attached to the underside of the rocks, especially *Polycarpa obtecta* and *Pyura vittata,* the latter with its bright red siphonal openings.

But it is the mollusks that are so characteristic. They are too numerous to mention all of them, but in the Sanctuary a few species are noteworthy, especially *Pisania pusio*, *Leucozonia cingulifera*, *Conus regius* (possibly poisonous), *Mitra floridana*, *Cypraea spurca* and *cervus Trivia quadripunctata*, *Tegula fasciata* and *Lima scabra*.

The following list of the rubble region is taken only from the site surveys (Table 3).

Table 3. List of the species inhabiting the rubble zone (combined sites 1 - 17) recorded from the 4-m^2 quadrats.

ALGAE

Amphiroa sp.
Anadyomene stellata
Batophora oerstedii
Dasycladus vermicularis
Dictyota cervicornis
Dilophus alternans
Galaxaura cylindrica
Goniolithon sp.
Halimeda incrassata
H. opuntia
H. tuna
Lithothamnion sp.
Neomeris annulata
Padina sanctae-crucis
Stypopodium zonale
Valonia ventricosa
Laurencia sp.

PORIFERA

Aplysina cauliformis
Callyspongia fallax
C. vaginalis
Chondrilla nuclea
Cliona sp.
Dysidea etherea
Haliclona compressa
Homaxinella rudis
Pseudopterogorgia kallos
P. rigida
Ircinia campana
I. felix
I. strobilina
Iotrochota birotula
Leucosella floridana
Merriamium tortugaensis
Microcionid
Mycale sp.
Siphonodictyon siphonum
Spongia cerebriformis
Niphates erecta
Thalysias juniperus
Tricheurypon viridea

COELENTERATA

Horny corals

Bartholomea sp.
Eunicea tourneforti
Gorgonia ventilina
Millepora alcicornis
M. complanata
Muriceopsis flavida
Palythoa mammilosa
Plexaura flexosa
P. homomalla
Pseudopterogorgia acerosa
P. americana
P. bipinnata

Stony Corals

Agaricia agaricites
Acropora cervicornis
Diploria labyrinthiformis
D. clivosa
Favia fragum
Dichocoenia stokesi
Meandrina meandrites
Porites astreoides
P. porites
Siderastrea siderea
S. radians

POLYCHAETA

Eunice kinbergi
E. mutilata
E. longicirrata
Glycera sp.
Pomatostegus sp.
Sabellid

Table 3. List of the species inhabiting the rubble zone (combined sites 1 - 17) recorded from the 4-m^2 quadrats (cont.).

MOLLUSCA	CRUSTACEA
Ischonochiton erythronotus	*Calcinus tibicen*
Stenoplax floridana	Mantis shrimp
Cerithium eburneum	*Mithrax forceps*
C. guinacum	*Paguristes wassi*
C. litteratum	*Xantha denticulata*
C. algicola	
Gorio sp.	ECHINODERMATA
Polinices lactea	
Thais deltoides	*Diadema antillarum*
Vasum muricatum	*Eucidaris triculoides*
Barbatia candida	*Echinometra viridis*
B. domingensis	*Ophiocoma echinata*
Anadara notabilis	*O. pumila*
Periglyphus listeri	*Ophiothrix oerstedii*
Lithophaga sp.	*Ophiozona impressa*
	TUNICATA
	Styela sp.
	Ascidia nigra
	Didemnum candidum

6.1.5. Hardbottom Habitat

The hardbottom habitat in the Sanctuary and Park is widely distributed. There are two forms that seem similar but are in fact different. The first type is the offshore hardbottom formed on the fossilized Holocene reefs and associated rubble usually covered by a thin veneer of calcareous sediments ranging from fine silts to coarse sands. This type of hardbottom is found in the fore reef and probably forms a nearly continuous band along the outer line of the reefs. The second type of hardbottom is exposed Pleistocene limestone in the near shore areas. This limestone outcrops along the shore of the keys, in the passes between the keys, and often a considerable area swept by tidal currents in the mouth of each pass. It is particularly noticeable as the rocky bar extending across the entrances to North and South Channels into Largo Sound.

6.1.5.1. Offshore Hardbottom

This habitat is found primarily in the fore reef zone. It is an area swept by clear, clean ocean water, and is probably relatively little affected by changes in salinity, temperature or pollutants from inshore. In this study, each reef transect began on hardbottom at about 18 m depth. The rock substrate was covered by a thin layer of coarse calcareous sand with rock outcrops. Viewed from above, the bottom appeared speckled or spotted. Viewed from the bottom, however, it has a shaggy, almost unkempt garden appearance. The growth is mainly various species of both green and brown algae such as *Halimeda, Dictyota, Dilophus* and *Sargassum.* Various sponges including the large vase sponge, a great variety of sea feathers and whips, scattered coral heads and associated animal life occur. This is interspersed with low ledges and considerable expanses of almost barren calcareous sands. Coralline algae such as Amphiroa, Lithothamnion and Goniolithon coat the bare rocky surfaces. The characteristic sponge is *Agelas schmidti*. Common corals are *Montastraea annularis, Favia fragum, Diploria labyrinthiformis, Dichocoenia stokesi, Siderastrea siderea* and others. It is much richer in coelenterates than the inshore hardbottom.

6.1.5.2. Inshore Hardbottom

The inshore hardbottom habitat has a much lower profile than its offshore counterpart and is rather smooth, but filled with holes and erosion cavities. As it lies in rather shallow water, this habitat is subject to many environmental changes such as varying salinities and temperatures and increased sedimentation, but it is relatively free from wave and surge disturbances. The water is often turbid. The bottom has a very rich algal flora consisting primarily of calcareous greens such as *Batophora*, *Halimeda, Acetabularia* and *Udotea,* with some browns such as *Sargassum*. The common sponges are *Aplysina cauliformis, Chondrilla nucula* and *Ircinia strobilina*.

The inshore hardbottom is impoverished as compared with the offshore hardbottom (Table 4). There is only about one half as many coelenterates including only about one third of the corals and one third of the alcyonarians. The corals are *Favia fragum,* the finger coral, *Porites furcata,* two *Siderastrea, Stephanocoenia michelini* and *Solenaster hyades*.

There are over twice the number of sponges on the outer hardbottom as compared with the inner hardbottom bars. Other groups are about evenly distributed between the two areas.

The common fish of this habitat are not separated from those of the seagrass habitat and are given in that section.

Table 4. Number of species obtained from 4-m^2 quadrats from hardbottom habitats from the outer reef area and inshore hardbottom bars.

Phylum	Outer Reef Hardbottom	Inshore Hardbottom
Protozoa	1	0
Algae	16	22
Porifera	15	7
Coelenterata	36	15
Polychaeta/Sipunculidea	5	3
Mollusca	3	8
Crustacea	6	3
Echinodermata	5	4
Total	87	62

6.1.6. Sand Habitat

The second largest area of bottom in the Sanctuary and Park, accounting for about 10% of the bottom coverage) is formed of sediments of fine calcareous silts or calcareous sands, the latter often coarse. The sands are easily moved by wave action and may be smooth or rippled. The bottom is usually bare but occasional thin patches of grass, coral boulders, or other hard objects may have organisms growing on them, including small corals and alcyonarians. Over most of the sand bottom the surface is bare. Some large animals live on the surface or burrow just beneath it.

