OCS Study
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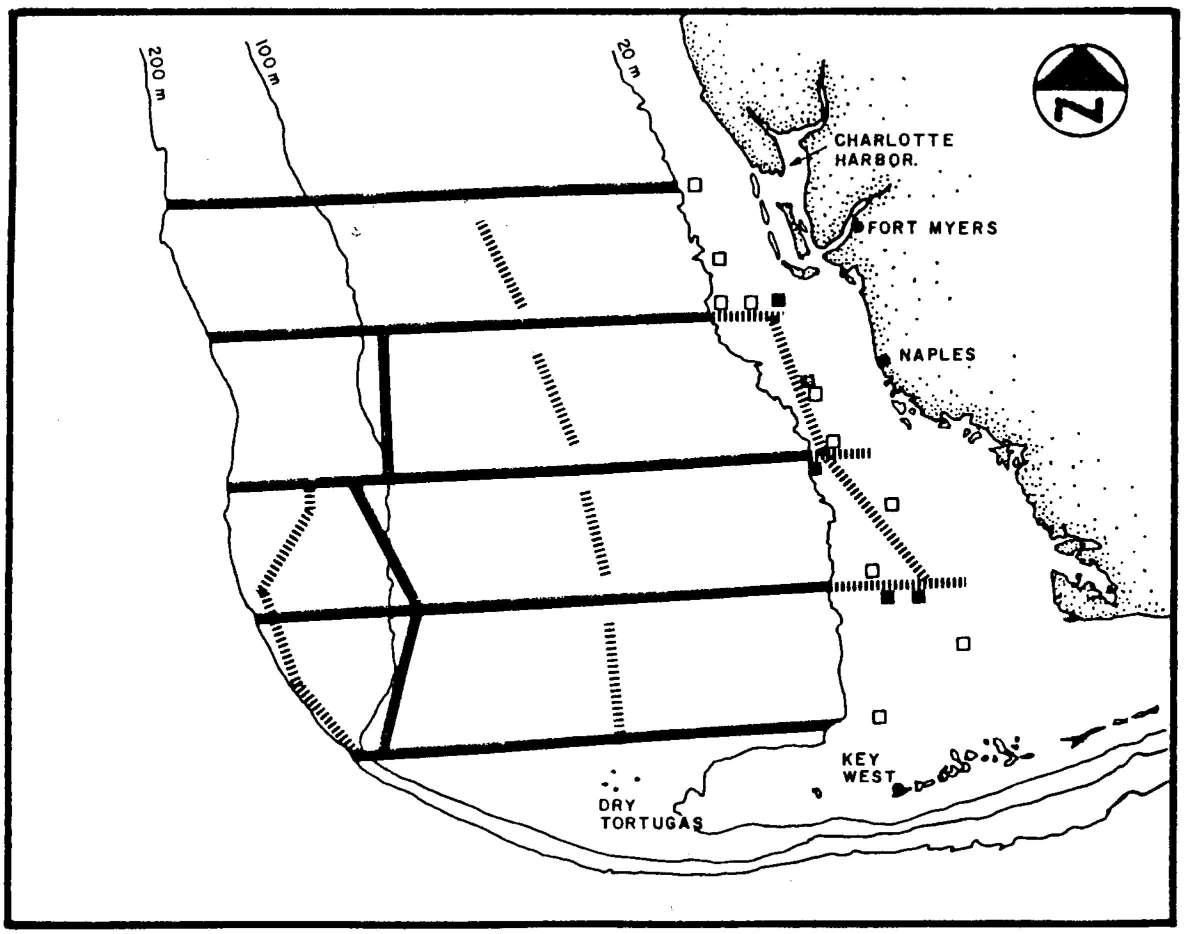
Southwest Florida Shelf Regional Biological Communities Survey: Year 3 Final Report

Volume II
Technical Report



MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS STUDY MMS 86-0109

SOUTHWEST FLORIDA SHELF REGIONAL BIOLOGICAL COMMUNITIES SURVEY

YEAR 3 FINAL REPORT
VOLUME II -- TECHNICAL REPORT

PREPARED FOR:

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
New Orleans, Louisiana

PREPARED BY:

Continental Shelf Associates, Inc.
759 Parkway Street
Jupiter, Florida 33477
Telephone: (305) 746-7946

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REPORT CONTRIBUTORS

EDITOR

Neal W. Phillips

AUTHORS

Continental Shelf Associates, Inc.

Neal W. Phillips
M. John Thompson
Keith D. Spring
David B. Snyder
Alan D. Hart

Mote Marine Laboratory

Richard H. Pierce, Jr.
Robert C. Brown
James K. Culter
Selvakumaran Mahadevan

Independent Consultant

Kenneth D. Haddad

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Minerals Management Service
Gulf of Mexico OCS Regional Office
U.S. Department of the Interior
1201 Elmwood Park Boulevard
New Orleans, LA 70123-2394
Attn: Public Information Section
Telephone: (504) 736-0557

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CHAPTER 1
INTRODUCTION

In 1980, the U.S. Department of the Interior began funding environmental studies of the continental shelf off southwestern Florida through the Bureau of Land Management's Environmental Studies Program. Two years of field sampling (Southwest Florida Shelf Ecosystems Study) have already been described in reports submitted to the Minerals Management Service (MMS) (the agency that now supervises the Environmental Studies Program*). This report describes the third year of field sampling (Southwest Florida Shelf Regional Biological Communities Survey) and integrates findings with those of the two previous study years.

Figure 1.1 shows the study area, which encompassed water depths of 10 to 200 m on the continental shelf between Charlotte Harbor and just north of the Dry Tortugas. This is a frontier area for both petroleum exploration and benthic ecological study. Recent industry interest in the oil and gas potential of the area has prompted concerns about impacts of drilling and related activities upon shelf benthic communities. A major concern is the potential for damage to "live bottom." The term refers to

> "seagrass communities; or those areas which contain biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography; or whose lithotope favors the accumulation of turtles, fishes, and other fauna" (U.S. Department of the Interior, MMS, 1984).

When the MMS studies began, live bottom was known to occur on the southwest Florida shelf, but little was known of its spatial distribution, its species composition, or the environmental factors influencing them. Thus, mapping and characterization of live bottom were major focuses of the present study.

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* In May 1982, all Bureau of Land Management leasing and resource management functions for the outer continental shelf, including the Environmental Studies Program, were consolidated within the MMS.

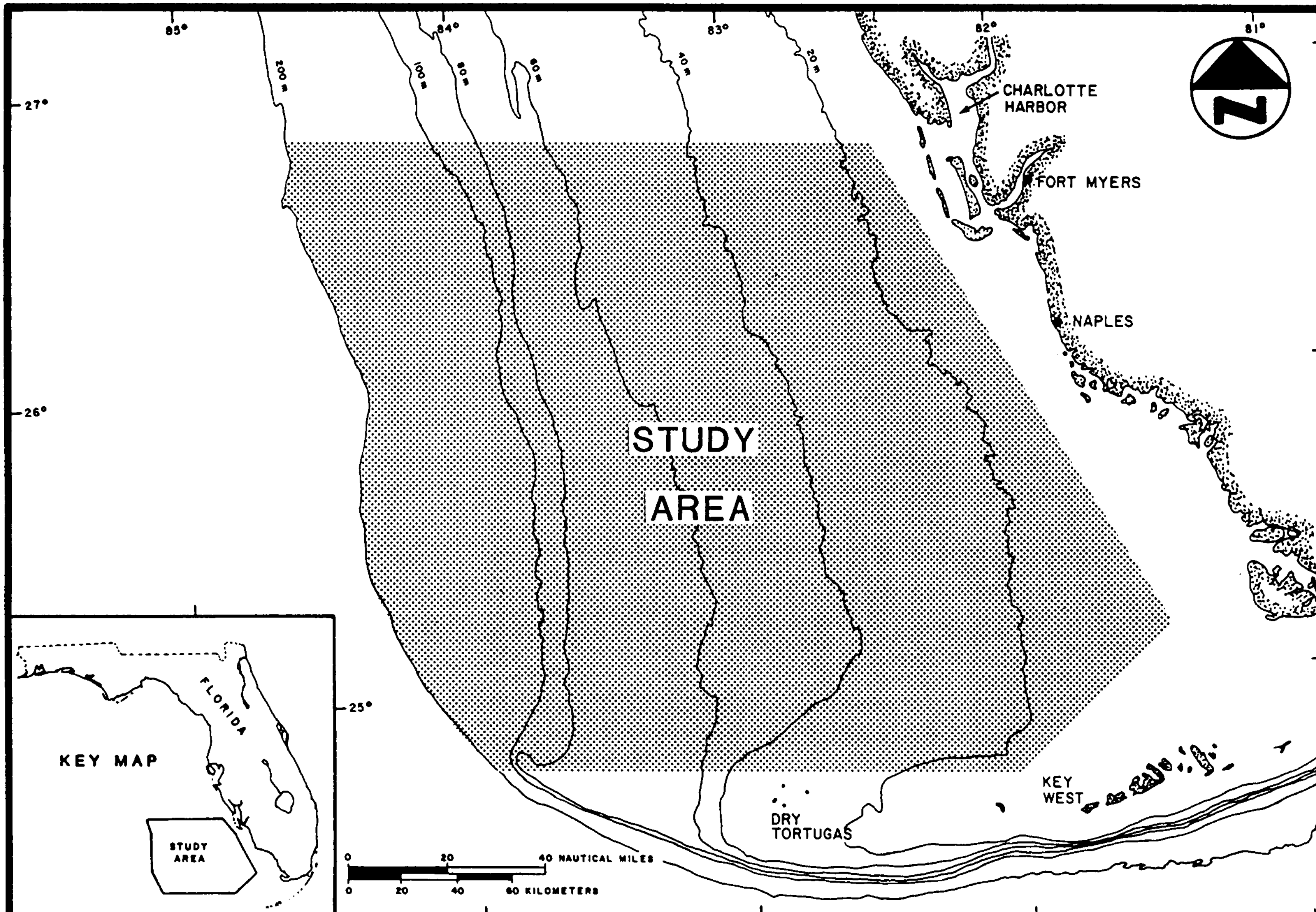


FIGURE 1.1. STUDY AREA FOR THE SOUTHWEST FLORIDA SHELF REGIONAL BIOLOGICAL COMMUNITIES SURVEY.

1.1 PREVIOUS STUDIES IN THE AREA

The most comprehensive previous investigation of the southwest Florida shelf was the Southwest Florida Shelf Ecosystems Study, of which the present effort is an outgrowth. Hereafter, we refer to the earlier study as Years 1 and 2, with the present study constituting Year 3. The elements of Years 1 and 2 are presented in Chapter 2 to provide background for the elements of Year 3.

Figure 1.2 shows the locations of some other previous studies of the west Florida shelf. These are described briefly below.

The Bureau of Land Management funded several studies that focused on portions of the west Florida shelf. The Mississippi-Alabama-Florida (MAFLA) Baseline Environmental Surveys (State University System Institute of Oceanography, 1977, 1978; Dames & Moore, 1979) encompassed a range of transect locations from south of Ft. Myers to the Mississippi coast; benthic biological collections included box core, trawl, and dredge samples. The Northern Gulf of Mexico Topographic Features Study (Hopkins et al., 1981) included coverage of the biota of the Florida Middle Ground, a high-relief carbonate outcropping located in mid-shelf depths west of Tarpon Springs, Florida. The Eastern Gulf of Mexico Marine Habitat Mapping Study (Woodward-Clyde Consultants, 1979) involved geophysical and remote photographic surveys of oil and gas lease blocks ranging in location from south of Ft. Myers to the Alabama-Florida border.

The Florida Department of Natural Resources Marine Research Laboratory conducted the Hourglass cruises (so named for the configuration of sampling stations) between August 1965 and November 1967. Five stations on each of two cross-shelf transects (one west of Tampa Bay, the other west of Sanibel Island) were sampled approximately monthly by dredge and trawl. Results have emerged in a series of reports describing particular taxa that have so far been processed. Lyons and Camp (1982) provide a preliminary overview of the results.

The U.S. Geological Survey conducted a geophysical investigation of the shelf and slope off southwest Florida (south of 26°N Lat) in 1980. The results are reported by Holmes (1981, 1985), who describes bottom features and discusses processes affecting the formation of these features and the deposition of unconsolidated sediments on the shelf.

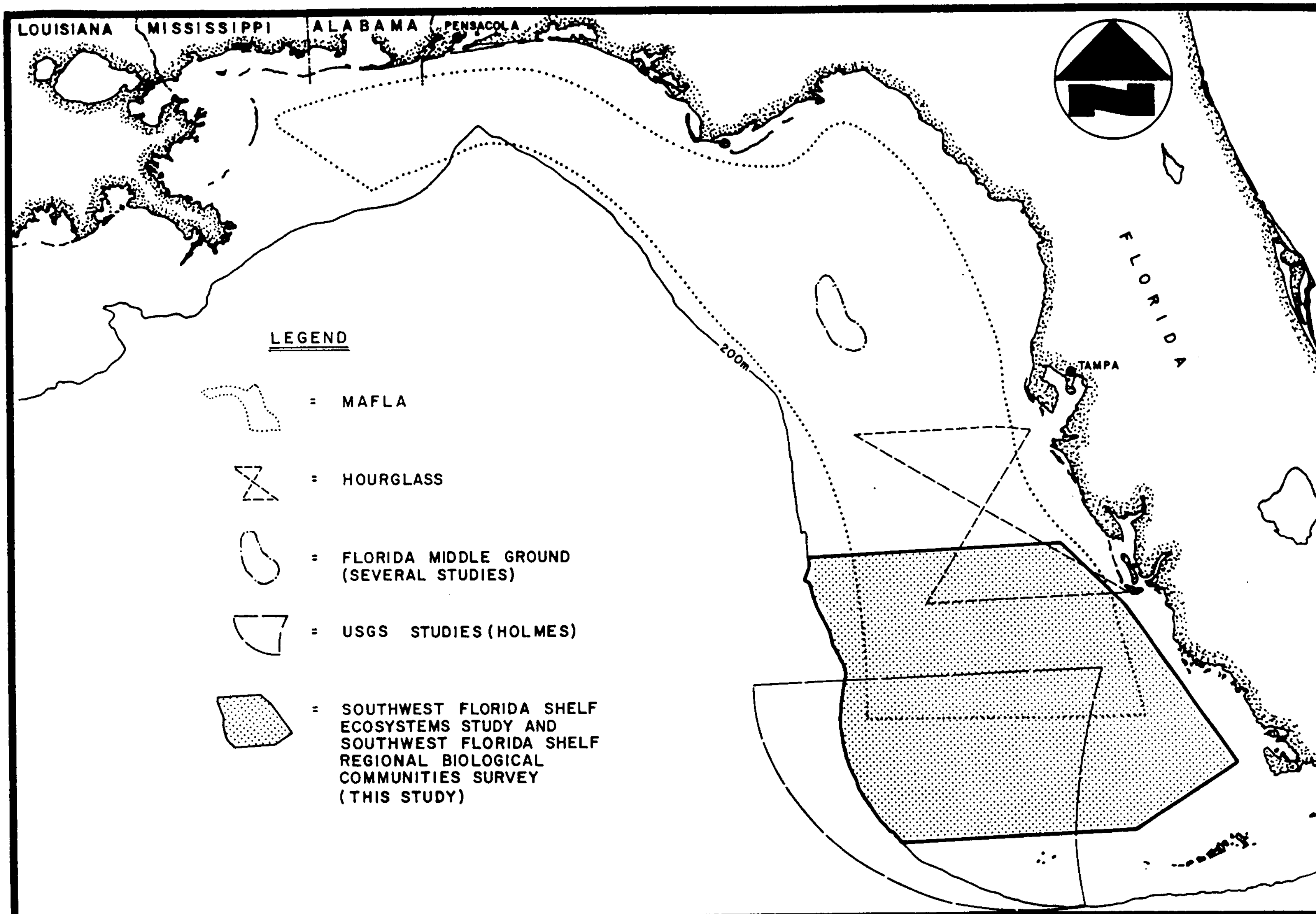


FIGURE 1.2. LOCATIONS OF RELEVANT PREVIOUS STUDIES ON THE WEST FLORIDA SHELF IN RELATION TO THE PRESENT STUDY AREA.

1.2 STUDY OBJECTIVES

The general objectives of the Year 3 study were as follows:

1) To map the distribution of substrate types and benthic community types on the shelf.

2) To characterize the substrate and the benthic community at representative soft-bottom and live-bottom stations.

3) To examine relationships between the composition of benthic communities and factors such as water depth, latitude, and substrate type;

4) To compare and evaluate certain methodologies (e.g., side-scan sonar vs. remote photography; remote vs. diver sampling techniques).

5) To determine the hydrographic structure of the water column at selected locations.

6) To discuss findings in relation to pertinent previous and ongoing studies of the west Florida shelf.

In addition to these general objectives, particular topics for analysis, interpretation, and synthesis were specified in the MMS contract for the study. These are addressed in the individual subject chapters of the report.

1.3 REPORT ORGANIZATION

This report consists of three volumes. Volume I is the Executive Summary. Volume II is the final report proper (this volume). Volume III contains appendices providing methodological details and data listings.

Within this volume, scope and general methods are presented in Chapter 2, followed by separate subject chapters devoted to hydrography, habitat mapping, live-bottom stations, soft-bottom stations, sediment hydrocarbons, and potential impacts of offshore oil-related activities. Specific details of methodology for each type of sampling conducted are presented in the appropriate subject chapters.

CHAPTER 2
SCOPE AND GENERAL METHODS

This section describes the scope of Year 3 in relation to Years 1 and 2 and summarizes general methodology, including navigation and data management.

2.1 BACKGROUND: YEAR 1 AND 2 SCOPE

The Year 1 and 2 program is described in reports by Woodward-Clyde Consultants and Continental Shelf Associates, Inc. (1983a, 1985). Here, we provide a brief overview.