Although none were captured or seen during the survey three large, spectacular animals inhabit this region. *Oreaster reticulatus*, the cushion star, was formerly often seen lying on the open sand, searching for small bivalve mollusks. The large numbers formerly seen have been collected out for the curio trade. The spectacular giant helmet shell, *Cassis madagascarensis spinella*, occurs spottily in sand patches where it hunts down and eats the long spined sea biscuit, *Plagiobrissus grandis,* which burrows as much as 0.3 m beneath the surface of the loose sand. Both of these animals formerly occurred in sand patches between the reefs and could be very common locally. More than 100 individuals of this species of *Cassis* have been taken in one single sand patch, the largest weighing up to 9 - 13 kilos (Voss, 1949). The largest of these is now in the collections of the Museum of Comparative Zoology at Harvard. None were found or seen during the survey. *Plagiobrissus grandis* may attain a length of over 25 cm and is the largest sea biscuit in Florida waters. Several starfish, *Astropecten duplicatus, A. articulatus* and *Luidia senegalensis,* burrow beneath the surface of these sandy areas. Only *Astropecten duplicatus* was taken in the survey.

The major animals of the sand community in the Sanctuary were polychaete worms, often plentiful in sand, and mollusks. The number of species and individuals would have been greatly increased if a smaller-mesh sieve had been used; it would also have greatly increased the amount of time for identifications even to families. The animals were collected by removing the top 10 cm of sand from each of the four 1-m^2 quadrats and sieving it.

The sand community is composed of animals that live in or on the sand and are not associated with rubble, old bivalve shells, emergent hard substrate and grass patches. Those listed below in the first group are sand restricted (Table 5). The second group contains species noted in the sand quadrats but where obviously there was a thin layer of sand over rock substrate that permitted attachment of sessile forms. The sand community, so called here, does not seem to reflect the Level Sea Bottom Communities of Thorson (1957). More extensive, careful grab sampling and fine sieving might show that some of these standard communities are present as were described from Biscayne Bay by McNulty *et al.* (1962). Certainly a *Cassis*/*Plagiobrissus* community is present in some areas, but apparently the reef sand areas have too low an organic composition to afford a home for complex, stable, self-maintaining communities, especially those containing infaunal brittle stars.

The sands of this habitat have been studied by Ginsburg (1956) who showed that they are composed of carbonates. The larger particles are formed of fragments of calcareous algae, *Halimeda* coralline algae, foraminifera, corals and mollusks shells. Non-calcareous structures such as sponge and horny coral spicules are often included.

In addition to the coarser sands, fine silty sediments are common especially in nearshore areas. The fine, mudlike fraction is composed largely of carbonate particles precipitated from the calcium carbonate-supersaturated water when seeded by bottom particles in suspension during stormy weather. This results in the "milky" waters during and after storms (Smith, 1940). Supersaturation occurs when the waters are warm and have a high CO_2 load. This condition is commoner in shallow water near shore where the fine silty bottom is more frequently encountered. Few silicate or quartz sands are present as most quartz sands are of Carolinian origin swept southward by the inshore counter current, reaching their southern limit just south of Miami; only small amounts of quartz sand occurs in the keys, mainly at Big Pine Key. Renaud-Debyser (1955) in work at Bimini, Bahamas, reported that the interstitial fauna of calcium carbonate sands is much richer than in silicate sands.

The sandy bottom areas are probably maintained through continual build up, shifting loose sands discouraging seagrass growth, and destruction of pioneering seagrass by strong wave surges during winter storms and occasional hurricanes. Sand areas between coral patches or rubble and seagrass beds are caused by herbivorous reef-dwelling fish such as parrotfish and other organisms foraging near the reef.

6.1.7. Turtle Grass Habitat

Over 75% of the bottom within the Sanctuary and Park is covered by seagrass meadows (see Marszalek maps). These begin at the intertidal zone at the shore and extend seaward to the back reef zone of the outer reefs, approaching to within a few meters of the living reef. The seagrasses are limited only by the depth of the sediments in the back reef and the decrease of illumination due to turbidity in the deeper waters of the Hawk Channel in depths of about 10 - 12 m.

The dominant plant is a phanerogam or true flowering plant unrelated to the marine algae, the turtle grass, *Thalassia testudinum* Koenig and Sims. It produces long flat leaves about 4 - 8 mm wide growing upward from rhizomes or runners that also send roots down into the substrate. The richness of the turtle grass (number of leaf blades/m^2 and their length) is determined by a number of factors including the depth of the substrate which permits full development of the rhizome system. Scattered tufts of short blades are typical of turtle grass in shallow sediments over rock bottom. This may be seen in the back reef area where sediments are thin. Where there are depressions in the rock bottom and sediments are deep, the turtle grass is often lush and dense. In mature turtle grass, the flat blade surfaces may increase attachment surface for sessile organisms by as much as tenfold.

Table 5. Sand habitat animals. Group 1 consists of true sand dwelling organisms. Group 2 consists of organisms attached to hard objects in the sand habitat. All data from 4-m^2 sand quadrats.

Group 1

POLYCHAETA

Eunice sp.
Nepthys sp.
Glycera sp.
Ophelidae
Capitellidae
Flabelligeridae
Hesionidae
Terebellidae
Sabellidae
Lumbrinereidae
Goniadidae
Cirratulidae
Nereidae
Onuphidae
Siqualionidae

SIPUNCULIDA

Phascolion sp.

MOLLUSCA

Hastula hastata
Olivella nivea
Calliostoma jujubinum
Dentalium calamus
Tellina listeri
Mycale angulosa

CRUSTACEA

Cycloes bairdi

ECHINODERMATA

Astropecten duplicatus
Meoma ventricosa
Mellita sexiesperforata

Group 2

ALGAE

Halimeda tuna
Goniolithon sp.
Laurencia sp.
Dasycladus vermicularis
Acetabularia crenulata
Penicillus capitatus
Caulerpa prolifera
Bostrychia montagnei

PORIFERA

Aplysina cauliformis
Ircinia strobilina

COELENTERATA

Millepora alcicornis
Plexaura homomalla
Eunicea tourneforti
Siderastrea siderea
Favia fragum
Agaricia agaricites
Porites astreoides

MOLLUSCA

Crepidula aculeata
Chama macrophylla
Arca imbricata

ECHINODERMATA

Lytechinus variegatus

In the Sanctuary and Park areas, the manatee grass, *Syringodium filiforme* Kutzing (= *Cymodocea filiforme*), is often found mixed in with turtle grass, and occasionally in pure stands. Manatee grass may be easily recognized as the leaves are round, tapered and long. Viewed among the turtle grass, manatee grass may have a yellowish appearance. Manatee grass has not been shown to be of major importance in the marine habitat because its slender leaves permit little surface for attachment, weak sediment entrapment and poorly developed root and rhyzome systems.

When all new blades of turtle grass grow out after a hurricane has stripped the plants, the leaves are bright green because they are clean and have no *aufwuchs*. Very shortly, however, the blades become covered with the whitish calcareous sediments, attached foraminifera, hydroids, diatoms, colonial tunicates, sponges, a large number of species of epiphytic algae, and many species of mollusks. As a result the leaves appear grayish. If the *aufwuchs* becomes too great the plants may suffer from lack of sunlight, have a wilted appearance, and slough off their leaves. This condition often occurs during the warmest periods of the year, when the grass beds may have a "sick" appearance. The leaves may also be killed off in shallow water during a severe cold spell. Thus, leaf kill may occur at both extremes during late summer and late winter (Phillips, 1960). Turtle grass in Largo Sound has been killed back in summer by heavy blooms of filamentous red algae that covered over the turtle grass like the webs of tent caterpillars (Voss, pers. observ.). This condition may last for several months and it may take weeks for the grass to recover its normal condition as the waters cool.

Although reproduction is both vegetative and sexual, the 3-petalled flowers are seldom seen in the Keys except offshore in rich back reef areas. They have been found over many years around Long Reef and Molasses (Voss, pers. observ.).

The turtle grass community is one of the richest known in the marine world. It is filled with both macro- and micro-organisms. As many as 29,130 individuals/m^2 of six species of micro-mollusks have been recorded in Biscayne Bay (Moore, 1963) and Humm (1964) has listed 113 species of epiphytic algae in the Biscayne Bay area. A number of Shannon-Weaver species diversity indices have been calculated for the grass community. In shallow waters off Key Biscayne indices of 4.57 and 4.52 were recorded by State biologists while studies made by RSMAS personnel yielded an index of 5.45, perhaps the highest ever recorded for this habitat (Toll, unpublished). These indices were obtained from analyses based upon grab samples sieved through a 1-mm^2 mesh.

Much of the turtle grass community is composed of organisms smaller than 1 cm, the size limit of this study. The larger organisms (greater than 1 cm) are still very numerous but it is difficult to list species that are solely restricted to the grass community. Many species, however, are typically found in turtle grass and are considered part of the community. The plants and animals in Table 6 are commonly found in turtle grass but may also be found in one or more of the other Sanctuary habitats. Missing from the list are two species that formerly were very commonly found in turtle grass, the pink conch, *Strombus gigas*, and the hawksbill turtle. In the 1930s, conchs were so numerous that in some areas over a hundred mature conchs could be captured in no more than a 10 by 10 m area (Voss, pers. observ.). In the survey, the transect line passed over only one specimen. Likewise, one or more hawksbills would be seen, on each visit to the reefs, feeding in the turtle grass beds. None were seen in the survey.

The geographical distribution of turtle grass in Florida and the factors involved in limiting its depth have been discussed by Moore (1963), and hurricane effects on the grass meadows have been reported by Thomas *et al.* (1961). Phillips (1960) discussed the ecology of turtle grass and the effects of temperature extremes.

Table 6. List of the species inhabiting the seagrass habitat (combined sites) recorded for the 4-m^2 quadrats.

ALGAE

Green Algae

Acetabularia crenulata
Anadyomene stellata
Avrainville nigricans
Batophora oerstedii
Caulerpa cupressoides
Dasycladus vermicularis
Dictyosphaeria cavernosa
D. versluysii
Enteromorpha sp.
Halimeda globosa
H. incrassata
H. lacrimosa
H. monile
H. opuntia
H. o. minor
H. o. triloba
Penicillus capitatus
P. dumetosus
P. lamourouxii
Phipocephalus phoenix
Udotea flabellum
Ulva lactuca
Valonia ventricosa

Brown Algae

Dictyota cervicornis
Dilophus alterans
Laurencia sp.

Red Algae

Acanthophora sp.
Colpomenia sinuosa
Laurencia sp.

GRASSES

Thalassia testudinum
Syringodium filiforme
Diplanthera wrightii

PORIFERA

Aplysina cauliformis
Chondrilla nucula
Cliona deletrix
Dysidea etheria
Geodia gibberosa
Haliclona compressa
H. viridis
Ircina campana
Lissodendrix stigmata
Spheciospongia vesparia
Verongia longissima

COELENTERATA

Briareum asbestinum
Porites divaricata
P. furcata
P. porites
Siderastrea siderea

MOLLUSCA

Modiolus modiolus
M. m. squamosus
Pecten antillarum
Pinctada imbricata

POLYCHAETA

Cistenides gouldi
C. regalis
Hermodice carunculata
Eunice unifrons
Loimia sp.
Marphysa sp.
Sabella melanostigma

Table 6. List of the species inhabiting the seagrass habitat (combined sites) recorded for the 4-m^2 quadrats (cont.).

MOLLUSCA	CRUSTACEA
Gastropoda	*Dardanus venosus*
	Paguristes puncticeps
Astraea tecta americana	*Pitho anisodon*
A. phoebia	
Calliostoma jujubinum	ECHINODERMATA
Haminoea sp.	
Modulus modulus	*Ophioderma brevispinum*
Tegula fasciata	*O. rubricundum*
	Ophionereis squamosa
Pelecypoda (Bivalvia)	*Ophiothrix lineata*
	O. oerstedii
Americardia media	*Clypeaster rosaceus*
Anadara notabilis	*Lytechinus variegatus*
Arca zebra	*Actinopyga agassizi*
Chione cancellata	*Astichopus multifidis*
C. paphia	
Codakia orbicularis	TUNICATA
Glycymeris pectinata	
Laevicardium laevigatum	*Didemnum candidum*
Linga pensylvanica	*D. savigni*
	Microcosmus jelleri
Octopoda	*Styela* sp.
Octopus joubini	

The importance of turtle grass beds as nursery grounds for many important commercial and sports species of fish and invertebrates was first brought to attention by Tabb *et al.* (1962). While the blades of grass offer little nourishment or nutrient themselves, the proliferating leaf blades greatly increase the amount of attachment surface for small sessile plants and animals that in turn afford food for young fish, crawfish and other animals in their early life histories.

Other important functions served by *Thalassia* is bottom stabilization by means of the dense network of roots and rhyzomes, and sediment entrapment by the long leaves. Because of its many beneficial attributes turtle grass is protected by both local and State laws.

Few animals feed directly on turtle grass, but Randall (1965) has discussed various herbivores. The most important grazers are several species of parrot fishes (Randall, 1965) and *Diadema antillarum* (Randall *et al.*, 1964). The latter are sometimes very numerous and the last authors reported counts of 1.2 urchins per square meter in the turtle grass off Lower Matecumbe, south of the present study areas.