The Year 1 and 2 program had three major elements:

1) Benthic habitat mapping.
2) Benthic station sampling.
3) Hydrographic sampling.

Field sampling was conducted between September 1980 and February 1982. During each year, habitat mapping was conducted first. There were separate geophysical and photographic survey cruises during Year 1, whereas there was a combined geophysical/photographic survey cruise during Year 2. Following review of the videotapes from the habitat mapping survey(s), representative new stations were selected during each year. Stations were sampled during two biological/hydrographic cruises each year.

2.1.1 Benthic Habitat Mapping

During Years 1 and 2, five east-west transects (A-E) were surveyed between the 20- and 200-m isobaths, and one north-south transect (F) was surveyed across the outer ends of Transects C, D, and E (Figure 2.1).

The surveys were conducted using geophysical (side-scan sonar, subbottom profiler, precision depth recorder) and remote photographic (black-and-white television camera, color 35-mm still camera) instrumentation. Substrates and geologic features were delineated through interpretation of videotapes, photographs, and geophysical records. Benthic habitats were categorized on the basis of visually conspicuous epibiota. Results were compiled into a Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983b).

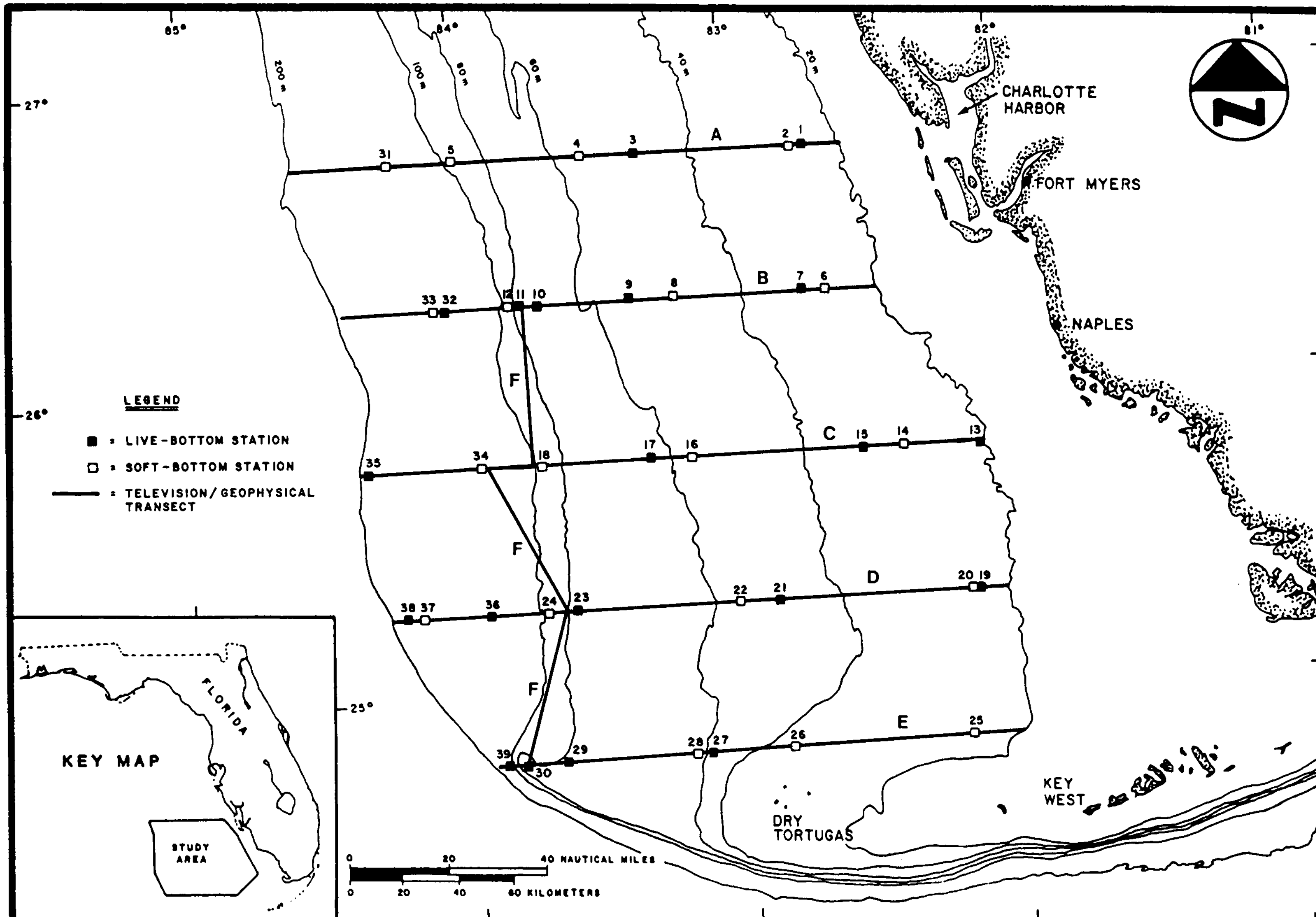


FIGURE 2.1. LOCATIONS OF YEAR 1 AND 2 STATIONS AND TELEVISION/GEOPHYSICAL TRANSECTS.

2.1.2 Benthic Station Sampling

Figure 2.1 shows the locations of stations sampled during Years 1 and 2. During Year 1, 15 live-bottom stations and 15 soft-bottom stations in water depths of 20 to 100 m were sampled during fall and spring cruises. During Year 2, 5 live-bottom stations and 4 soft-bottom stations were replaced by new stations in water depths of 100 to 200 m. These new stations and the remaining Year 1 stations were sampled during summer and winter cruises. Thus, there were four seasons of data from each of 10 live-bottom and 11 soft-bottom stations, as well as two seasons of data from 10 live-bottom and 9 soft-bottom stations.

Sampling at the live-bottom stations consisted of a remote photographic survey and dredge and trawl sampling. The photographic survey was conducted using a television/still camera system that was towed over a total length of several kilometers within a square-kilometer station block. Three dredge samples and one trawl sample were collected on each sampling date.

Sampling at the soft-bottom stations consisted of a remote photographic survey, trawl sampling, and box core sampling of infauna and sediments. The photographic survey was performed in the same manner as at the live-bottom stations. One trawl sample and five box core samples were collected at each station on each cruise. All sediment samples were analyzed for grain size and carbonate content. All Year 1 samples also were analyzed for hydrocarbons and trace metals. During Year 2, there were no trace metal analyses and only sediment samples from the new (Year 2) soft-bottom stations were analyzed for hydrocarbons.

2.1.3 Hydrographic Sampling

During Year 1, hydrographic profiling (temperature, salinity, dissolved oxygen, nutrients, chlorophyll _a_, transmissivity, and light) was conducted at all 30 Year 1 stations during fall and spring. During Year 2, profiling was conducted at 15 stations during summer and winter.

Additional hydrographic sampling was conducted during Year 2 as part of a separate "Year 2 modification" study designed to document the potential importance of the Loop Current as a driving mechanism for shelf ecosystems. Hydrographic sampling cruises were conducted during April and September 1982, and a concurrent high-altitude overflight by the NASA Ocean Color Scanner was used to map surface chlorophyll distributions during the April cruise. The results demonstrated the impingement of a Loop Current filament onto the shelf and associated enhancement of nutrient levels and water column primary production (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983).

2.2 YEAR 3 SCOPE

The major study elements during Year 3 were the same as during Years 1 and 2: benthic habitat mapping, benthic station sampling, and hydrographic sampling. The main difference was in geographic scope. Specifically, Year 3 was designed to fill gaps in habitat maps produced during Years 1 and 2 and to sample stations in shallower water depths (10 to 20 m) than those previously sampled.

Field sampling consisted of three cruises. Table 2.1 summarizes the sampling conducted during each cruise. Additional details are provided below.

Cruise I (October 1982) was a habitat mapping cruise. Geophysical/photographic survey transects B, C, and D were extended landward of the 20-m isobath and six new north-south transects (G-L) were added (Figure 2.2). Photographic coverage of Transect L was not completed during Cruise I due to loss of the television/still camera sled; the missing coverage was obtained during Cruise III. Geophysical and photographic data from the Year 3 transects were analyzed to produce a Marine Habitat Atlas (Continental Shelf Associates, Inc., 1985a) that complements the one produced during Years 1 and 2.

Hydrographic sampling was also conducted during Cruise I. Surface salinity and temperature samples were collected along and between survey transects. Hydrographic profiling (temperature, salinity, dissolved oxygen, and transmissivity) was conducted at both ends of each transect.

Cruises II (December 1982) and III (May-June 1983) were biological/hydrographic sampling cruises. Five new live-bottom stations and 11 new soft-bottom stations were sampled. Figure 2.3 shows station locations, and Table 2.2 lists water depths, latitude/longitude, and Loran-C coordinates for the stations. All Year 3 stations were in water depths of 10 to 20 m, where diver sampling methods could be used to supplement or replace remote sampling methods used during previous study years.

TABLE 2.1. CRUISES CONDUCTED DURING YEAR 3.

Cruise	Dates	Purpose
I	15-28 Oct 1982	Geophysical and television/ still camera surveys of Transects G-L and landward extensions of Transects B, C, and D; surface salinity sampling and hydrographic profiling.
II	4-15 Dec 1982	Biological, hydrographic, and sediment sampling at 5 live-bottom and 11 soft-bottom stations; deployment of sediment traps and recording thermographs.
III	29 May - 8 Jun 1983	Same as Cruise II plus recovery of sediment traps and thermographs. Additional television/still camera coverage of Transect L and Charlotte Harbor Area Block 887.

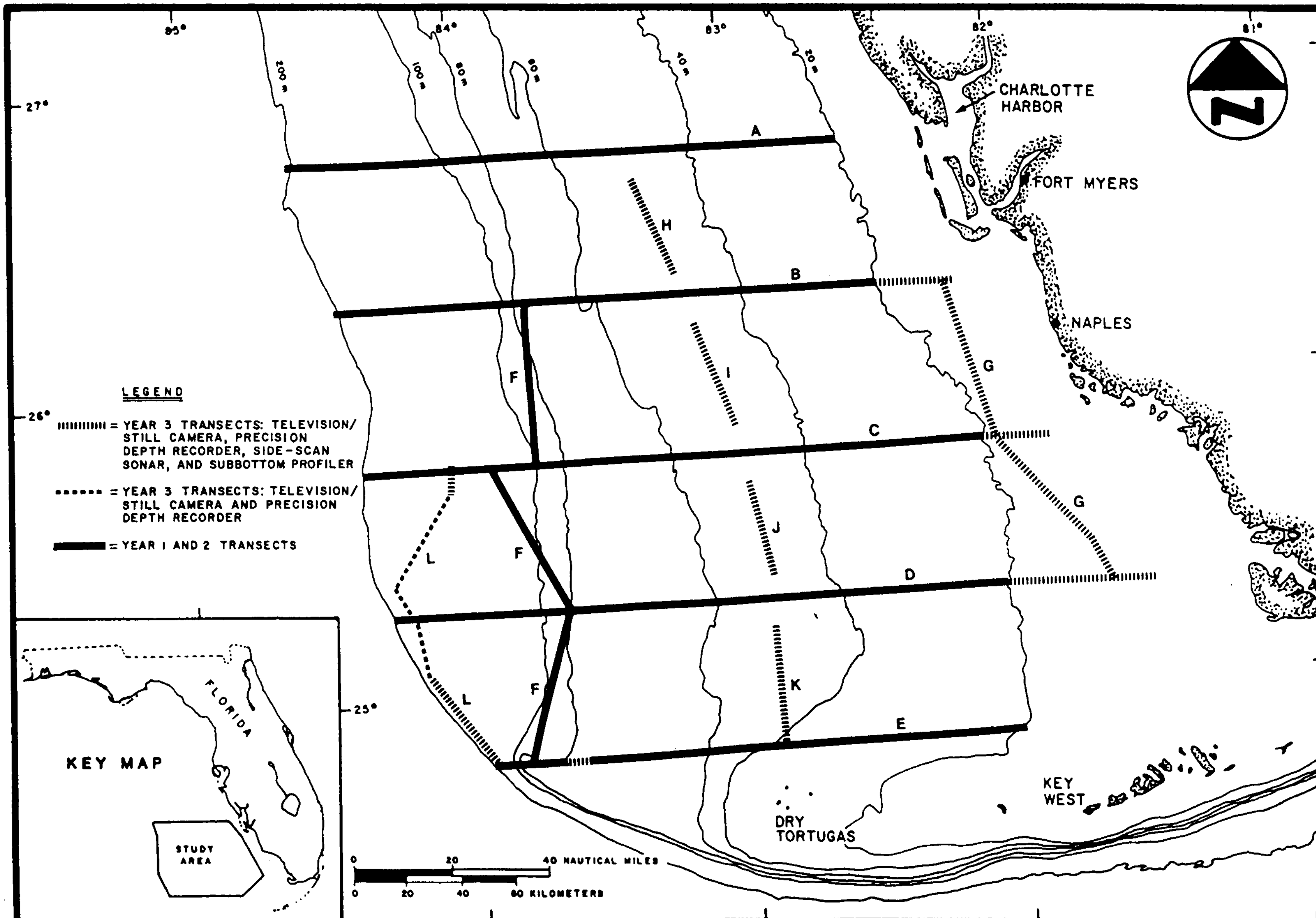


FIGURE 2.2. LOCATIONS OF YEAR 3 TRANSECTS IN RELATION TO YEAR 1 AND 2 TRANSECTS.

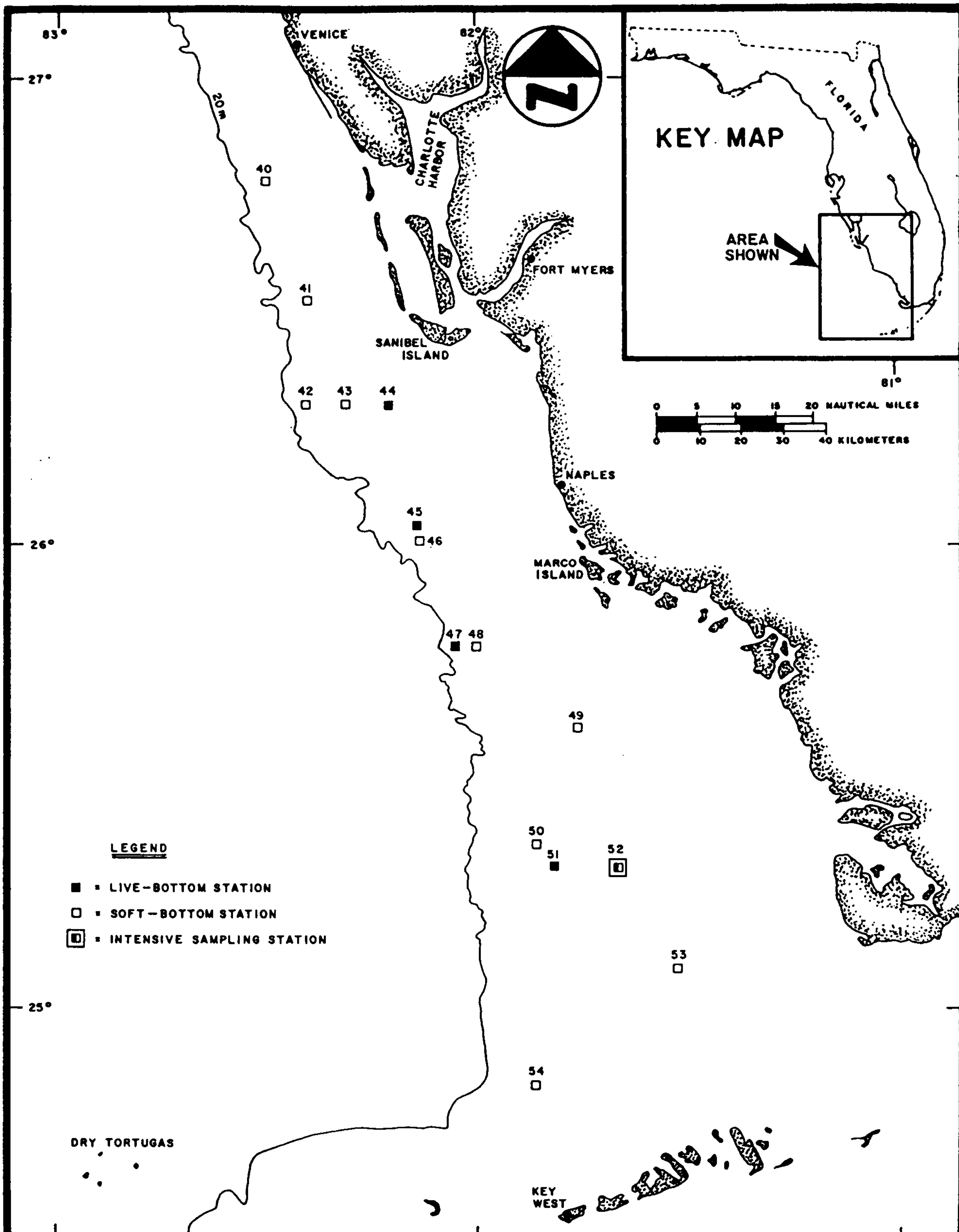


FIGURE 2.3. LOCATIONS OF YEAR 3 BENTHIC SAMPLING STATIONS.

TABLE 2.2. WATER DEPTHS AND LOCATIONS OF STATIONS SAMPLED DURING YEAR 3.