Randall has shown by field experiments (Randall, 1965) that the primary cause of the sand halos between the reefs and the grass beds is directly caused by several species of parrot fishes and surgeon fishes. The general fauna and flora of the turtle grass meadows is rather uniform throughout the keys. In areas of deep sediments, there is little variation in the grass assemblages. However, in the intertidal and very shallow waters along the shores of the keys the turtle grass becomes intermixed with low, extensive colonies of *Porites furcata* and numerous corallines, especially *Goniolithon*, *Jania*, and *Amphiroa*. This zone, often tens of meters wide, gradually thins out and gives way to the fully developed grass beds.

The importance of turtle grass in the Sanctuary and Park cannot be over emphasized. It serves as a nursery ground for many of the animal species of the area, filters sediments from the water thus aiding in water clarity for the corals and stabilizes the bottom sediments. It provides the largest single habitat within the study area and much of its nutrients.

Numerous species of fish are found swimming about over the grass areas. In the fish census no distinction was made between grass and the intermixed inshore hardbottom. As the great preponderance of bottom is grass, the fishes of this mixed area are listed here. The ten most commonly encountered species ranked in order of their occurrence are: white grunt, *Haemulon plumieri,* bridled goby, *Coryphopterus glaucofrenum*, sand perch, *Diplectrum formosum*, banner goby, *Microgobius microlepis*, redtail parrotfish, *Sparisoma chrysopterum*, tiger goby, *Gobiosoma macrodon*, rockcut goby, *Gobiosoma grosvenori*, high hat, *Equetus acuminatus*, gray angelfish, *Pomacanthus arcuatus*, and the cocoa damselfish, *Pomacentrus variabilis*.

6.2. Cryptic Fauna

Several recent papers have dealt with the cryptic faunas of Florida, the Bahamian, and Caribbean reefs. Uebelacku (1977) studied the cryptic fauna of the coral reef sponge *Gelliodes digitalis* in the Bahamas. Bonem (1977) investigated the fauna of coral reef cavities in sites near Miami, while Cuffey and Fonda (1977) studied the cryptic bryozoans of coral cavities at Andros and Eleuthera, and Logan (1977) the brachiopods at Grand Cayman. Earlier Voss and Bayer (1968) had investigated the fish and invertebrate fauna of patch reefs at Margot Fish Shoal in the Biscayne National Park. There are many other accounts of cryptic fauna studies including the classic report by Pearse (1932) of the organisms inhabiting the canals in the loggerhead sponge, *Spheciospongia vesparia.* No full study of the cryptic fauna of the Florida reef tract has been undertaken because of the magnitude of the task.

Cryptic fauna, as can be seen from the literature cited, includes both animals that live within other animals such as burrowing or boring organisms in coral skeletons, sponges and seagrass rhyzomes and those that live hidden in crevices, crannies, under rocks or in cavities and caverns.

No investigations were undertaken in this study of the burrowing and boring fauna of the corals, sponges and other hosts. Corals may be the host of gall forming crabs, tube-dwelling polychaete worms and others. Gall crabs are seen most frequently in the two species of *Acropora,* while the tube-dwelling polychaetes such as *Pomatostegus stellatus* and *Spirobranchus giganteus* are common in the massive corals such as *Montastraea* and *Porites*.

Acorn worms or sipunculids prefer to burrow or bore into dead coral rock. The boring bivalves *Lithophaga nigra* and *L. antillarum* also live in coral rock.

Sponges are hosts to myriads of small shrimp of the genus *Alpheus* and *Synalpheus*. Pearse (1932) at Loggerhead Key, the Dry Tortugas, found 16,000 *Synalpheus* snapping shrimp in a single large loggerhead sponge, and 13,500 in another somewhat smaller one. Sponges of the genus *Ircinia* in the Keys often are hosts to large eunicid polychaetes such as *Eunice spongicola* that forms a thin papery lining to its burrow.

The cryptic life beneath rocks and in cavities and caverns may be both seeking shelter and occupying a niche with reduced illumination thus permitting some deeper dwelling animals to live in shallower depths (Bonem, 1977). The undersides of rocks and the roofs of caves are often covered by encrusting corallines, bryozoans and even some deep water corals.

The major cryptic species of the Sanctuary are the crustaceans and fishes that occupy the open spaces in the reef. During the day these may be mainly nighttime feeders while at night daytime feeders take their place. Studies at Margot Fish Shoal (Voss and Bayer, 1968), using rotenone to bring the cryptic organisms out of the patch reef matrix, revealed a much greater reef population than could be seen by diving operations.

In order to assess the major cryptic species of the Sanctuary, it was originally planned to poison several small patch reefs as had been done previously at Margot Fish Shoal where no adverse effects on the living corals was observed either immediately thereafter or in later years. Because of the possibility of adverse impact on the user public, the poison operations were reduced to only four stations at Grecian Rocks: a coral ledge with numerous small caves, rubble bottom with sand and solid carbonate substrate, an isolated coral head and a living coral patch. Each area was about 10 m^2 in size.

Twenty-three species of invertebrates (Table 7) were obtained of which only 3 or 13% had been recorded from the transects and quadrats. The 87 percent remaining consisted of 2 polychaete worms, one mollusk and 18 crustaceans, of which 14 were caridean shrimp belonging to 6 genera. All but one species were represented by single individuals at each station.

The fish were far more numerous (Table 8). Thirty-five species were taken. Of these only 8 species or 23% were not also recorded by Bannerot and Schmale. However, 129 individual specimens were collected, graphically demonstrating the amount of refuge offered by the cavities within the coral reef matrix.

While poisoning is an effective method for obtaining shrimp and fish, it does not provide information on the large number of polychaete worms living in borings or burrows in the reef. These must be obtained by collecting and breaking up large coral heads and carefully extracting the animals living within. Ebbs (1966) thus studied the cryptic species of polychaetes at Margot Fish Shoal where he obtained 10 species, of which *Hermenia verruculosa* and *Eunice*

Table 7. List of cryptic invertebrates collected from poison stations at Grecian Rocks.

	Number of Individuals stations			
Species	1	2	3	4
POLYCHAETA				
Notopygos crinita	-	1	-	-
Eurythoe complantata	-	-	1	-
Hermodice carunculata	-	-	1	-
MOLLUSCA				
Tridachia crispata	-	-	-	1
Octopus briareus	1	-	-	-
CRUSTACEA				
Alpheus amblyonyx	1	1	1	-
A. cristulifrons	1	-	-	-
A. formosus	1	1	-	1
A. normanni	-	1	-	-
A. ridleyi	1	1	-	-
A. sp. A	1	-	-	-
A. sp. B	-	1	-	-
Brachycarpus biunguiculatus	1	1	-	-
Hippolyte nicholsoni	-	1	-	-
Lysmata intermedia	-	1	1	-
Mithrax sp.	1	-	-	-
Paguristes cadenati	-	1	1	1
P. sp. A	1	-	-	-
Petrolisthes galathinus	6	1	-	1
Synalpheus fritzmuelleri	1	-	-	-
S. minos	1	-	-	-
S. townsendi	1	-	-	-
Thor manningi	1	1	-	-

Table 8. List of fishes collected from poison stations at Grecian Rocks.