Station	Bottom Type	Water Depth (m)	Latitude (N)	Longitude (W)	Loran-C Coordinates	
40	Soft	18	26°46.75'	82°30.42'	14105.1	44216.5
41	Soft	16	26°32.22'	82°24.50'	14084.7	44106.3
42	Soft	17	26°17.01'	82°25.42'	14049.2	44058.0
43	Soft	16	26°17.40'	82°18.89'	14064.1	44008.8
44	Live	13	26°17.86'	82°12.61'	14078.2	43961.5
45	Live	17	26°03.19'	82°08.45'	14055.9	43888.5
46	Soft	18	26°01.02'	82°07.88'	14052.6	43878.9
47	Live	19	26°46.02'	82°06.06'	14025.9	43833.5
48	Soft	16	25°46.15'	82°01.10'	14036.4	43798.8
49	Soft	12	25°35.46'	81°46.23'	14045.1	43681.5
50	Soft	16	25°20.50'	81°51.50'	14006.3	43700.1
51	Live	16	25°17.67'	81°48.00'	14008.0	43675.7
52	Live/Soft	14	25°17.80'	81°39.80'	14024.3	43625.4
53	Soft	10	25°05.31'	81°31.68'	14017.1	43572.0
54	Soft	17	24°49.92'	81°50.55'	13952.6	43672.0

At each Year 3 live-bottom station, a remote photographic survey and dredge and trawl sampling were conducted during Cruises II and III in the same manner as during Years 1 and 2. In addition, divers photographed and harvested epibiota, measured sediment thickness, and counted fishes at each station. Sediment trap arrays were deployed at each live-bottom station during Cruise II to be recovered during Cruise III.

At each Year 3 soft-bottom station, divers collected infaunal and sediment samples during Cruises II and III. Sediment samples from all stations were analyzed for grain size and carbonate content. Samples from 10 of 11 stations were analyzed for hydrocarbons. No trawling or remote photographic surveys were conducted at the Year 3 soft-bottom stations.

During Cruises II and III, hydrographic profiling (temperature, salinity, dissolved oxygen, and transmissivity) was conducted at the five live-bottom stations. In addition, recording thermographs were deployed at two live-bottom stations during Cruise II to be recovered during Cruise III.

During Cruise III, additional photographic data were obtained in Charlotte Harbor Area Block 887 as the vessel was returning to port following completion of all other sampling. This location was not sampled during the previous cruises, but the area had been surveyed by Continental Shelf Associates, Inc. for Shell Oil Company during 1982. An unusually dense bloom of the green alga *Codium isthmocladum* was noted during the earlier survey, and the extra station was included during Cruise III to determine whether the bloom had persisted.

2.3 VESSEL AND NAVIGATION

All three cruises were conducted aboard the 33.5-m R/V SUNCOASTER, which is owned and operated by the Florida Institute of Oceanography, St. Petersburg, Florida. Navigation was accomplished using an EPSCO integrated Loran-C positioning system consisting of a C-NAV XL receiver, a C-Plot II 24-cm plotter, and a steer-to meter interfaced with an alphanumeric printer. Further specific information concerning navigation is provided in Chapter 4 in connection with a description of geophysical mapping.

2.4 DATA MANAGEMENT

A data manager was designated by Continental Shelf Associates, Inc. to be responsible for entering, validating, processing, and analyzing data. The data manager provided data products requested by the various investigators.

Raw data on keypunch forms were forwarded to the data manager by the appropriate investigators. Forms received were checked for completeness, entered onto the computer system, and checked and corrected according to quality control procedures (see below). Then, tabulations and analyses of the verified data sets were provided to the original investigators upon request.

Most of the Year 3 data were from live- and soft-bottom stations in water depths of 10 to 20 m. Additional data sets were available from the two previous years of study, which encompassed stations in water depths of 20 to 159 m. Data sets from Years 1 and 2 were obtained on magnetic tape from Woodward-Clyde Consultants, the prime contractor on the Year 1 and 2 program.

2.4.1 Hardware and Software

Data entry and initial processing were performed on an Apple III microcomputer (operating system SOS 1.0). Quality control procedures were written in Pascal. Data analysis was performed on the microcomputer using Pascal programs and on the Texas A&M Computing Center Amdahl 470 V/8 system under MVS/SP/JE53. Data were transferred to the Amdahl through TELENET using WYLBUR. Data base management and analysis were performed on the Amdahl system using the Statistical Analysis System (SAS) (SAS Institute, 1982) and the Ecological Analysis Package (EAP) (Smith, 1979) through the WYLBUR text editor.

2.4.2 Quality Control

Raw data were sent to the data manager as original or photocopied laboratory bench sheets, which were checked by visual inspection for accuracy and completeness prior to keypunching. Data entered onto the computer system were checked for obvious data-type related errors--e.g., alphanumerics in a numeric field, etc. The computer was then used to check each data file for valid entries in each field by cross-checking data files containing valid entries for each field. Printouts (facsimile bench sheets) were provided to the appropriate investigator(s), who checked the listings against original data sheets. Errors were corrected accordingly. Data analyses requested by various investigators were conducted using the final, verified data files.

Because transmission errors can occur when data are transferred via telephone lines, quality control measures were implemented to ensure accurate transmission of data to the Amdahl system. Each data set was transferred to the mainframe system twice into two different data files, which were then compared on a character-by-character basis using WYLBUR. If the files did not match exactly, the data set was retransmitted until agreement between files was complete.

2.4.3 Data Encoding and Submission

Taxonomic data were encoded using the system developed by the National Oceanographic Data Center (NODC). In this system, each taxon is represented by a two to 12-digit code number. The encoding system is described in detail in the Year 2 report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985) and in NODC (1984).

Continental Shelf Associates, Inc. has agreements with the NODC and the National Geophysical Data Center for submission of all biological, physical, and geophysical data. All data will be submitted as per these agreements.

CHAPTER 3
HYDROGRAPHY

3.1 INTRODUCTION

Previous southwest Florida shelf studies involved extensive hydrographic measurements (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983; Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a, 1985), but Year 3 hydrographic investigations were much more limited in scope. Sampling was conducted as follows:

1) During Cruise I (October 1982), surface salinity and temperature samples were collected at approximately 10-km intervals along and between geophysical/television survey transects (Figure 3.1). Depth profiling of temperature, salinity, dissolved oxygen, and transmissivity was conducted at both ends of each transect surveyed (except Transect L--southern end only).

2) During Cruises II (December 1982) and III (May-June 1983), depth profiling of temperature, salinity, dissolved oxygen, and transmissivity was conducted at each live-bottom sampling station (Figure 3.2).

3) During Cruise II, a recording thermograph was deployed near the bottom at Stations 44 and 52. The thermograph at Station 52 was recovered intact on Cruise III, but the one at Station 44 was lost.

In addition, weather and sea state observations were recorded at approximately 4-h intervals during each cruise.

3.2 METHODS

3.2.1 Field Methods

Surface salinity and temperature samples were collected with a bucket. Samples for temperature, salinity, and dissolved oxygen profiling were collected by hydrocast using 10-l Van Dorn bottles. Near-surface and near-bottom samples were obtained at each sampling location, and mid-depth samples were collected at 10-m depth intervals where water depth exceeded about 15 m. Near-surface and near-bottom bottles were equipped with reversing thermometers. Transmissivity profiles were

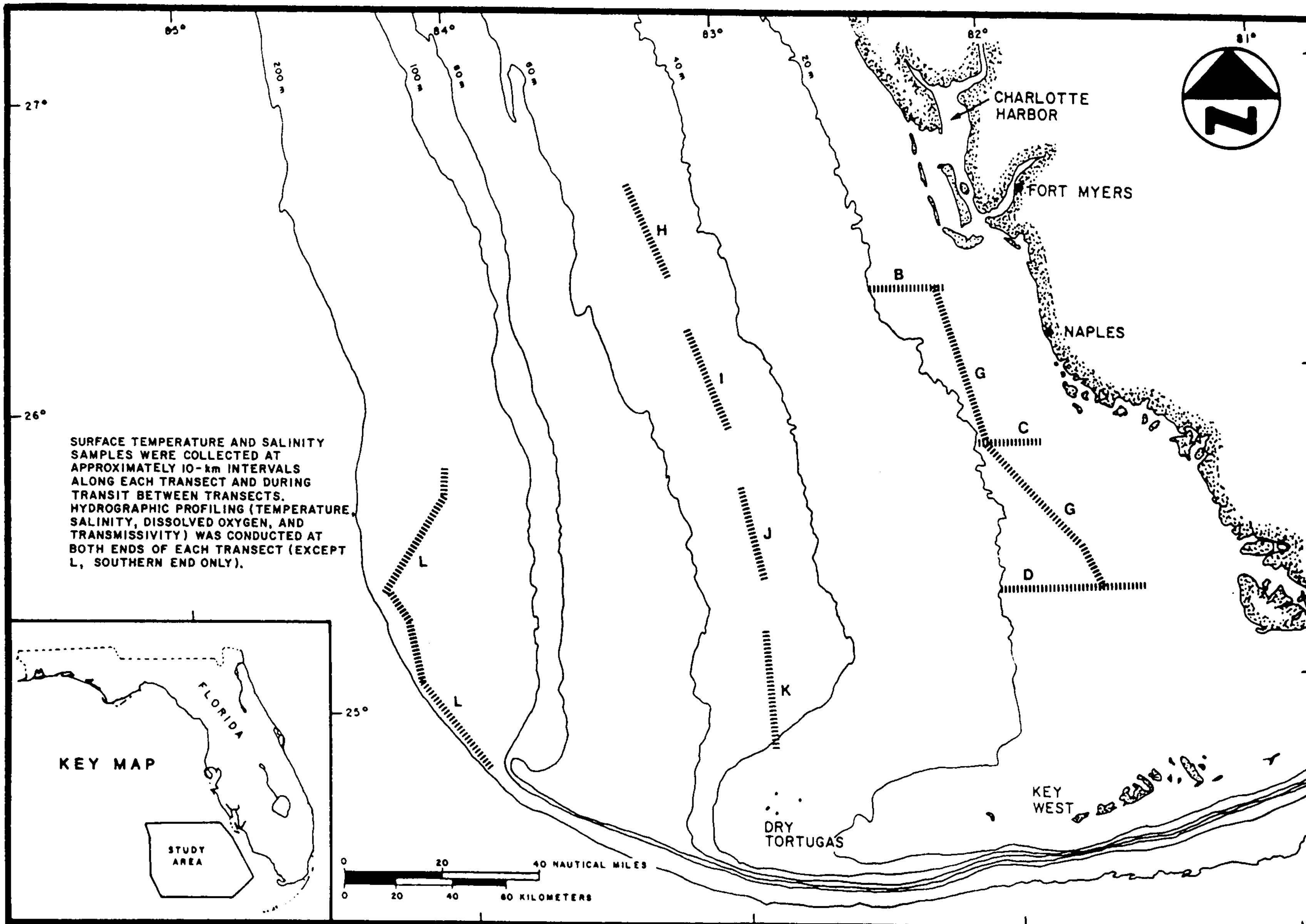


FIGURE 3.1. LOCATIONS OF CRUISE I SURVEY TRANSECTS.

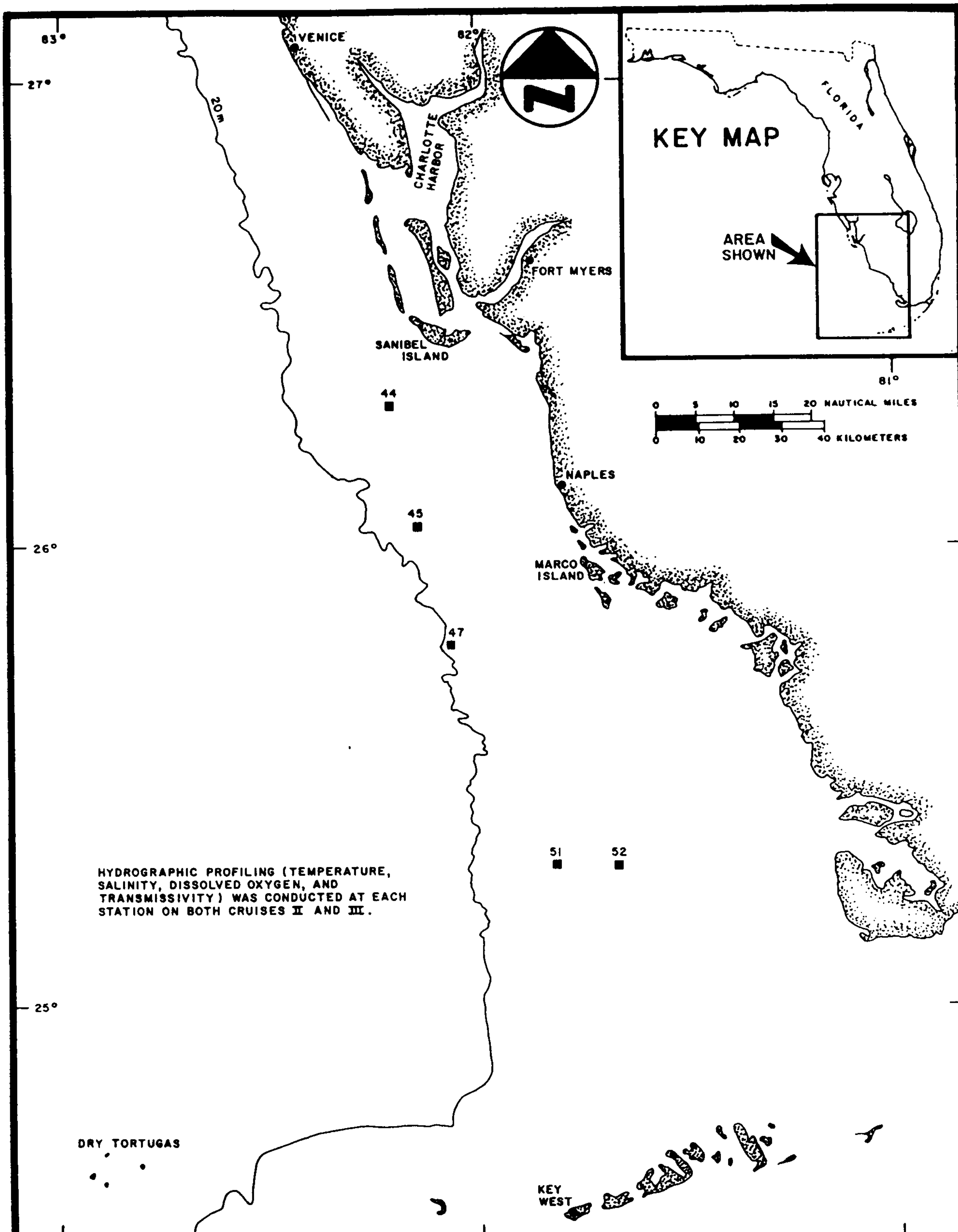


FIGURE 3.2. LOCATIONS OF LIVE-BOTTOM/HYDROGRAPHIC STATIONS SAMPLED DURING CRUISES II AND III.

obtained using a Hydro Products Model 912S transmissometer, which also records temperature and depth. Transmissivity and temperature values were read at approximately 5-m depth intervals.

During Cruise II, a Ryan Model J-180 thermograph was deployed on the sediment trap arrays (see Chapter 5) at Stations 44 and 52. The instrument was located about 1.5 m above the seafloor and set to record temperature at 12-h intervals. The Station 44 array was not recovered during Cruise III; it may have been dragged off station by a shrimp trawler.

3.2.2 Laboratory Methods

On board ship, temperature values were read from the reversing thermometer to the nearest 0.1°C, and dissolved oxygen was measured by the Winkler method. On shore, salinity was measured using a Grundy Model 6230N salinometer.

3.3 RESULTS

3.3.1 Weather and Wave Observations

Cruise I was conducted during 15 to 28 October 1982. Winds were primarily from the northeast, and speeds were typically in the range of 12 to 25 kt except during brief intervals of rough weather with winds of 30 to 35 kt. Wave heights ranged from 0.3 to 1.0 m most of the time, with maximum heights of 1.5 m. Swell heights were 0.6 to 1.5 m most of the time, but increased to 1.8 to 2.7 m during rough weather. Midday air temperatures ranged from 23° to 37°C and were generally lower during the second half of the cruise following the passage of a cold front on 23 October.

Cruise II was conducted during 4 to 15 December 1982. Winds were primarily from the east or east-southeast at 10 to 20 kt; swells typically were 0.6 to 1.5 m with wave heights of <0.3 to 0.9 m. A storm passed through on 12 December, bringing winds of 30 to 35 kt from the west and generating swells of 1.8 to 3.0 m. Swells of 1.5 to 2.1 m were building at the end of the cruise. Midday air temperatures varied little over the course of the cruise (23° to 26°C).

Cruise III was conducted during 29 May to 8 June 1983. Winds were typically light (0 to 15 kt) and from the east, southeast, or south. Twenty-five-knot winds were noted on the last day of the cruise as thunderstorms moved in. Seas were generally calm, with most wave and swell heights in the range of <0.3 to 0.6 m. Swells of 0.9 to 1.8 m were noted on the last day of the cruise. Midday air temperatures increased over the interval from 27° to 32°C.

3.3.2 Hydrographic Data

Data for each hydrographic parameter are summarized below. Cruise I data are too voluminous to be presented in the text; the reader is referred to Appendix A. Cruise II and III data are summarized in Tables 3.1 and 3.2, respectively.

Temperature. Surface and near-bottom temperature values cited below are based on thermometer readings. Temperature values recorded during transmissometry profiling are cited to illustrate vertical structure. Temperatures recorded by the transmissometer were in close agreement with those from reversing thermometers (Tables 3.1 and 3.2).

Figure 3.3 shows near-surface and near-bottom temperature values recorded at each end of the geophysical survey transects during Cruise I (October). Surface temperature values ranged from 24.0°C along the southern part of offshore Transect L to 28.5°C at the west end of the Year 3 portion of Transect C. Surface temperatures decreased with time of collection during the cruise due to decreasing air temperature; nearshore transects were sampled first and had higher surface temperature values. Near-bottom temperatures ranged from 18.5°C (104 m depth, southern end of Transect L) to 28.5°C (18 m depth, west end of Transect C). Temperature profiles indicate the surface mixed layer extended to approximately 35 to 40 m depth. No anomalous temperature events were noted during Cruise I.

Cruise II (December) near-surface and near-bottom temperatures ranged from 23.9°C (Station 44) to 24.7°C (Station 51) (Table 3.1). Temperatures generally increased toward the south. No vertical structure was evident.

Cruise III (May-June) near-surface temperatures ranged from 26.4°C (Station 45) to 28.5°C (Station 52) (Table 3.2). Near-bottom temperatures ranged from 24.0°C (Station 47) to 27.6°C (Station 52). Temperature generally increased toward the south. Minor vertical structure was apparent, with evidence of a thermocline at Station 47.

TABLE 3.1. CRUISE II (DECEMBER 1982) HYDROGRAPHIC DATA.

Station	Water Depth (m)	Sampling Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen (ml l^{-1})	Transmittance (%)
44	13	1.5	23.9(23.9*)	35.16	6.30	62
		6.0	23.9*	--	--	73
		11.0	23.8*	--	--	74
		12.0	23.9	35.16	6.34	--
45	17	1.5	24.0(24.0*)	35.37	6.55	74
		5.5	--	35.36	6.42	--
		6.0	24.0*	--	--	76
		11.0	24.0*	--	--	78
		14.0	24.0*	--	--	78
		15.5	24.0	35.36	6.46	--
47	19	1.5	24.5(24.5*)	35.99	6.53	80
		6.0	24.5*	--	--	82
		8.5	--	35.97	6.58	--
		11.0	24.3*	--	--	82
		16.0	24.3*	--	--	81
		18.5	24.4	35.97	6.68	--
		19.0	24.3*	--	--	81
51	16	1.5	24.7(24.7*)	35.51	6.40	58
		6.0	24.7*	--	--	61
		11.0	24.7*	--	--	62
		14.0	24.7	35.52	6.48	--
52	14	1.5	24.6(24.6*)	35.30	6.60	38
		6.0	24.6*	--	--	43
		10.0	24.6*	--	--	44
		11.5	24.6	35.30	6.58	--

Salinity and dissolved oxygen values are from near-surface, mid-depth (at some stations), and near-bottom bottle samples. Near-surface and near-bottom temperatures are from reversing thermometers attached to the bottle samplers. Additional temperature values (indicated by *) are from a separate lowering of the recording transmissometer, which outputs percent transmittance and temperature.

TABLE 3.2. CRUISE III (MAY-JUNE 1983) HYDROGRAPHIC DATA.

Station	Water Depth (m)	Sampling Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen (ml l^{-1})	Transmittance (%)
44	13	1.5	26.5(26.5*)	35.14	6.50	70
		5.0	26.5*	--	--	70
		9.5	26.5	35.14	6.37	--
		10.0	26.5*	--	--	70
45	17	1.5	26.4(26.4*)	35.22	6.50	80
		4.0	--	35.22	6.66	--
		5.0	26.4*	--	--	81
		10.0	26.4*	--	--	83
		14.0	25.9(25.9*)	35.52	5.82	76
47	19	1.5	27.1(27.0*)	35.18	6.58	80
		5.0	26.7*	--	--	79
		7.5	--	35.50	6.61	--
		10.0	25.7*	--	--	78
		15.0	24.0*	--	--	64
		17.5	24.0	35.81	7.22	--
		18.0	24.0*	--	--	60
51	16	1.5	27.8(27.8*)	35.92	6.66	64
		5.0	27.0*	--	--	66
		10.0	26.9*	--	--	70
		12.0	26.9(26.9*)	35.92	6.70	70
52	14	1.5	28.5(28.5*)	35.64	6.70	52
		5.0	27.7*	--	--	46
		10.0	27.6(27.6*)	35.77	6.75	33

Salinity and dissolved oxygen values are from near-surface, mid-depth (at some stations), and near-bottom bottle samples. Near-surface and near-bottom temperatures are from reversing thermometers attached to the bottle samplers. Additional temperature values (indicated by *) are from a separate lowering of the recording transmissometer, which outputs percent transmittance and temperature.

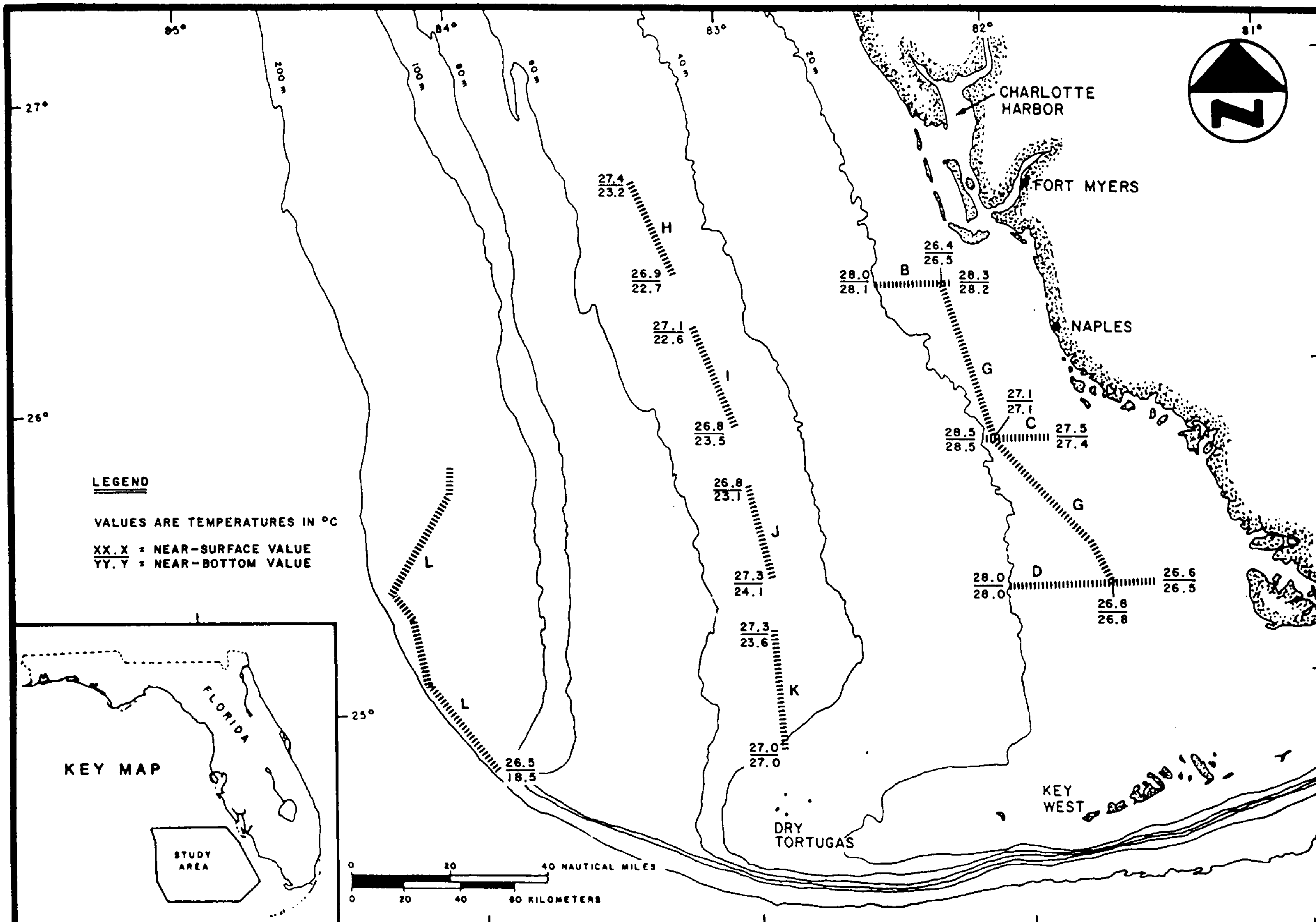


FIGURE 3.3. NEAR-SURFACE AND NEAR-BOTTOM TEMPERATURES RECORDED AT BOTH ENDS OF GEOPHYSICAL/TELEVISION SURVEY TRANSECTS DURING CRUISE I.

Salinity. Cruise I surface salinities ranged from 32.54°/oo near the entrance to Charlotte Harbor to 36.97°/oo on the southern part of Transect G (Florida Bay area). Near-bottom salinities ranged from 35.16°/oo (east end of Transect C) to 36.82°/oo (south end of Transect G). A halocline was evident at the middle and outer shelf transects, with bottom waters having higher salinities. In general, the highest salinities were noted in the southeast portion of the study area (Figure 3.4).

Cruise II salinities ranged from 35.16 to 35.99°/oo (Table 3.1). There were no significant salinity differences between surface and near-bottom waters.

Cruise III salinities similarly varied little spatially, ranging from 35.14 to 35.92°/oo (Table 3.2). Vertical salinity gradients were minimal.

Dissolved Oxygen. Cruise I surface dissolved oxygen values ranged from 5.9 to 6.4 ml l^{-1}. Near-bottom values similarly ranged from 5.3 to 6.5 ml l^{-1}, except at the south end of Transect L where a value of 4.4 ml l^{-1} was recorded. Figure 3.5 shows near-surface and near-bottom values recorded at each end of the geophysical survey transects.

During Cruise II, both near-surface and near-bottom dissolved oxygen values ranged from 6.3 to 6.6 ml l^{-1} (Table 3.1). Vertical gradients at the sampling stations were minimal.

Maximum and minimum near-surface values during Cruise III were 6.7 and 6.5 ml l^{-1}, respectively (Table 3.2). Near-bottom values ranged from 5.8 to 7.2 ml l^{-1}.

Transmissivity. Cruise I percent transmittance values ranged from 39% on the nearshore Transect C to 100% on the offshore Transect L (Figure 3.6). Transmittance was lowest (40 to 50%) in the Florida Bay area (southeast part of the study area). Nearshore waters were turbid from surface to bottom. On the mid-shelf transects (H, I, J, and K), transmittance was generally lower near the bottom than at the surface, indicating some near-bottom turbidity. Bottom waters at the 100-m isobath (Transect L) were clear.

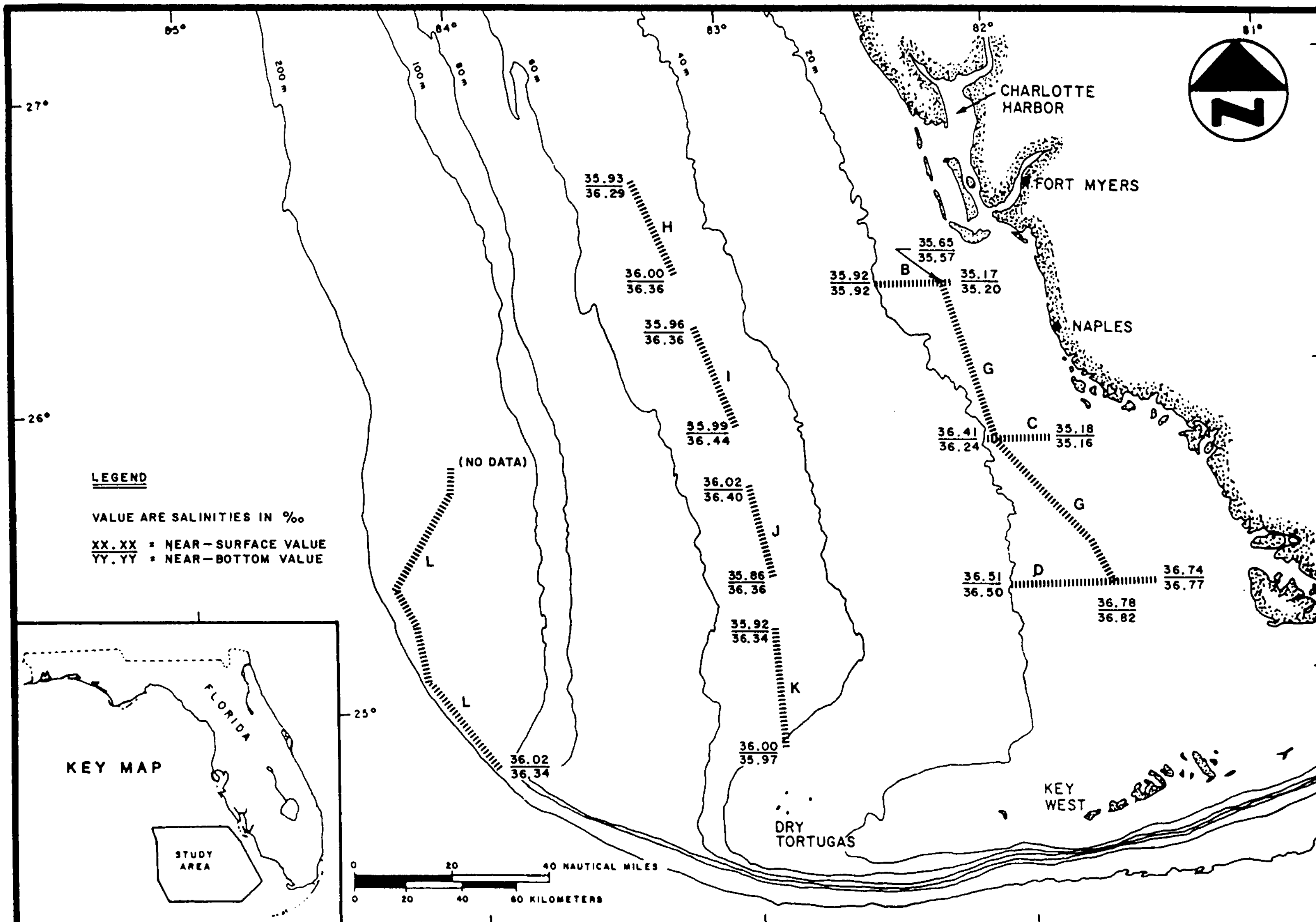


FIGURE 3.4. NEAR-SURFACE AND NEAR-BOTTOM SALINITIES RECORDED AT BOTH ENDS OF GEOPHYSICAL/TELEVISION SURVEY TRANSECTS DURING CRUISE I.

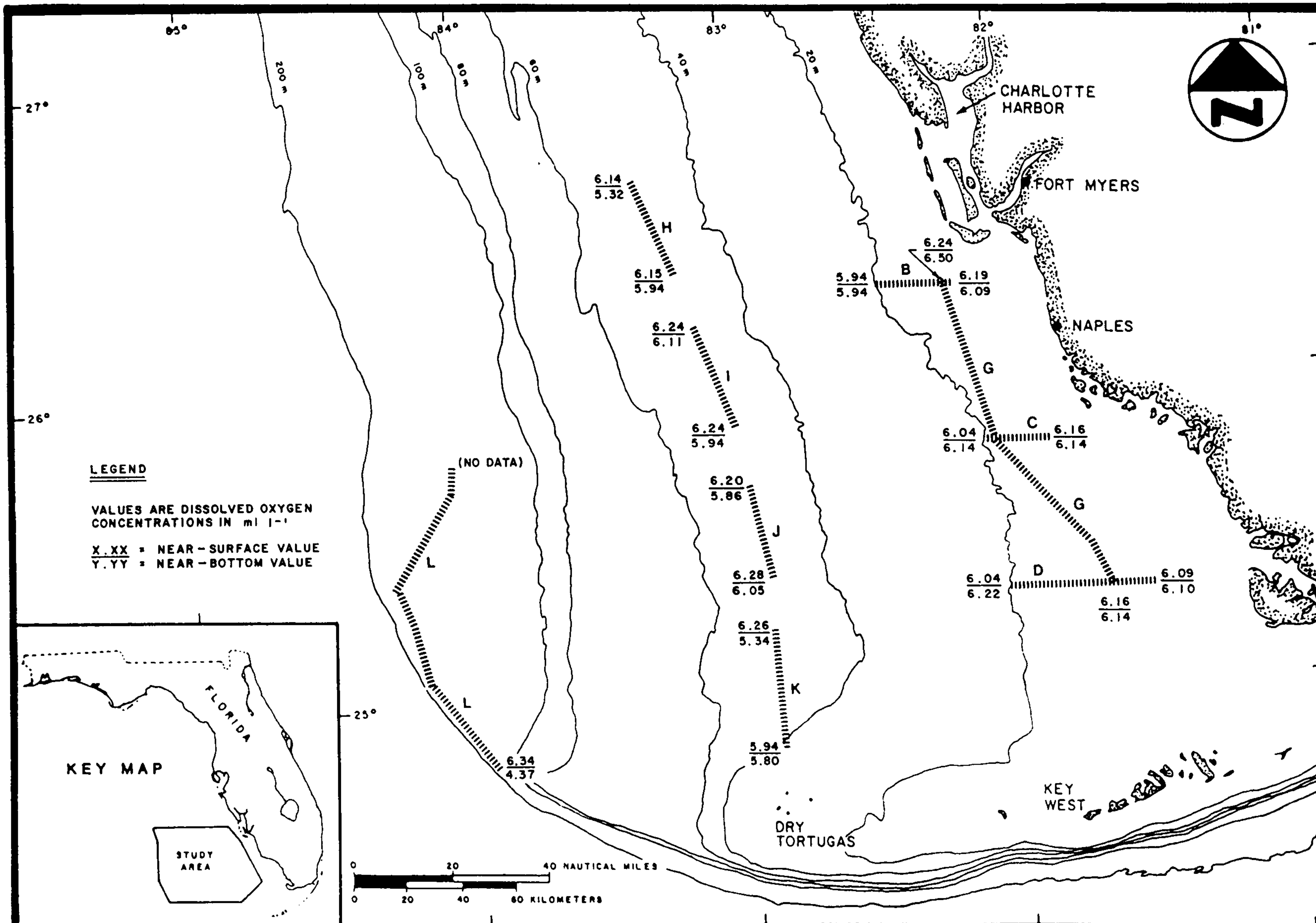


FIGURE 3.5. NEAR-SURFACE AND NEAR-BOTTOM DISSOLVED OXYGEN CONCENTRATIONS RECORDED AT BOTH ENDS OF GEOPHYSICAL/TELEVISION SURVEY TRANSECTS DURING CRUISE I.