Species	Number of Individuals Station					Total Individuals
Acanthuridae (surgeonfishes)					6	
Acanthurus bahianus	-	3	-	-		3
Acanthurus coeruleus	-	-	1	2		3
Apogonidae (cardinalfishes)					11	
Apogon bionatus	2	-	-	-		2
Apogon maculatus	2	1	-	1		4
Phaeoptyx pigmentaria	5	-	-	-		5
Aulostomidae (trumpetfishes)					1	
Aulostomus maculatus	-	-	-	1		1
Balistidae (filefishes)					1	
Cantherhines pullus	-	-	1	-		1
Bythitidae (viviparous brotulas)					5	
Ogilbia cayorum	1	3	1	-		5
Clinidae (clinids)					56	
Acanthemblemaria chaplini	7	7	8	2		24
Enneanectes jordani	6	4	-	2		12
Labrisomus bucciferus	1	2	-	1		4
Malacoctenus triangulatus	1	-	7	-		8
Paraclinus marmoratus	-	1	2	1		4
Starksia ocellata	2	1	-	-		3
Stathmonotus hemphilli	1	-	-	-		1
Dactyloscopidae (sand stargazers)					8	
Platygillelus rubrocinctus	2	2	1	3		8
Gobiidae (gobies)					4	
Coryphopterus dicrus	-	1	1	-		2
Gnatholepis thompsoni	-	1	-	-		1
Gobiosoma oceanops	-	-	1	-		1
Grammistidae (soapfishes)					1	
Rypticus saponaceus	1	-	-	-		1
Lutjanidae (snappers)					1	
Ocyurus chrysurus	-	-	1	-		1
Muraenidae (morays)					1	
Gymnothorax moringa	-	-	1	-		1
Ophichthidae (snake eels)					1	
Myrichthys oculatus	-	1	-	-		1

Table 8. List of fishes collected from poison stations at Grecian Rocks (cont.).

Species	Number of Individuals Station				Total Individuals	
Pempheridae (sweepers)					2	
Pempheris schomburgki	2	-	-	-		2
Pomacentridae (damselfishes)					10	
Pomacentrus diencaeus	1	1	-	-		2
Pomacentrus partitus	-	2	1	-		3
Pomacentrus planifrons	-	-	1	1		2
Pomacentrus variabilis	1	1	-	-		2
Micropathodon chrysurus	-	-	1	-		1
Priacanthidae (bigeyes)					1	
Priacanthus cruentatus	1	-	-	-		1
Scaridae (parrotfishes)					16	
Scarus croicensis	-	1	-	-		-
Sparisoma viride	1	1	12	1		15
Serranidae (sea basses)					2	
Serranus tigrinus	-	-	2	-		2
Sygnathidae (pipefishes)					1	
Corythoichthys albirostris	-	-	-	1		1
Tetraodontidae (puffers)					1	
Canthigaster rostrata	-	-	1	-		1
Total Individuals					129	
Total Species					35	
Total Genera					30	
Total Families					19	

schemacephala were at that time known only from the Florida back reef areas. The most common species was *Eunice schemacephala,* the Atlantic palolo, which is also coral destructive, actually boring into the coral heads.

6.3. Coral Health

Coral health is of interest to Sanctuary and Park scientists and managers because the fate of the coral reefs and their faunal and floral assemblages depends on the health of the corals. The state of health of corals is difficult to determine and no reliable methods of assessment are known. A health indicator now commonly used is the presence or absence of white spotting on a coral colony. White spotting is the presence of small to large areas of white, freshly bared, coral skeleton. These areas stand put distinctly from the healthy creamy-brown coral tissue. The presence or absence of white spots can be easily noted and estimates can be made of the percent of white areas versus natural living surface.

When white spotting was first interpreted as a sign of possible coral deterioration, it was used as a general term. White spotting may be caused simply by the loss of symbiotic zooxanthellae in which case the living tissue is still present. As used in most studies, it refers to the loss of the tissue itself, baring the skeleton which bleaches white. The term is here used in this sense.

White spotting may occur from a variety of causes: tissue eaten by coral predators such as certain bristle worms, mollusks and fishes; physical damage by boats and anchors; diver and swimmer contact; heavy siltation; storm damage; pollution; infection by bacteria and viruses; destruction by algal invaders, and others. In few cases has it been possible to isolate or pinpoint the causative agents. White spotting, its occurrence and possible causes has been reviewed and discussed by several writers (Antonius, 1981a and 1981b; Dustan, 1977a; Voss, 1973).

Because white spotting and coral death occur from both natural and man-made causes, it is widespread and to some degree nearly universal. It is only when the incidence of white areas becomes higher than usual that it is noticeable and an alarm is raised. It is seldom possible to determine whether the occurrence is from natural or man-made causes. Recent outbreaks of extensive coral reef damage from infections of the cyanophyte *Oscillatoria submembranacea* (Antonius, 1981b) have raised the question whether corals living under stress conditions, such as pollution, may be more susceptible to the disease. Antonius (1977) has suggested that Shut-down-reaction (SDR) or the sloughing off of the entire living surface under stress, may be a more important factor. That very serious destruction may occur is vividly shown by the near total death of the coral reefs in the Gulf of Chiriqui, Panama, in a documented period of little more than four months (Glynn, personal communication). No cause has been discovered although pollution from pesticides and heavy metals is suspected.

Two cases of major coral death have been recorded in the Florida reef tract. The first occurred at Hen and Chickens Reef in the winter of 1969 - 70 (Voss, 1973) when apparently cold water killed off approximately 90% of the corals (Hudson *et al.* 1976). Antonius (1977) suggested that SDR caused the massive kill while the corals were under stress. Likewise, Grecian Rocks suffered a heavy coral kill in 1978, after Antonius (1974) had presented data on the health of that reef. Shinn (letter) reported that this was probably caused by warm water during a particularly warm period in the summer.

While natural catastrophes such as those at Hen and Chickens and Grecian Rocks cannot be guarded against, coral loss through man's activities can be controlled and prevented provided means are found for assessing coral health and the causes of deterioration can be detected. One of the methods of assessing coral health is the determination of the amount and extent of dead versus living coral.

In 1974, Antonius described a method of analysis using transect lines. Each coral under the line was recorded at 1-m intervals. If over 50% of the coral was dead, the coral was listed as dead. If less than 50% was dead, it was listed as living. A coral with 100% dead surface, but which could still be identified to species by its skeletal structure, was listed as dead. When identification from the skeleton was impossible, it was listed as rock.

In the present survey, corals were recorded at every 5 m. The number of coral point samples was low and the incidence of dead surfaces was negligible. The photographic survey, however, in which at least 1 m^2 was photographed at each 5 m, permitted the observation of a large number of corals and an assessment of the percentage of dead surfaces. In Table 9, four items are listed: (1) the total number of corals seen, (2) the number of corals with no dead areas, (3) the number of corals containing dead areas, and (4) the number of corals with 50% or greater dead surfaces. To facilitate comparisons with Antonius' (1974) figures, the numbers and percentages of living versus dead corals are given in Table 10 following the format given by Antonius.