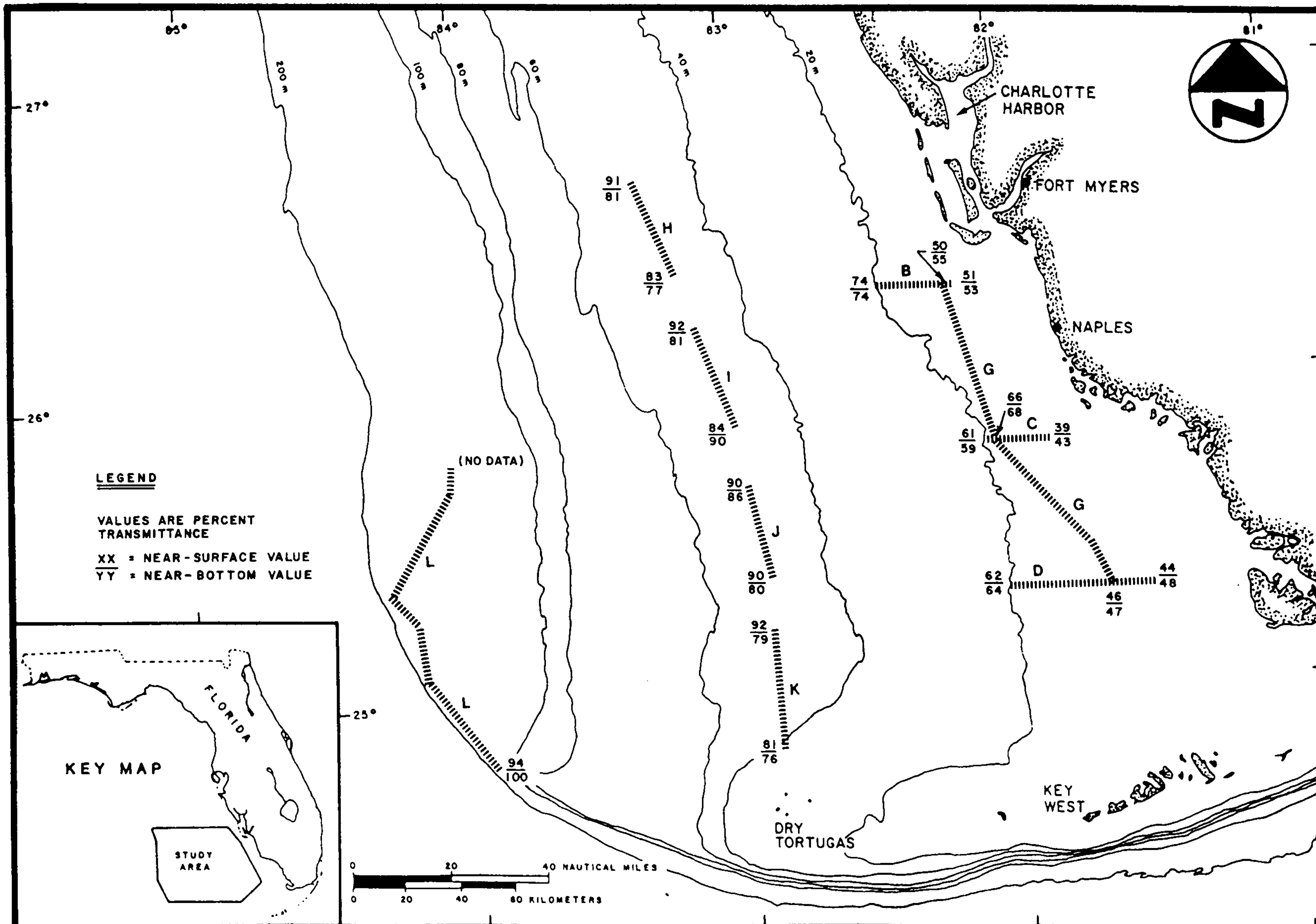


FIGURE 3.6. NEAR-SURFACE AND NEAR-BOTTOM TRANSMISSIVITY VALUES RECORDED AT BOTH ENDS OF GEOPHYSICAL/TELEVISION SURVEY TRANSECTS DURING CRUISE I.

Cruise II transmittance values ranged from 38% (Station 52) to 81% (Station 47) (Table 3.1). There was little or no change from surface to bottom.

Cruise III values ranged from 33% to 83% (Table 3.2). Station 52 again exhibited low transmittance values. A near-bottom increase in turbidity was evident at Stations 47 and 52.

3.3.3 Thermograph Data

Figure 3.7 shows temperature data from the recording thermograph at Station 52. Data were recorded at 12-h intervals; on the figure, each point represents a daily average. Raw data are presented in Appendix A.

During the six-month deployment, near-bottom temperature decreased from about 24°C on 10 December 1982 to a minimum of 17.8°C in the last week of January 1983, then increased to 25.8°C by the recovery date of 4 June 1983. Cooling was evident during mid-December, following which temperatures remained steady for about three weeks. Another cooling period occurred during the third week of January, bringing temperatures to their winter minimum. Temperatures of <18°C persisted for only a few days. Warming was gradual, with pronounced temperature increases evident during the second week of March and the second and third weeks of April.

3.4 DISCUSSION

Because of the limited scope of the hydrographic sampling efforts, an in-depth discussion of water column processes is not warranted. Southwest Florida shelf hydrography is discussed in detail in Woodward-Clyde Consultants and Skidaway Institute of Oceanography (1983) and Woodward-Clyde Consultants and Continental Shelf Associates, Inc. (1985).

Temperature and Salinity. Cruise I hydrographic profiles showed the presence of a thermocline and halocline at about 35 to 40 m depth on the middle and outer shelf transects. At the southern end of Transect K, the mixed layer apparently extended to at least 42 m depth. During the fall cruise of the Year 1 study (October to November 1980), the thermocline penetrated to only about the 60-m isobath (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). The difference is probably attributable to the earlier timing of our

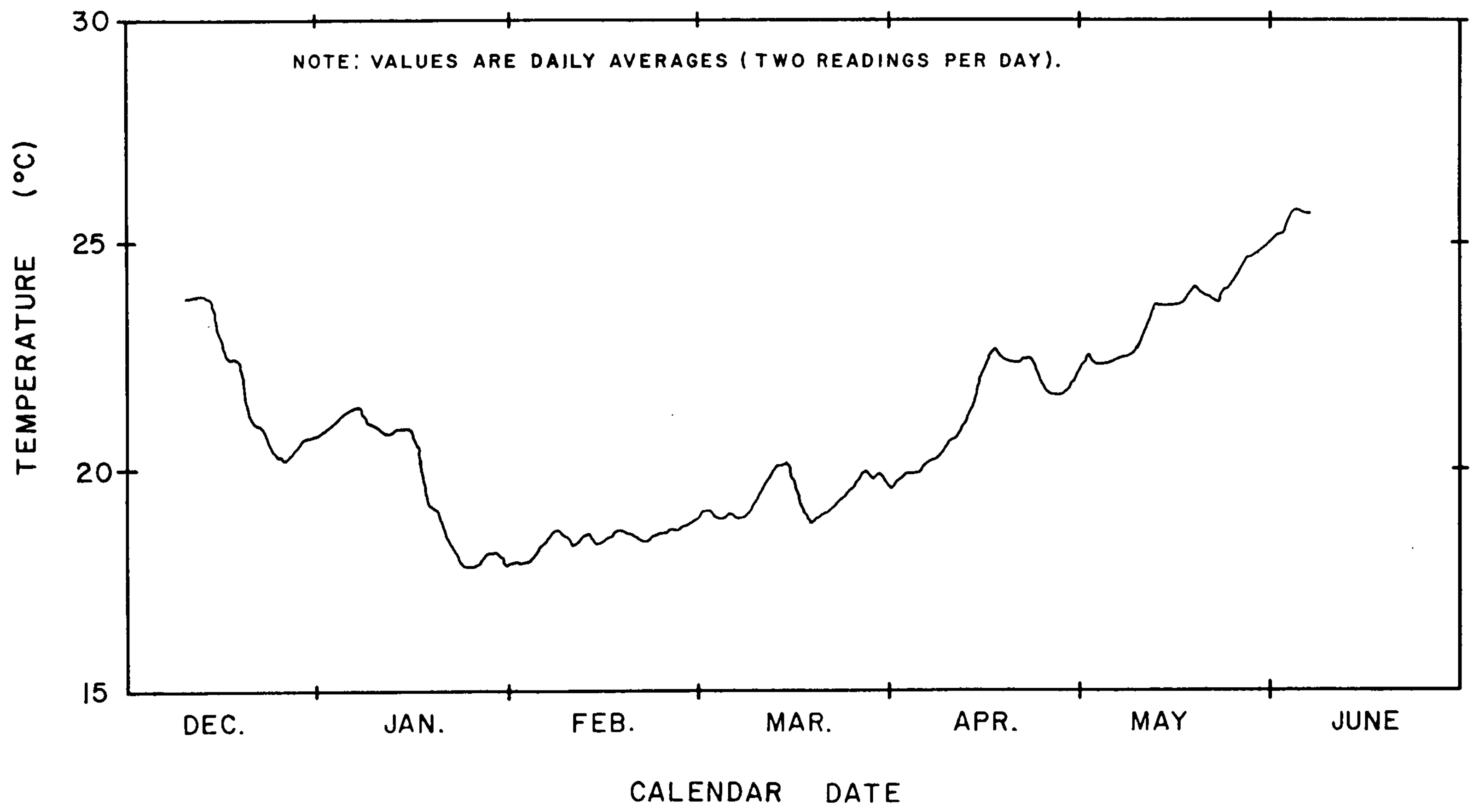


FIGURE 3.7. NEAR-BOTTOM TEMPERATURES RECORDED BY THERMOGRAPH DEPLOYED AT STATION 52 BETWEEN 10 DECEMBER 1982 AND 4 JUNE 1983.

Cruise I; wind mixing was just beginning to occur as Cruise I was being conducted.

The water column was essentially homogeneous with respect to hydrographic parameters at the nearshore transects and stations. However, during Cruise III, there was evidence of a thermocline and a halocline at the deepest nearshore station (Station 47; water depth 19 m). This accords with Year 1 and 2 data showing thermocline development during spring at nearby Station 13 (water depth 20 m) (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985).

Figure 3.8 depicts surface salinity contours constructed from Cruise I data. Two nearshore features are evident. The first is a region of low salinity (<36.0°/₀₀) near Charlotte Harbor. Salinities in this nearshore area are influenced by outflow from the Charlotte Harbor estuary, which receives freshwater input from the Myakka, Peace, and Caloosahatchee Rivers. Similarly, during Cruises II and III, the lowest salinity values were recorded at Station 44, which is nearest to Charlotte Harbor. The second feature is a region of high salinity in the southeast corner of the study area (Florida Bay region). A maximum salinity of 36.97°/₀₀ was measured, with a fairly large area exhibiting salinities greater than 36.6°/₀₀. High salinities were not evident in this area during Cruise II or III, suggesting the Cruise I data reflect a transient event. However, salinities in excess of 36.5°/₀₀ were noted previously in the vicinity during Year 1 and 2 investigations and were attributed to drought and evaporative loss in the shallow Florida Bay waters. Human alteration of Everglades drainage patterns may contribute to occasional hypersaline conditions in the Florida Bay area (Thomas, 1974).

Cruise I temperature and salinity data did not provide any evidence for direct Loop Current impingement on the shelf. Cruise II and III stations were located too far inshore to be affected by Loop Current impingement.

Dissolved Oxygen. Dissolved oxygen values recorded during this study are within the range of values observed during previous study years. With the exception of deep outer shelf waters at the southern end of Transect L, all waters sampled were saturated or supersaturated.

Transmissivity. Transmissivity data indicate oceanic water clarity across most of the shelf. Some near-bottom turbidity was evident

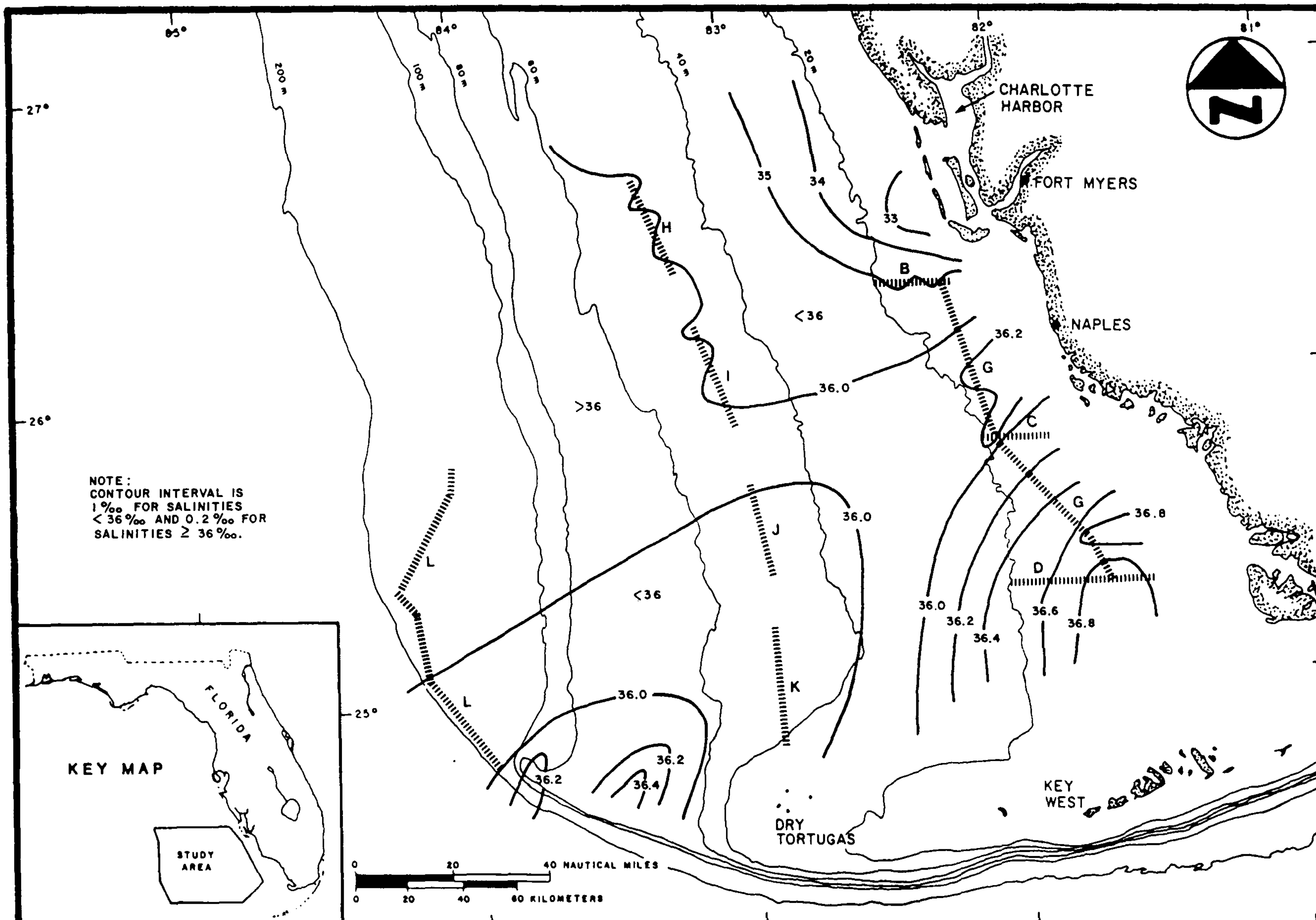


FIGURE 3.8. SURFACE SALINITY CONTOURS BASED ON CRUISE I DATA.

at the mid-shelf transects in association with the bottom thermocline. This could be attributable to near-bottom primary production or sediment resuspension. The mid-shelf values are not indicative of intense resuspension associated with strong currents. In contrast, high turbidity was common at the nearshore stations and transects. This probably reflects resuspension of bottom sediments due to tidal currents and/or surface waves. Higher productivity due to coastal nutrient inputs may be a contributing factor. The highest turbidity values on all three cruises were noted in the southeastern part of the area [inshore ends of Transects C and D during Cruise I; Station 52 (located on inshore end of Transect D) during Cruises II and III]. Sediments at Station 52 were coarse sand, but fine-grained, easily resuspended, calcareous muds occur to the south and southwest. During Year 1 sampling, the lowest transmittance values (approximately 40% near the bottom) were noted at Station 25, located about 75 km to the southwest of Station 52 in a water depth of 24 m (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985).

CHAPTER 4
BENTHIC HABITAT MAPPING

4.1 INTRODUCTION

Benthic habitat mapping was a major element of the Year 3 study, as it was during the two previous study years. During Years 1 and 2, combined geophysical and television/still camera surveys were conducted along six transects shown in Figure 4.1. The results have been presented in a two-volume Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983b). During Year 3, additional geophysical and remote photographic coverage was obtained as shown in Figure 4.1. The results have been presented in a second two-volume Marine Habitat Atlas (Continental Shelf Associates, Inc., 1985a). This section describes the methods and results of the habitat mapping efforts; for specific details of habitat distribution along the survey transects, the reader is referred to the previously cited Marine Habitat Atlases.

The Year 3 Marine Habitat Atlas (Continental Shelf Associates, Inc., 1985a) comprises two volumes: the atlas itself and an accompanying volume of explanatory text. Volume 1 contains (1) a Survey Locations Map (scale=1:500,000) showing transect locations; (2) a single Index Map (scale=1:500,000), which is a key to all other atlas maps; (3) two Regional Maps of Marine Habitats (scale=1:500,000) showing the broad distribution of biological communities along the survey transects; and (4) 23 detailed Habitat Maps (scale=1:48,000) summarizing navigational post-plot, side-scan, subbottom profiler, and television data. A legend clearly defines all symbols used on the maps. Volume 2 provides more detailed discussions of each habitat and substrate type; describes the field surveys, mapping procedures, and data analysis; and compares geophysical and remote photographic data.

4.2 FIELD SURVEY METHODS

4.2.1 Transects and Navigation

The survey pattern for Year 3 (Figure 4.1) extended previously sampled transects as follows:

1) Transect B was extended from the 20-m isobath to the Florida three-league line.

2) Transect C was extended from the 20-m isobath to the 82°W meridian.

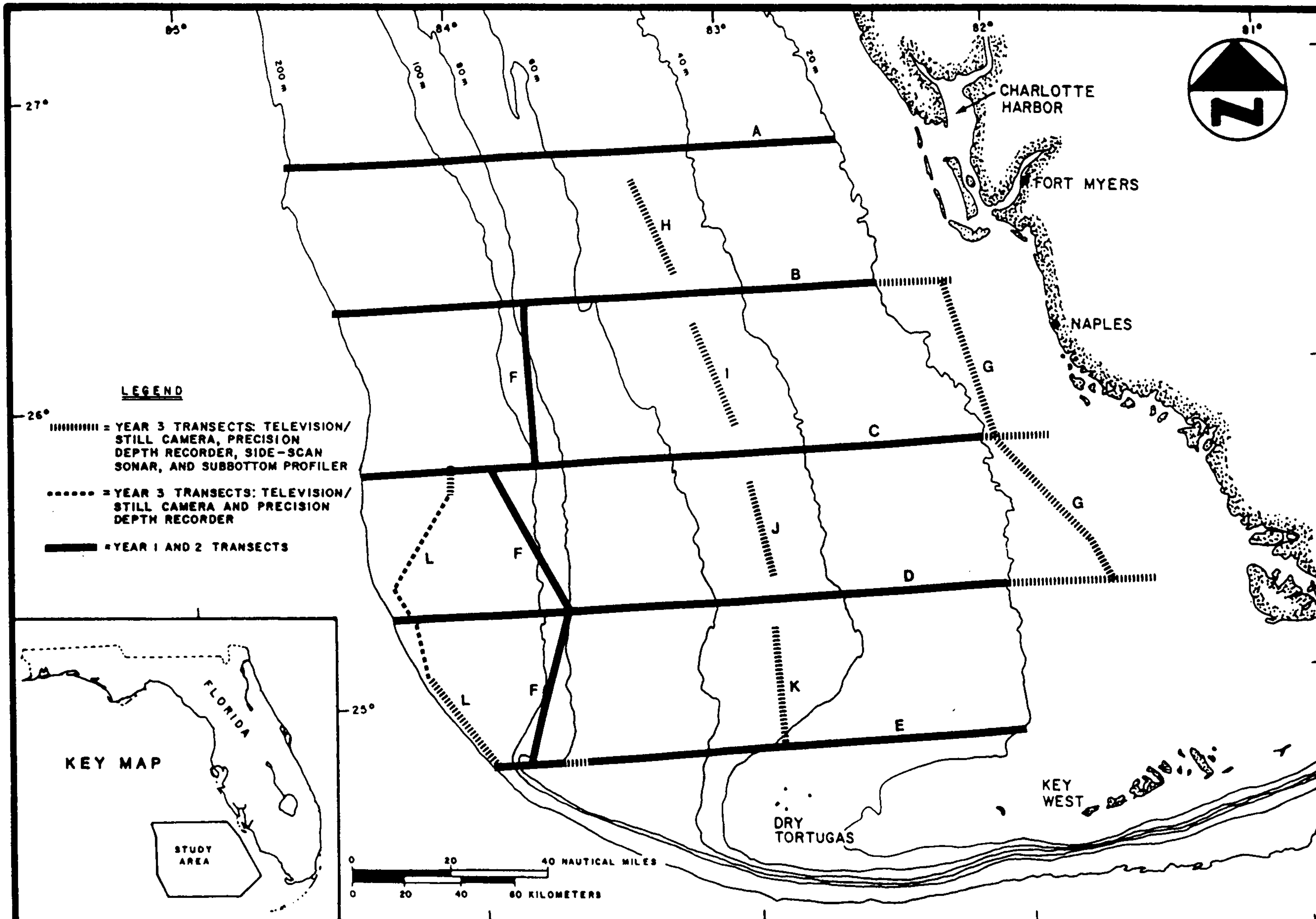


FIGURE 4.1. LOCATIONS OF YEAR 3 TRANSECTS IN RELATION TO YEAR 1 AND 2 TRANSECTS.

3) Transect D was extended from the 20-m isobath eastward a distance of 55 km.

4) A portion of Transect E characterized by an unusual algal nodule pavement substrate was surveyed again.

5) A north-south transect (G) connecting Transects B and D was surveyed between the 10- and 20-m isobaths.

6) North-south transects (H, I, J, and K) were surveyed along the 50-m isobath between Transects A and E.

7) A north-south transect (L) was surveyed along the outer edge of the continental shelf in a water depth of approximately 150 m between Transects C and E.

Navigation was accomplished using an EPSCO Loran-C system, which included a C-NAV XL receiver, a C-Plot-II 25-cm plotter, and an STM steer-to meter. When used with proper calibration and signal averaging and filtering techniques, the Loran-C system has an accuracy of ±30 to 60 m and a repeatability of ±15 to 45 m. A Digitec 6410 alphanumeric printer was interfaced with the Loran-C system and recorded the time delays from all four available secondary stations at each navigational fix. A receiver at the navigation console displayed ship location as a pair of Loran-C time delays to a resolution of 0.1 μs. This information was transferred instantaneously to both the plotter and the steer-to meter located on the ship's bridge. The steer-to meter continuously displayed the ship's position relative to a preplotted transect line. Error increments were 30 m to the right or left of the transect line.

The Loran-C navigation system was calibrated immediately prior to Cruise I. All transect lines had been preplotted and the appropriate courses programed into the navigational system. The navigator conned the ship by observing the ship's progress along the preprogramed course plot and issuing instructions to the bridge whenever necessary. While study transects were actually in progress, primary navigational fixes were recorded every 375 m. Two supplementary fixes were taken between each set of primary fixes at intervals of approximately 125 m. All geophysical instrumentation (fathometers, side-scan recorder, and subbottom recorder) was connected to a remote "mark" button located at the navigator's station. Navigational fixes were simultaneously marked on all three recordings. Navigational fixes were also recorded verbally on the sound track generated to accompany video and still camera records. Review of these records and calculation of variances in set-back of the geophysical and video instrument packages allowed precise, "real time" comparison of photographs, videotapes, and sonographic records.

4.2.2 Geophysical Equipment and Procedures

The geophysical equipment employed during the surveys is described below.

Depth Sounders. The Raytheon DE-719 fathometer, which is very accurate in shallow water, was used along the nearshore transects. Maximum depth range for the DE-719 is 122 m. For the deeper transects, a Raytheon DE-731 fathometer was employed. The DE-731 fathometer has a maximum range of 732 m and an accuracy level well within the required 5% of total depth specified in the contract.

Side-Scan Sonar. The Kline 431 side-scan sonar recorder is a three-channel recorder. One channel displays sonic return from the seafloor on the starboard, another displays sonic return on the port, and the third displays subbottom profiler data. Although this display pattern could be configured in a number of ways, the most practical display pattern was port signal displayed on port channel, starboard signal on starboard channel, and subbottom data on the remaining channel (Figure 4.2).

Two types of towed, dual beam transducers (towfish) were employed in attempting to resolve various types of biological signatures:

Kline Towfish	Application	Horizontal Beam Width	Output Frequency	Pulse Length	Vertical Beam Width
4225-101F	High Resolution	0.75°	100 kHz	0.1 ms	40° down 10° horizontal
4225-101AF	General Purpose	1.0°	100 kHz	0.1 ms	40° down 10° horizontal

The high resolution towfish was used in the areas of dense live bottom along the nearshore transects, and in the algal nodule-*Agaricia* coral community along Transect E. The general purpose towfish was used on the middle shelf transects and on Transect L along the shelf edge.

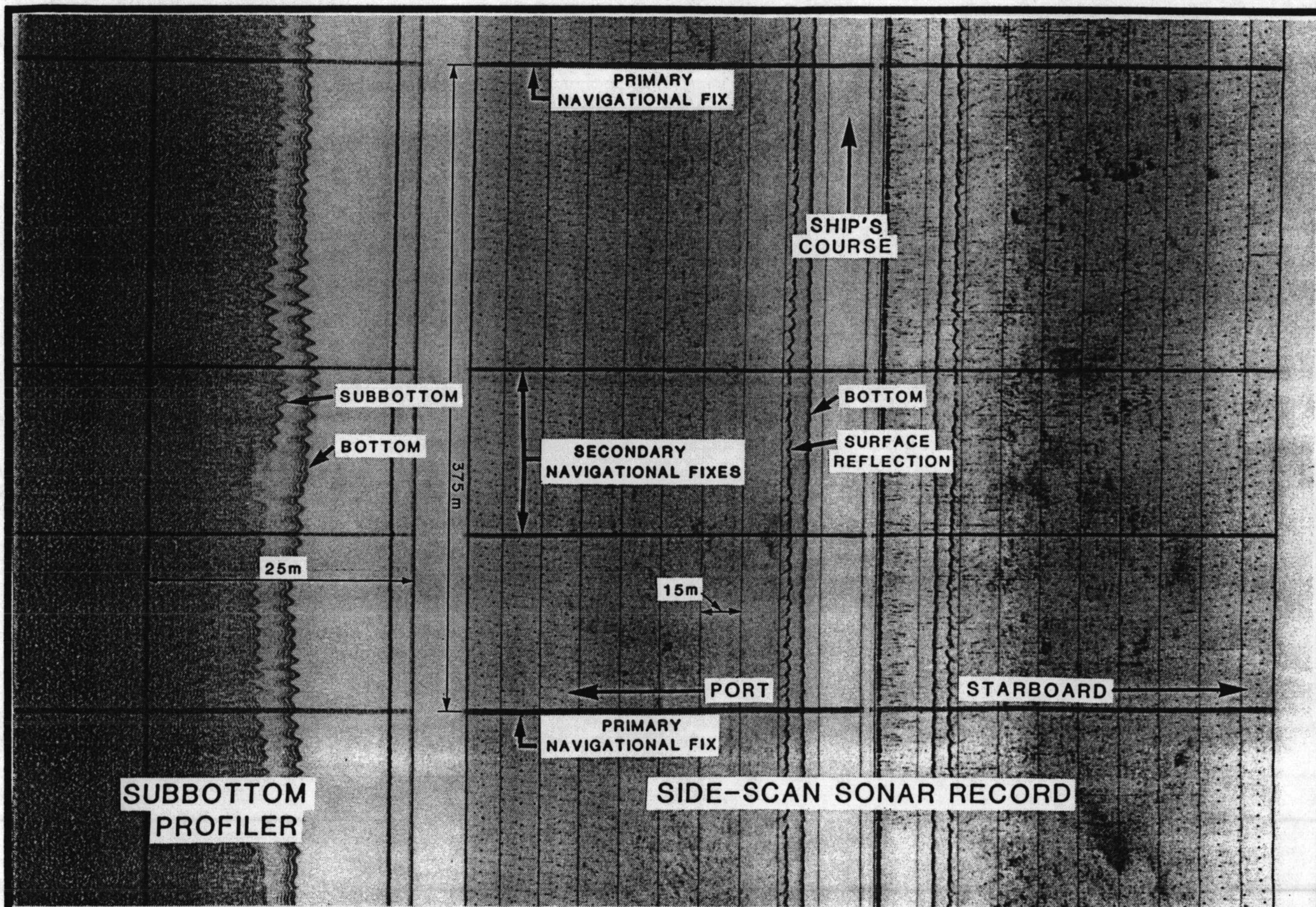


FIGURE 4.2. EXAMPLE OF THE OUTPUT FROM THE SIDE-SCAN SONAR AND SUBBOTTOM PROFILER SYSTEMS.

Subbottom Profiler. The Kline 5325-101 subbottom profiler has an output frequency of 3.5 kHz, a pulse length of 0.4 ms, and a conical beam width of 50° angled straight down. Its calculated resolution is approximately 0.6 m in carbonate sand. The Kline 611 digital processor was used to expand the subbottom profiler signal for display. The expanded signal contained only the top 25 m beneath the seafloor.

4.2.3 Television/Still Camera Photography

Video footage of the seafloor and benthic biota was recorded using a Hydro Products TC-125 underwater television camera, an LT-7 underwater light with a 250-w thallium iodide lamp, an SC-303 television control unit, an Elgar 121 power source (frequency stabilizer), and a Sony VO 1800 videocassette recorder. The camera had an f/1.4 lens with remotely controled focusing.

Color still photographs were taken with a Benthos 372 35-mm deep-sea camera with data chamber, a Benthos 382 deep-sea flash, and Ektachrome ASA 200, 35-mm color slide film. Both television and still camera systems were mounted on a Hydro Products RP-3 pan and tilt unit, which was attached to a television/still camera sled (Figure 4.3).

The television/still camera system was towed at a height of 1 to 3 m above the bottom at a speed of 1 m s^{-1} (2 kt). The still camera and synchronized flash were surface activated by personnel monitoring the television screen. During the synchronous collection of photographic and geophysical data, the television and still cameras were oriented so that their fields of view were identical.

During the surveys, photographs were taken on an average of one per minute. Additional photographs were taken at the discretion of the observer.

4.2.4 Data Collected

Table 4.1 summarizes geophysical and television/still camera coverage along the transect lines surveyed. Nearly 500 km of simultaneous geophysical and videotape data were recorded during Cruise I. Geophysical coverage of Transect L was not completed due to rough seas encountered at the end of Cruise I; only about half of the transect length was traversed. In addition, due to the loss of the television/ still camera sled on Transect L during Cruise I, the remaining footage

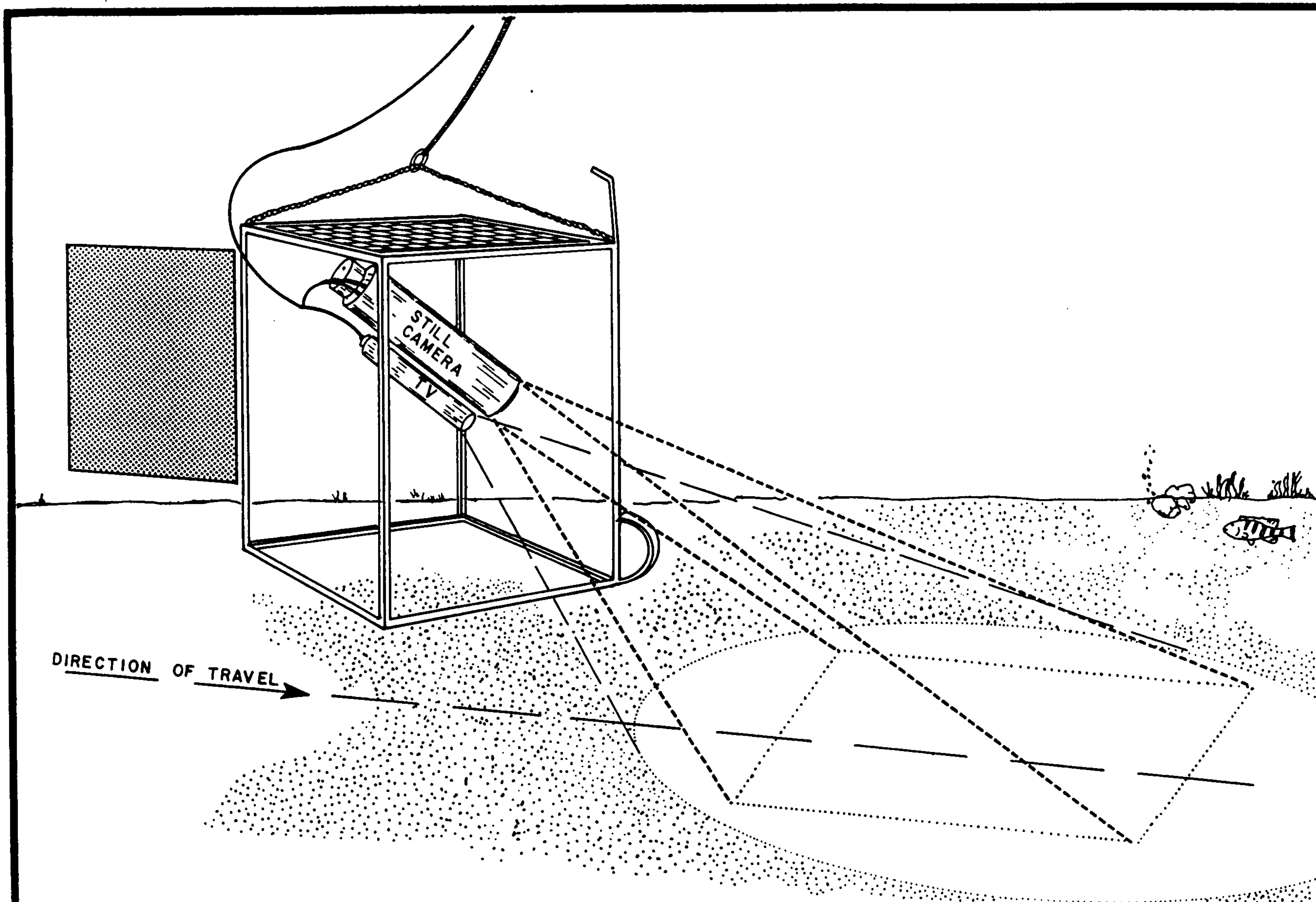


FIGURE 4.3. UNDERWATER TELEVISION/STILL CAMERA SYSTEM.