The results of the coral health assessment are interesting. The reefs following the outer line of the banks: Molasses, French, the Elbow and Carysfort have a percent dead coral range and mean of 1 - $\overline{3.1}$ - 6; the middle reefs represented by White Bank Dry Rocks, Grecian Rocks and Key Largo Dry Rocks show 12 - $\overline{18}$ - 22, while the inner reefs represented by Mosquito Bank, Basin Hill Shoals and Turtle Rocks have a range of 3 - $\overline{5.7}$ - 8.

Only five of these reefs were studied by Antonius in 1974. In Table 9, the number of corals recorded and the percentage of dead corals in the present study are given first, followed by Antonius' figures in parentheses.

It is doubtful that the differences shown are significant as the transects are not identical and the conditions of the corals could vary according to the nature of the reef at the transect line. The number of corals sampled does not appear to have significance. The major difference occurs at Grecian Rocks where in 1974 Antonius calculated 14% dead corals, while in 1980 there were 31% dead colonies. This reflects the kill recorded by Shinn (letter) and others in 1978, four years after the survey by Antonius and two years prior to the present survey.

Table 9. Comparison of number of corals and percent dead corals from present survey (1980 - 81) and that of Antonius (1974). Data from Antonius are enclosed in parentheses.

Reef	Number of Corals		Percent dead corals	
Molasses Reef	182	(160)	1%	(6.9%)
The Elbow	62	(197)	6%	(7.1%)
Carysfort Reef	116	(193)	1%	(7.3%)
Grecian Rocks 1980	120	(271)	31%	(14%)
Grecian Rocks 1981	121		22%	
Largo Dry Rocks	186	(289)	12%	(8%)

Table 10. Percentages of live versus dead corals based on combined transect data at 10 sites in the Key Largo Coral Reef Marine Sanctuary. Criteria for dead and living corals are as given by Antonius (1974). Data from transect photographs.

Site 1. Molasses Reef

Total	182	sample points	100%
Live corals	180	"	98%
Dead corals	2	"	1%

Site 2. White Bank Dry Rocks

Total	159	sample points	100%
Live corals	127	"	79%
Dead corals	32	"	20%

Site 3. French Reef

Total	99	sample points	100%
Live corals	94	"	94%
Dead corals	5	"	6%

Site 4. Mosquito Bank

Total	25	sample points	100%
Live corals	23	"	92%
Dead corals	2	"	8%

Site 5. Grecian Rocks (1980)

Total	120	sample points	100%
Live corals	83	"	69%
Dead corals	37	"	31%

Site 5. Grecian Rocks (1981)

Total	121	sample points	100%
Live corals	94	"	78%
Dead corals	27	"	22%

Site 6. Key Largo Dry Rocks

Total	186	sample points	100%
Live corals	164	"	88%
Dead corals	22	"	12%

Site 7. The Elbow

Total	62	sample points	100%
Live corals	58	"	93%
Dead corals	4	"	6%

Table 10. Percentages of live versus dead corals based on combined transect data at 10 sites in the Key Largo Coral Reef Marine Sanctuary. Criteria for dead and living corals are as given by Antonius (1974). Data from transect photographs (cont.)

<u>Site 9. Carysfort Reef</u>			
Total	116	sample points	100%
Live corals	115	"	99%
Dead corals	1	"	0.8%
<u>Site 9. Basin Hill Shoals</u>			
Total	65	sample points	100%
Live corals	63	"	96%
Dead corals	2	"	3%
<u>Site 10. Turtle Rocks</u>			
Total	44	sample points	100%
Live corals	41	"	93%
Dead corals	3	"	6%

Table 11. Percentages of corals, healthy corals, white spotted corals and dead corals at 10 sites in the Key Largo Coral Reef Marine Sanctuary based upon photographic transect data.

Site 1. Molasses Reef

Transect 1.

Total number of corals	66	sample points	100%
Healthy corals (no spotting)	57	"	86%
Corals with dead areas	9	"	14%
Dead corals (50% dead areas)	1	"	2%

Transect 2.

Total number of corals	57	sample points	100%
Healthy corals (no spotting)	50	"	87%
Corals with dead areas	7	"	12%
Dead corals (50% dead areas)	1	"	2%

Transect 3.

Total number of corals	59	sample points	100%
Healthy corals (no spotting)	49	"	81%
Corals with dead areas	11	"	19%
Dead corals (50% dead areas)	0	"	0%

Site 2. White Bank Dry Rocks

Transect 1.

Total number of corals	30	sample points	100%
Healthy corals (no spotting)	19	"	63%
Corals with dead areas	11	"	37%
Dead corals (50% dead areas)	5	"	17%

Transect 2.

Total number of corals	58	sample points	100%
Healthy corals (no spotting)	30	"	52%
Corals with dead areas	28	"	49%
Dead corals (50% dead areas)	9	"	16%

Transect 3.

Total number of corals	71	sample points	100%
Healthy corals (no spotting)	15	"	21%
Corals with dead areas	56	"	79%
Dead corals (50% dead areas)	18	"	22%

Table 11. Percentages of corals, healthy corals, white spotted corals and dead corals at 10 sites in the Key Largo Coral Reef Marine Sanctuary based upon photographic transect data (cont).

Site 3. French Reef

Transect 1.

Total number of corals	37	sample points	100%
Healthy corals (no spotting)	21	"	57%
Corals with dead areas	34	"	43%
Dead corals (50% dead areas)	2	"	5%

Transect 2.

Total number of corals	23	sample points	100%
Healthy corals (no spotting)	19	11	83%
Corals with dead areas	34	"	17%
Dead corals (50% dead areas)	1	"	4%

Transect 3.

Total number of corals	39	sample points	100%
Healthy corals (no spotting)	30	"	77%
Corals with dead areas	9	"	23%
Dead corals (50% dead areas)	2	"	5%

Site 5. Grecian Rocks (1980)

Transect 1.

Total number of corals	49	sample points	100%
Healthy corals (no spotting)	25	"	51%
Corals with dead areas	24	"	49%
Dead corals (50% dead areas)	10	"	20%

Transect 2.

Total number of corals	40	sample points	100%
Healthy corals (no spotting)	8	"	20%
Corals with dead areas	32	"	80%
Dead corals (50% dead areas)	12	"	30%

Transect 3.

Total number of corals	31	sample points	100%
Healthy corals (no spotting)	4	"	13%
Corals with dead areas	27	"	87%
Dead corals (50% dead areas)	15	"	48%

Table 11. Percentages of corals, healthy corals, white spotted corals and dead corals at 10 sites in the Key Largo Coral Reef Marine Sanctuary based upon photographic transect data (cont).

Site 5. Grecian Rocks (1981)

Transect 1.

Total number of corals	71	sample points	100%
Healthy corals (no spotting)	45	"	63%
Corals with dead areas	26	"	37%
Dead corals (50% dead areas)	8	"	11%

Transect 2.

Total number of corals	14	sample points	100%
Healthy corals (no spotting)	4	"	29%
Corals with dead areas	10	"	71%
Dead corals (50% dead areas)	6	"	43%

Transect 3.