TABLE 4.1. GEOPHYSICAL AND TELEVISION/STILL CAMERA COVERAGE OF SURVEY TRANSECTS.

Transect	Geophysical Coverage km	Geophysical Coverage NM	Television/Still Camera Coverage km	Television/Still Camera Coverage NM
B (extension)	26	14	26	14
C (extension)	24	13	27	14.5
D (extension)	56	30	56	30
E (repeat)	9	5	9	5
G	130	70	130	70
H	37	20	37	20
I	41	22	41	22
J	35	19	35	19
K	44	24	44	24
L	62	33.5	133	72
TOTAL	464	250.5	538	290.5

Values are approximate and are expressed to the nearest kilometer or half nautical mile.

had to be obtained during Cruise III. All collected data including sonograms, profiles, fathometer traces, videotapes, still photographs, and scientific logs were catalogued and returned to the laboratory for analysis.

4.3 MAPPING

4.3.1 Data Base and Maps

Base maps at the 1:500,000 scale for the Survey Locations Map, the Index Map, and the two Regional Maps of Marine Habitats were provided by the MMS. In the Marine Habitat Atlas, the maps are presented on protraction diagram bases showing the exact location of the transects surveyed relative to OCS lease blocks.

The Index Map is a key map on which all of the 1:48,000 Habitat Maps are indicated by sheet number (Figure 4.4).

The two Regional Maps of Marine Habitats summarize the geophysical and biological interpretation of the survey data. The first sheet (Figure 4.5) summarizes biological assemblage data from the east-west survey transects (B, C, D, and E). The second sheet (Figure 4.6) summarizes data from the north-south transects (G, H, I, J, K, and L).

Twenty-three Habitat Maps, at a scale of 1:48,000, were constructed to summarize the substrate, biological assemblage, and subbottom data obtained during the mapping survey. The maps each cover approximately six OCS lease blocks (Figure 4.7). Maps were drawn upon the Universal Transverse Mercator (UTM) Grid. Lease block boundaries were drawn from the official OCS protraction diagram furnished by the MMS. Latitude and longitude coordinates were obtained by computer conversion of the Loran-C navigational fixes. All data were rectified so that the northern or eastern end of the surveyed transects always appears to the right. Rectification was required in order that the atlas would conform to the one previously produced during the Southwest Florida Shelf Ecosystems Study (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983b).

Each of the 1:48,000 Habitat Maps is divided into three sections. The top section shows the lease block boundaries, latitude/longitude and UTM coordinates, post-plot cruise navigational data, videotape code numbers, and still photograph roll numbers corresponding to the position of the bottom photographs taken in the lease blocks traversed. The

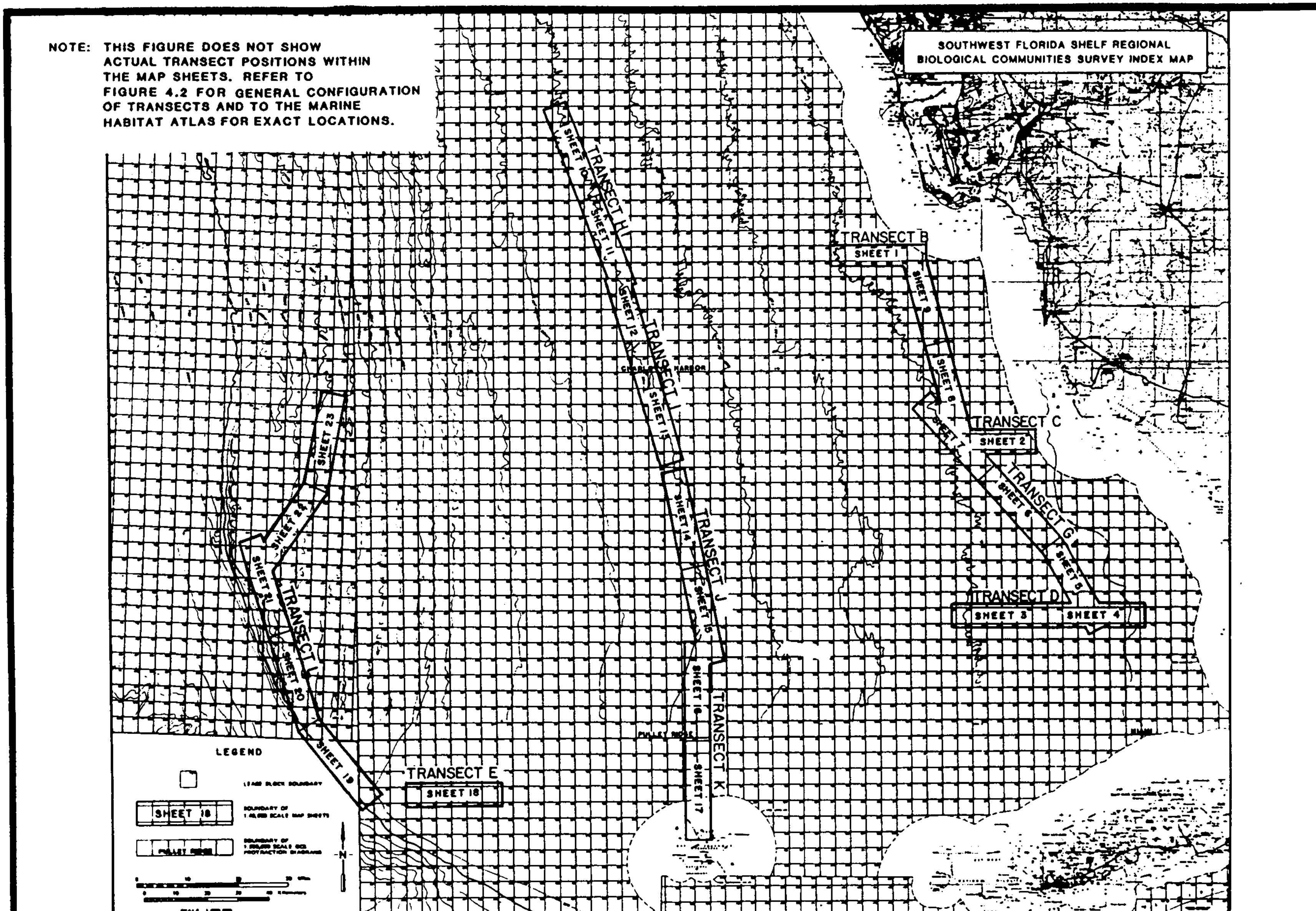


FIGURE 4.4. THE INDEX MAP FROM VOLUME 1 OF THE MARINE HABITAT ATLAS (GREATLY REDUCED).

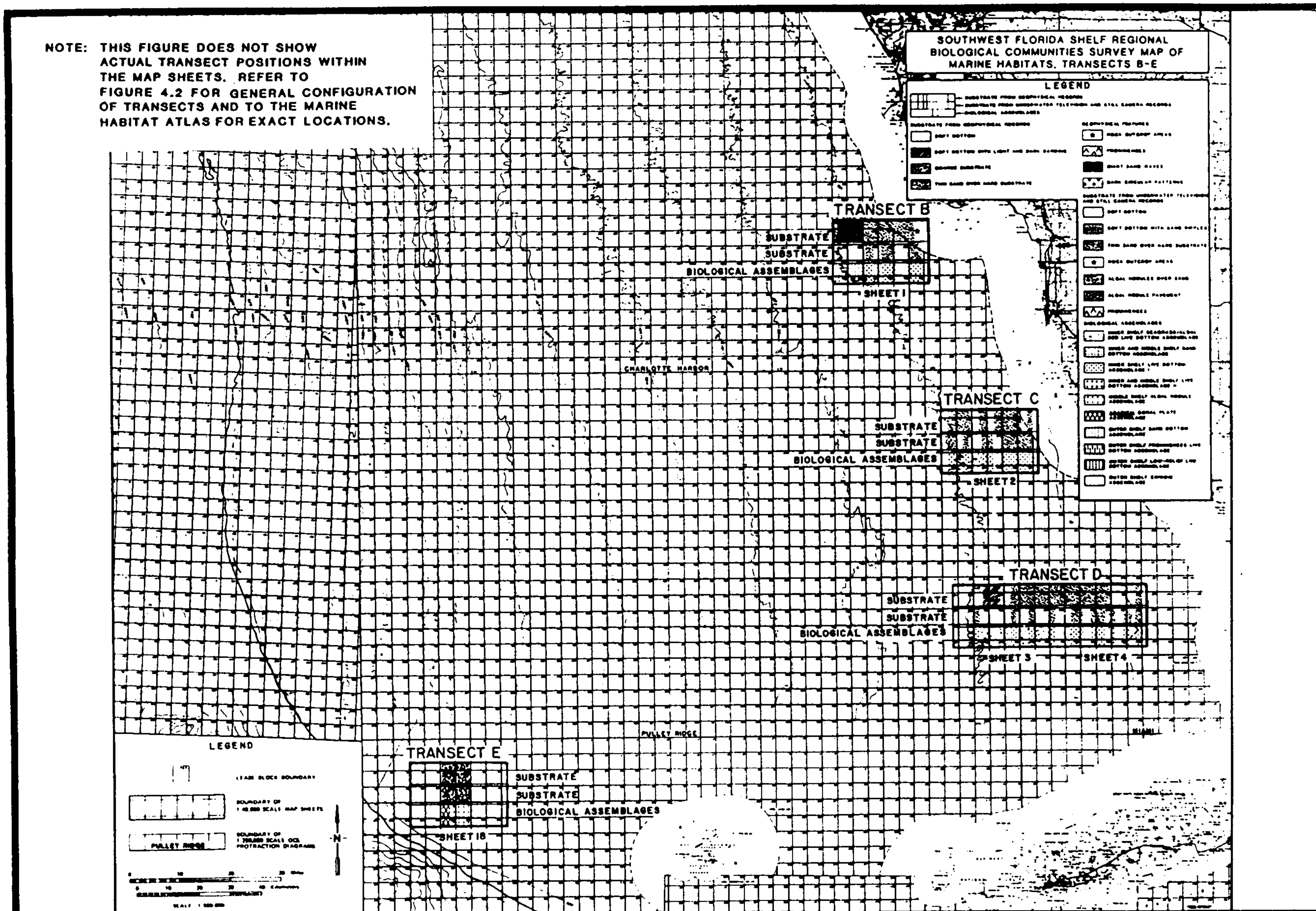


FIGURE 4.5. FIRST SHEET OF REGIONAL MAPS OF MARINE HABITATS FROM VOLUME 1 OF THE MARINE HABITAT ATLAS (GREATLY REDUCED).

NOTE: THIS FIGURE DOES NOT SHOW ACTUAL TRANSECT POSITIONS WITHIN THE MAP SHEETS. REFER TO FIGURE 4.2 FOR GENERAL CONFIGURATION OF TRANSECTS AND TO THE MARINE HABITAT ATLAS FOR EXACT LOCATIONS.

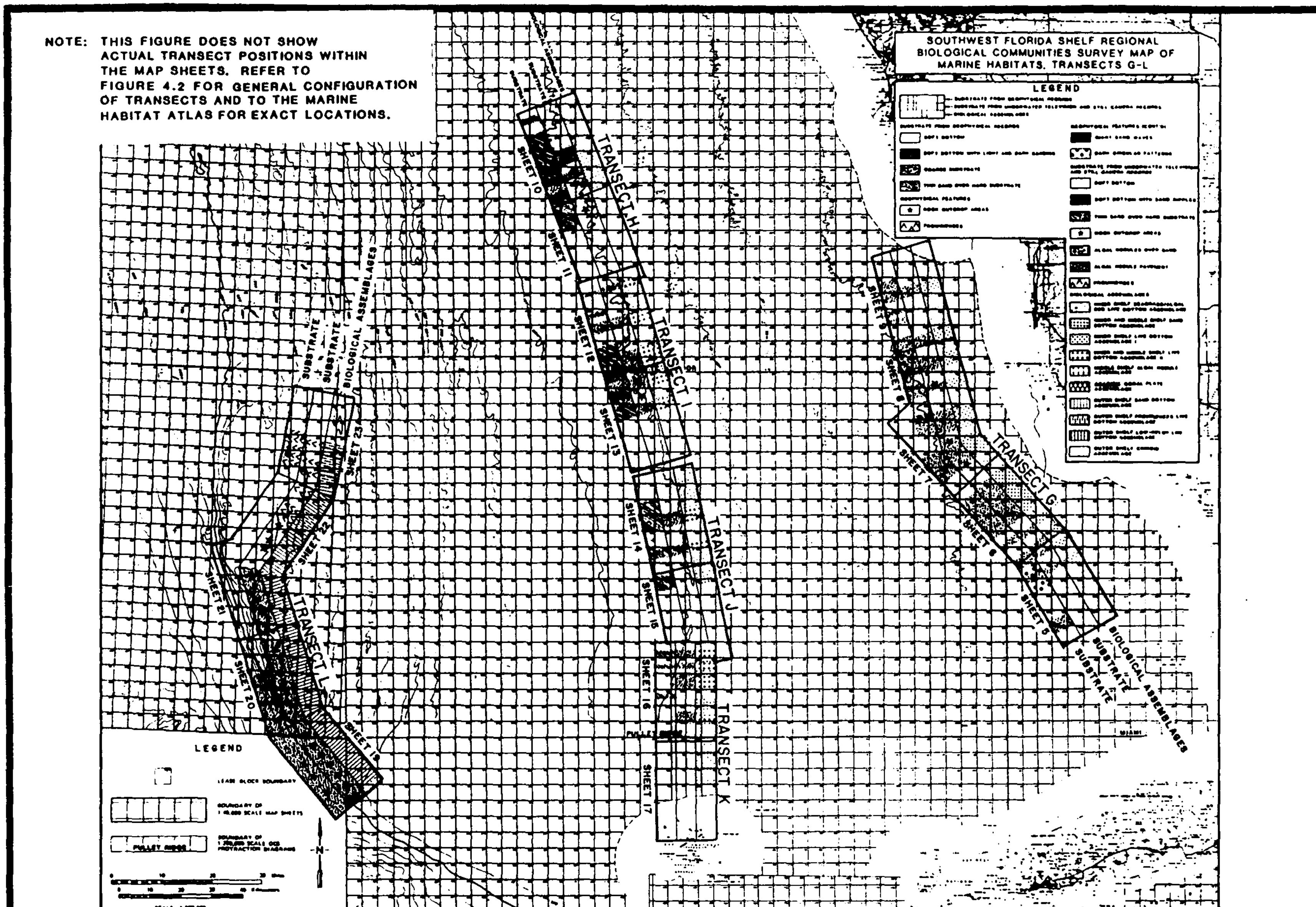


FIGURE 4.6. SECOND SHEET OF REGIONAL MAPS OF MARINE HABITATS FROM VOLUME 1 OF THE MARINE HABITAT ATLAS (GREATLY REDUCED).

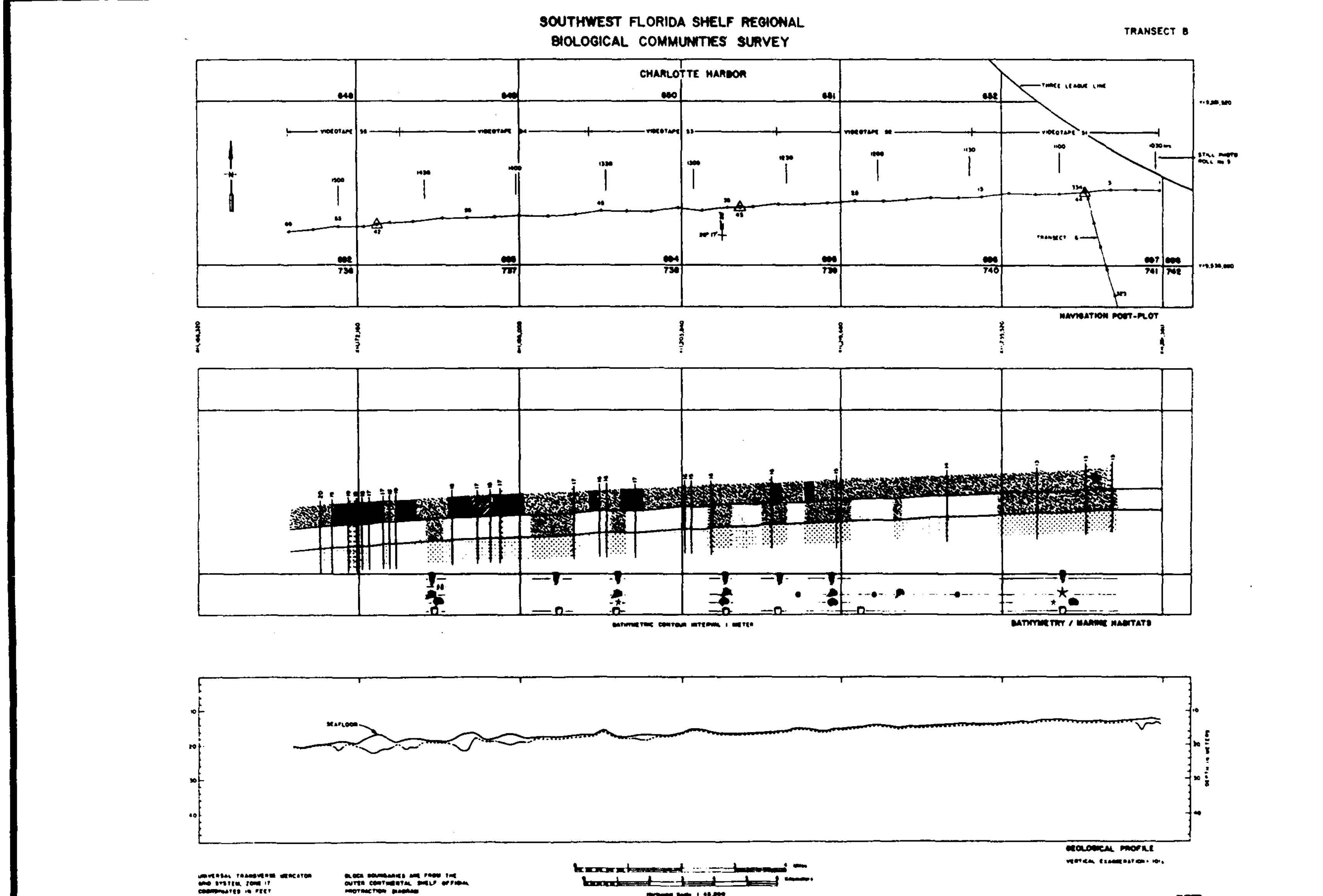


FIGURE 4.7. AN EXAMPLE HABITAT MAP FROM VOLUME 1 OF THE MARINE HABITAT ATLAS (GREATLY REDUCED).

second section shows the substrate and biological assemblage information. This information is presented in three strips; the top strip shows the substrate type and geophysical features defined from geophysical records alone, the middle strip shows the substrate type identified from television and still camera records, and the bottom strip indicates the linear extent of the biological assemblages identified from the television and still camera records (Figure 4.7). The bottom section of each map is a geological profile showing the shallow geological characteristics as determined from subbottom profiler data and bathymetry as indicated by precision fathometer.