Total number of corals	36	sample points	100%
Healthy corals (no spotting)	4	"	11%
Corals with dead areas	32	"	89%
Dead corals (50% dead areas)	13	"	36%

Site 6. Key Largo Dry Rocks

Transect 1.

Total number of corals	132	sample points	100%
Healthy corals (no spotting)	77	"	58%
Corals with dead areas	11	"	42%
Dead corals (50% dead areas)	2	"	2%

Transect 2.

Total number of corals	30	sample points	100%
Healthy corals (no spotting)	12	"	40%
Corals with dead areas	18	"	60%
Dead corals (50% dead areas)	11	"	37%

Transect 3.

Total number of corals	24	sample points	100%
Healthy corals (no spotting)	7	"	29%
Corals with dead areas	17	"	71%
Dead corals (50% dead areas)	9	"	38%

Table 11. Percentages of corals, healthy corals, white spotted corals and dead corals at 10 sites in the Key Largo Coral Reef Marine Sanctuary based upon photographic transect data (cont).

Site 7. The Elbow

Transect 1.

Total number of corals	22	sample points	100%
Healthy corals (no spotting)	14	"	63%
Corals with dead areas	8	"	36%
Dead corals (50% dead areas)	1	"	4%

Transect 2.

Total number of corals	9	sample points	100%
Healthy corals (no spotting)	6	"	67%
Corals with dead areas	3	"	33%
Dead corals (50% dead areas)	0	"	0%

Transect 3.

Total number of corals	31	sample points	100%
Healthy corals (no spotting)	23	"	76%
Corals with dead areas	8	"	25%
Dead corals (50% dead areas)	3	"	9%

Site 8. Carysfort Reef

Transect 1.

Total number of corals	63	sample points	100%
Healthy corals (no spotting)	50	"	79%
Corals with dead areas	13	"	21%
Dead corals (50% dead areas)	1	"	1%

Transect 2.

Total number of corals	36	sample points	100%
Healthy corals (no spotting)	32	"	88%
Corals with dead areas	4	"	12%
Dead corals (50% dead areas)	0	"	0%

Transect 3.

Total number of corals	17	sample points	100%
Healthy corals (no spotting)	15	"	88%
Corals with dead areas	2	"	12%
Dead corals (50% dead areas)	0	"	0%

Table 11. Percentages of corals, healthy corals, white spotted corals and dead corals at 10 sites in the Key Largo Coral Reef Marine Sanctuary based upon photographic transect data (cont).

Site 9. Basin Hill Shoals

Transect 1.

Total number of corals	33	sample points	100%
Healthy corals (no spotting)	19	"	57%
Corals with dead areas	14	"	43%
Dead corals (50% dead areas)	2	"	6%

Transect 2.

Total number of corals	23	sample points	100%
Healthy corals (no spotting)	22	"	95%
Corals with dead areas	1	"	4%
Dead corals (50% dead areas)	0	"	0%

Transect 3.

Total number of corals	9	sample points	100%
Healthy corals (no spotting)	6	"	66%
Corals with dead areas	3	"	34%
Dead corals (50% dead areas)	0	"	0%

Site 10. Turtle Rocks

Transect 1.

Total number of corals	0	sample points	0%

Transect 2.

Total number of corals	6	sample points	100%
Healthy corals (no spotting)	6	"	100%

Transect 3.

Total number of corals	38	sample points	100%
Healthy corals (no spotting)	18	"	47%
Corals with dead areas	20	"	53%
Dead corals (50% dead areas)	3	"	7%

In this study, Grecian Rocks was surveyed in both 1980 and 1981. While the transects did not cover exactly the same corals in the two surveys, 120 corals were recorded in 1980 and 121 in 1981. The 1980 survey showed 31% dead corals versus 22% dead in 1981. It is tantalizing to consider that the difference of 9% less dead corals in 1981 indicates a recovery. It is probable, however, that the difference is a reflection of different transect line position rather than improvement in reef health.

It is possible that the higher percentage of dead corals at Key Largo Dry Rocks, Grecian Rocks and White Bank Dry Rocks is partly due to the greater use of these reefs by visitors on private boats, commercial dive boats and Park tour boats. This is partially supported by the fact that even in 1974 when Antonius surveyed Grecian Rocks, the percentage of dead corals was 14, higher than any of the other reefs in this area.

Unfortunately, Tilmant *et al.* (unpublished report) did not evaluate coral health in Biscayne National Park just to the north of the Sanctuary, thus no comparisons can be made in that area. On the other hand at Looe Key, Antonius *et al.* (1978) found 25% dead corals on the reef flat, 10 percent on the fore reef and 22% on the deep reef. Looe Key, like Grecian Rocks and Key Largo Dry Rocks, is very popular with fishermen and divers. It may well be that the high percentage of dead coral at these reefs is due to overuse more than to natural factors, indicating the possible deterioration of the reefs in general if visitor impact increases with the planned increased development predicted for the Florida Keys.

6.4. Damage to Corals by Boats and Anchors

During this study an attempt was made to evaluate the amount and importance of damage to corals caused by boats and anchors in the waters of the Sanctuary and Park. All personnel working on the project were requested to note any damage seen. Twenty-seven persons were employed as divers at one time or another on the project. Each was questioned specifically as to the presence of boat and anchor damage. None was seen by the divers working on the transects and quadrats. The two divers on the fish census reported a single case of boat damage - a gash in a coral head apparently caused by a propeller blade.

As the divers on the two studies covered a considerable area of the reefs, it must be assumed that: (1) there is little boat and anchor damage on the reefs; (2) there is noticeable damage but not in the areas observed by the divers; or (3) the divers did not distinguish such damage. The third alternative seems unlikely unless the damage to the corals was old and was already obscured. It seems more likely that there is some damage but because of the locations of the transects and quadrats the divers did not see it. If the latter is the case, it seems likely that boat and anchor damage is not a significant problem except in a few localized areas.

Boat and anchor damage is often difficult to distinguish from damage from natural causes (hurricanes, storm surges, heavy seas). Unless a clear gash across a brain coral or a long scar of a dragged anchor is visible, broken coral, toppled masses of elkhorn coral and overturned heads may be due to waves rather than boats. Tilmant *et al.* (unpublished report) have attempted to assess boat and anchor damage in the Biscayne National Park. They concluded "that the vast majority of coral damage observed on the reef was the result of natural causes". However, boat groundings or wreckings on the reefs caused significant local damage.

Dustan (1977b) studied the effects of the 1974 wreck of a 38' catamaran at Key Largo Dry Rocks. The wreck site covered an area of about 6,000 square feet and Dustan called it "an ecological disaster." After one year little coral repair had occurred. Five other lesser groundings took place during his eighteen months study.

Hurricane damage can be very severe. Hurricane Donna in 1960 struck the vicinity of Key Largo Dry Rocks with winds of 160 kph with gusts to 240 kph (Ball *et al.*, 1967). The reef was in such a state that it was thought recovery would take decades but within a year storm damage was visible only to an experienced observer and in 1965 the reef had completely recovered (Shinn, 1975; Voss, personal observations). In late 1965 Key Largo Dry Rocks was again struck by a hurricane (Perkins and Enos, 1968) with extensive coral destruction. By 1967, storm damage was not noticeable (Shinn, 1975). Today, Key Largo Dry Rocks still has the most beautiful stands of elkhorn and staghorn coral in the Sanctuary.

Antonius (1981c) has reported upon the condition of corals in the bombing range at Vieques Island, Puerto Rico. He found that despite the years of bomb explosions in the reefs, the coral damage was negligible when compared to natural damage from storm waves on control reefs, and the health (percentage of diseased and/or dead corals) was better on the Vieques reefs.

Anchor damage may be severe in some localities. Dustan (1977b) reported that on a busy day up to two hundred boats visit Molasses Reef, only two acres in areas, while the average is twenty to fifty boats. He estimated that anchors were dropped 15,000 times each year. Most of these are not on the reef proper but along its edge and on the reef flat. Nonetheless, visible damage to bottom life occurs. Davis (1977) surveyed bottom damage by anchors at the Fort Jefferson National Monument, the Dry Tortugas, and found 20% of an extensive staghorn coral reef badly damaged. Staghorn coral with its slender branches and low tensile greatly increase with the predicted population increase of South Florida. It may already be the cause of part of the deterioration of Grecian Rocks, Key Largo Dry Rocks and Looe Key. It requires constant monitoring and the possibility exists that user impact may have to be controlled by limiting the number of visitors to disturbed areas or by using mooring systems that do not injure the coral reefs.

6.5. Species Diversity

The expression of species diversity takes a number of forms and has various meanings. Species diversity alone is best expressed by the simple number of species found at a given place. This type of species diversity is shown directly in the tabulation of the transects and quadrats and is perhaps the most reliable.

For each transect and quadrat the number of specimens of each species was tabulated and these data were then used to calculate the Shannon Weaver Species Diversity Index of H'. H' shows not only the diversity of species but the evenness of the number of specimens of each. While it neither reflects the number of species nor the number of individuals, it does afford a number which, used with caution, can be compared with other numbers to give an indication of the richness of one sample to another.

Table 12 shows both the diversity as indicated by the actual number of species and the species diversity calculated for H'. An examination of the data in the table presents no surprises. In general the transects show a higher diversity for the outer reefs with that of Molasses Reef the highest. Key Largo Dry Rocks has the lowest diversity figures for an outer reef probably because of the large expanse of living coral represented by the two species of *Acropora.* The transects in the turtle grass sites have the lowest because of the uniformity of the grass beds. Almost without exception, the quadrat figures show that the coral quadrats have the highest diversity. Eight coral quadrats out of 11 had indices above 3.00; 3 hardbottom quadrats out of 5 exceeded 3.00. Only 3 of 13 grass quadrats exceeded 3.00. The lowest quadrat indices were from the sand areas; none of the 9 attained 2.00.

Indices calculated on collections of smaller individuals such as are retained by a 1 mm^2 aperture sieve would yield higher indices in some habitats, especially in the *Thalassia* meadows.

Table 12. Species diversity of transects and 4-m^2 quadrats from 18 sites in the Key Largo Coral Reef Marine Sanctuary and the Pennekamp Coral Reef State Park. Number of species is taken from data in appendix 1. H' was calculated using the Shannon Weaver Species Diversity Index as given under Methodology.

Site	No. of species	H'
1. Molasses Reef		
Transect 1	32	3.02
Transect 2	27	2.76
Transect 3	46	3.18
Coral	52	3.19
Rubble	23	2.66
Hardbottom	48	3.17
Sand	5	1.23
2. White Banks		
Transect 1	34	2.96
Transect 2	30	2.18
Transect 3	28	2.46
Coral	40	3.19
Rubble	40	2.66
Grass	25	2.58
Sand	7	1.91
3. French Reef		
Transect 1	35	2.86
Transect 2	18	2.31
Transect 3	24	2.66
Coral quadrat	47	3.07
Rubble	37	2.72
Hardbottom	45	3.01
Sand	5	1.00
4. Mosquito Bank		
Transect 2	22	2.05
Transect 2	19	1.84
Transect 3	41	2.53
Coral	66	3.48
Grass	40	3.36
5. Grecian Rocks		
Transect 1	17	2.44
Transect 2	29	2.85
Transect 3	18	2.52
Coral	28	2.53
Rubble	55	1.85
Grass	54	2.90
Sand	6	0.98
6. Key Largo Dry Rocks		
Transect 1	16	2.20
Transect 2	16	1.52
Transect 3	17	2.34
Coral	43	2.80
Rubble	53	3.01
Grass	34	3.04
Sand	30	1.98
7. The Elbow		
Transect 1	25	2.45
Transect 2	32	2.68
Transect 3	26	2.52
Coral	50	3.08
Rubble	45	2.98
Hardbottom	45	2.65
Sand	10	1.28
8. Carysfort Reef		
Transect 1	32	2.51
Transect 2	33	2.66
Transect 3	18	2.46
Coral	54	3.19
Rubble	43	2.90
Hardbottom	53	3.23
Sand	9	1.14
9. Basin Hill Shoal		
Transect 1	28	2.16
Transect 2	10	0.75
Transect 3	15	1.64
Coral	35	2.57
Grass	17	1.53
Sand	14	2.43
10. Turtle Rocks		
Transect 1	22	2.51
Transect 2	16	1.94
Transect 3	33	2.59
Coral	53	3.35
Grass	43	2.81
Sand	12	1.98

Table 12. Species diversity of transects and 4-m^2 quadrats from 18 sites in the Key Largo Coral Reef Marine Sanctuary and the Pennekamp Coral Reef State Park. Number of species is taken from data in appendix 1. H' was calculated using the Shannon Weaver Species Diversity Index as given under Methodology (cont.).

Site	No. of species	H'	Site	No. of species	H'
11. Ocean Reef			**15. Rock Harbor**		
Transect 1	9	0.80	Transect 1	17	1.35
Transect 2	7	0.62	Transect 2	16	1.33
Transect 3	2	0.63	Transect 3	16	1.20
Grass	15	2.35	Grass	14	1.32
12. Turtle Harbor			**16. Port Elizabeth**		
Transect 1	1	0.00	Transect 1	15	1.60
Transect 2	5	0.37	Transect 2	9	0.99
Transect 3	12	1.02	Transect 3	6	0.84
Grass	24	2.61			
			17. Angelfish Creek		
13. North Channel			Transect 1	28	2.35
Transect 1	19	2.42	Transect 2	11	1.13
Transect 2	12	1.02	Transect 3	18	1.54
Transect 3	23	2.58	Coral	70	3.47
Hardbottom	24	1.21	Grass	33	2.63
Grass	32	2.74			
			18. Molasses Deep Drive		
14. South Channel					
Transect 1	26	2.56	Transect 1	10	2.24
Transect 2	20	2.56	Transect 2	11	2.37
Transect 3	16	2.29	Transect 3	18	2.34
Grass	66	3.33			