4.3.2 Substrate Mapping

Substrate mapping employed two techniques. One utilized only side-scan sonar and subbottom profiler data, whereas the other was based entirely on analysis of the underwater television and still camera data. Side-scan sonar and subbottom profiler data have in the past been the principal information sources used to detect the presence of hard- or live-bottom areas on the continental shelf, but recently, the use of geophysical data alone to detect low-relief live-bottom areas has been questioned (Continental Shelf Associates, Inc., 1979; Henry et al., 1981; Gettleson et al., 1983). During two previous years of geophysical investigations on the southwest Florida shelf, questions arose concerning the ability of side-scan sonar and subbottom profilers to detect or differentiate specific types of live bottom seen there. Some live-bottom areas either were not detected using geophysical techniques or produced signatures that were difficult to interpret (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). During Year 3, substrate maps were prepared showing the two types of substrate interpretations side-by-side to facilitate comparisons of the two techniques.

Substrates Identified from Geophysical Data. Four substrate types were identified from the geophysical data: (1) soft bottom; (2) soft bottom with light and dark banding; (3) coarse substrate; and (4) thin sand over hard bottom.

Three textures of soft-bottom substrates were identified. Soft-bottom areas were defined as those having a distinct subbottom layer at some depth below the seafloor, and they characteristically showed reduced backscatter (that is, light shading) in side-scan sonar records. Textural interpretations generally rest on three levels of intensity of backscatter recorded on the side-scan sonar records: weak, moderate, and strong. The signals produce light, moderate, and dark signatures, respectively, on the sonograms and correspond roughly to fine, medium, and coarse sediment textures. Other variables, such as particle shape and packing, angle of sonic incidence, slant range, and machine settings, can affect the apparent texture of a sonogram record, but experienced interpreters can minimize false interpretation by taking these other variables into account. Differentiation of the fourth category, thin sand over hard substrate, was based on loss of a distinct subbottom trace accompanied by a general darkening (intensification) of the side-scan sonar signature. The characteristics of each geophysically defined substrate type are summarized below.

Soft Bottom -- Soft bottom consists of sand and/or silt underlain at some depth by hard substratum (as indicated by the subbottom profiler data). Soft bottom may be planar, or it may exhibit sand ripples or sand waves (see Geologic Features below).

Soft Bottom with Light and Dark Banding -- In some areas (e.g., along Transects H, I, J, and K), bands or ribbons of fine sediments (which have a light appearance in side-scan sonar records) were interspersed with areas of darker, coarse sediments. These "sand ribbon" formations are characteristic of the middle west Florida shelf and reflect sorting of sediments during lower stands of sea level. Figure 4.8 illustrates this type of pattern seen on side-scan sonar records.

Coarse Substrate -- The coarse substrate designation generally applies to areas of coarse shell hash, calcareous algal rubble, or algal nodules. Coarse substrate was differentiated from finer soft-bottom substrates on the basis of the darker and rougher side-scan sonar signature of the former. Subbottom profiler penetration in areas of coarse substrate, especially those characterized by coralline algal nodules or an algal nodule pavement with Agaricia (coral) accumulations (Transect E), was sporadic, leaving the interpretation to be based primarily on side-scan sonar records.

Thin Sand over Hard Substrate -- The signature for this widespread substrate type was the most difficult to assign. Generally, thin sand over hard bottom was inferred from the loss of a distinctive subbottom trace and a concurrent intensification (darkening) of the side-scan sonar signature.

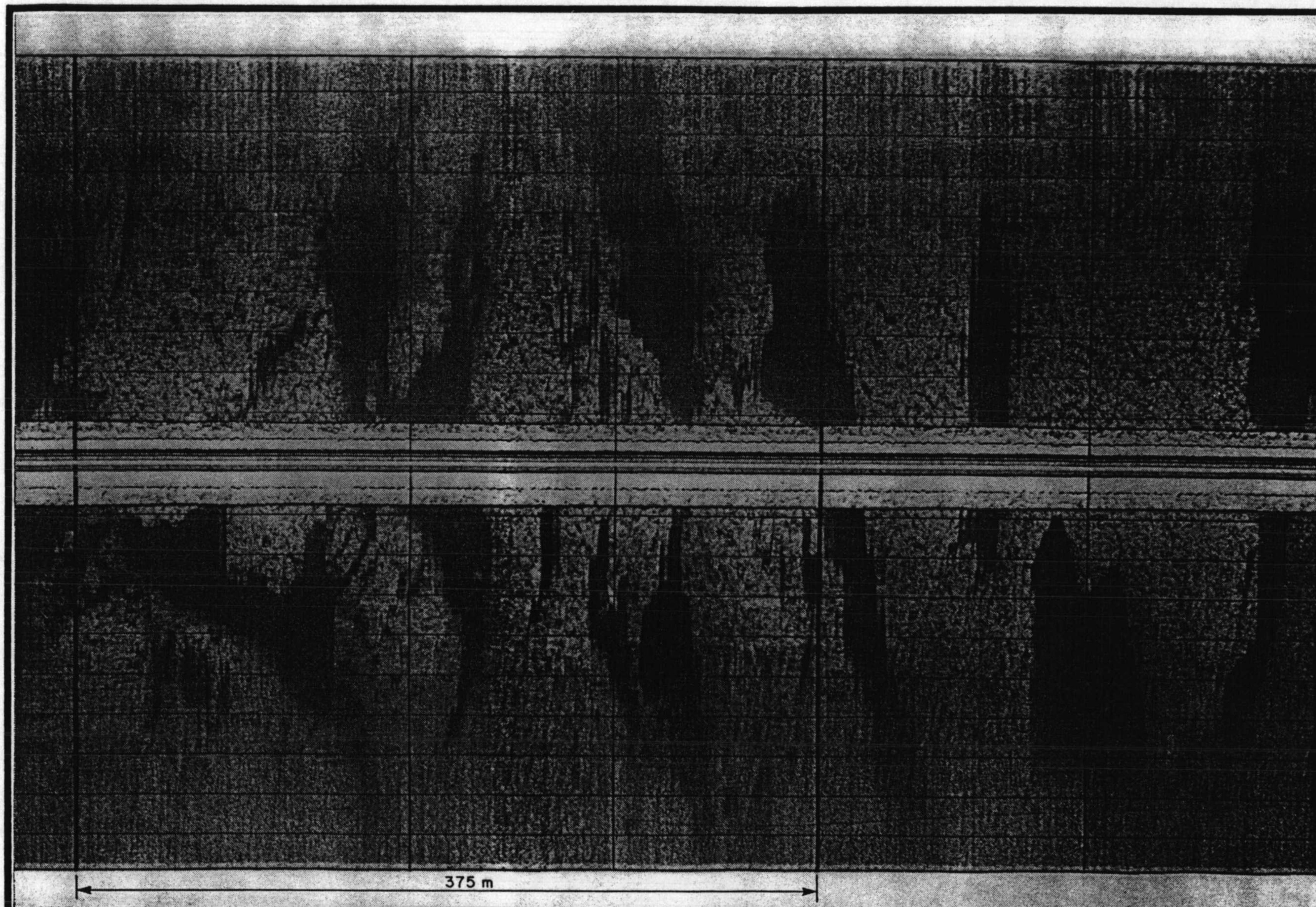


FIGURE 4.8. SIDE-SCAN SONAR RECORD SHOWING SOFT BOTTOM WITH LIGHT AND DARK BANDING.

Geologic Features Identified from Geophysical Data. Four geologic features were identified from the geophysical data: (1) rock outcrop areas; (2) prominences; (3) giant sand waves; and (4) dark circular patterns. The characteristics of these features are summarized below.

Rock Outcrop Areas -- Rock outcrops were easily identifiable from the side-scan sonar records. Generally, the outcrops ranged up to 1 m in relief.

Prominences -- Prominences (also referred to as pinnacles) are a particular kind of high-relief outcrop identified in geophysical records from the shelf edge (Transect L). The prominences rise from a hard substrate some distance beneath the seafloor to an exposed relief of 0.5 to 3 m (Figure 4.9). The features are believed to be remnants of an ancient carbonate reef complex that has undergone successive bouts of aerial and subsurface erosion during several changes in sea level (Holmes, 1981).

Giant Sand Waves -- Giant sand waves (bedforms with wavelengths >100 m and a height of 1 to 3 m) were noted along the inshore portion of Transect B. These features may represent old, submerged dune lines, or they may reflect sculpturing of surficial sediments associated with fluctuations in the subbottom contours seen there. Such sculpturing might be due to persistent circulation patterns or to storm events. The features were not seen along the deeper (>20 m) portions of Transect B surveyed during Years 1 and 2. Neurauter (1979) has reported similar giant bedforms in nearshore sediments off southwest Florida.

Dark Circular Patterns -- The dark, circular patterns noted during this survey were a unique feature of the sonographic record. They appeared in clusters, lending a polka-dot appearance to the sonograms. The patterns were seen only near the intersection of Transects D and G and appeared to be associated exclusively with live-bottom areas. Similar, though less distinct, patterns have been noted in side-scan sonar records from live-bottom areas on the shelf off northwest Florida (J. Thompson, Continental Shelf Associates, Inc., personal observation). The cause of this unusual side-scan signature is not known.

Substrates Identified from Remote Television/Still Camera Photography. Seven types of substrates or geological features were identified from the remote television/still camera data: (1) soft bottom; (2) soft bottom with sand ripples; (3) thin sand over hard substrate;

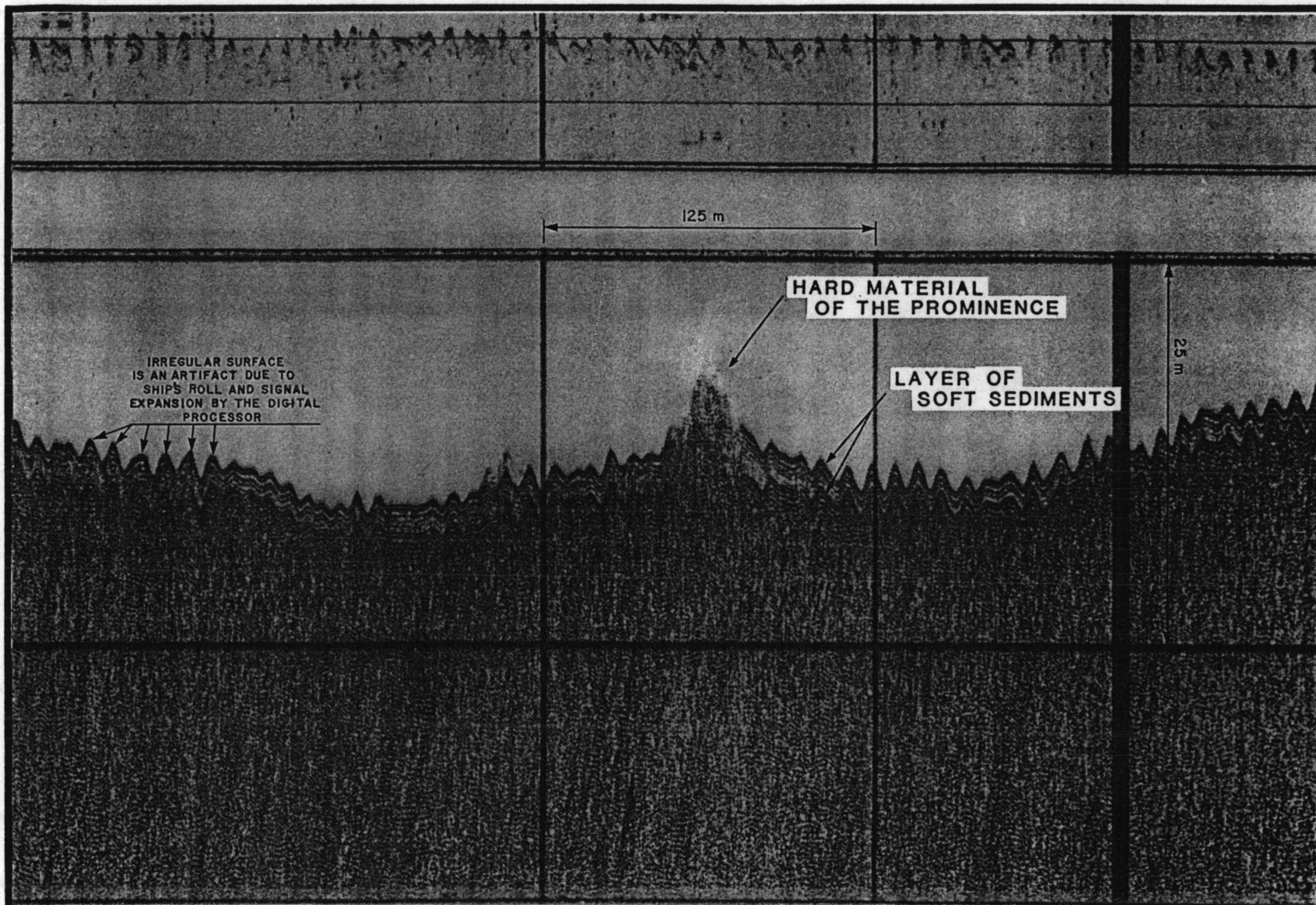


FIGURE 4.9. SUBBOTTOM PROFILER RECORD SHOWING PROMINENCES SEEN ALONG TRANSECT L.

(4) rock outcrop areas; (5) algal nodule layer over sand; (6) algal nodule pavement; and (7) prominences. The identification of rock outcrops and prominences was straightforward and requires no elaboration; assignment of the other designations deserves further explanation.

In areas where little or no exposed rock was visible, the substrate could be categorized as soft bottom, soft bottom with sand ripples (if they were present), or thin sand over hard substrate. The presence of underlying hard bottom was inferred from the presence of sessile epibiota (e.g., gorgonians, sponges) that require hard substrate for attachment. Patches of exposed, low-relief hard bottom were usually seen in such areas, and their presence helped to confirm the designation of thin sand over hard substrate.

In some portions of the middle shelf (Transects B, C, D, E, and F from the Years 1 and 2 surveys and the portion of Transect E surveyed during this study), the substrate consists of sand covered by a dense layer of loose coralline algal rubble or nodules (algal nodule layer over sand). On Transect E, the coralline algal growth occurs in places as a fused crust or pavement, usually in association with accumulations of the plate-like coral Agaricia (algal nodule pavement). These substrate types were readily distinguishable in the television videotapes and still photographs.

4.3.3 Biological Assemblage Mapping

Black-and-white television videotapes and color still camera photographs from the survey transects were viewed in the laboratory to delineate visually distinct benthic biological "assemblages." Identification of epibiota from the videotapes and photographs was facilitated by identification of specimens from dredge, trawl, and diver collections made during Cruises II and III and dredge and trawl collections made during the two previous study years.

The classification scheme involving visually distinct assemblages is both arbitrary and subjective to some degree. The visual groupings are supported to some degree by cluster analysis results (Section 5.5) but should not be construed as communities in the strict ecological sense of an association of interacting populations.

Nine biological assemblages were recognized along the survey transects. Eight had been delineated during the two previous years of study, and one new type, the Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage, was recognized during Year 3. A tenth designation from the previous years of study, the Outer Shelf Crinoid Assemblage, was not seen during Year 3 but is described here for use in the overview provided in the Results section.

Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage. This assemblage was noted in soft-bottom areas on the nearshore transects in water depths of 11 to 20 m. It was typified by seagrass (Halophila decipiens) and various algae, including Caulerpa mexicana, C. sertularioides, Dictyopteris jamaicensis, Halimeda incrassata, and Laurencia intricata. In some areas, the seagrass and algae were interspersed with patches of sessile epifauna typical of other live-bottom areas; however, by the definition presented in Chapter 1, seagrass beds constitute live bottom whether or not hard-bottom epifauna are present.

Inner and Middle Shelf Sand Bottom Assemblage. This assemblage designation refers to inner and middle shelf (10 to 90 m water depth) sand-bottom areas with an average attached macroepifaunal density of less than approximately one individual per square meter. Algae such as Caulerpa spp., Halimeda spp., Udotea spp., and coralline algae were conspicuous in these sand-bottom areas. Associated biota consisted of asteroids (Astropecten spp., Goniaster tessellatus, Luidia spp., Narcissia trigonaria, and Oreaster reticulatus), bryozoans (Celleporaria spp. and Stylopoma spongites), hard corals (Scolymia lacera), echinoids (Clypeaster spp., Diadema antillarum, and Lytechinus spp.), holothuroids, sea pens, and sponges (Geodia gibberosa). Algae covered up to 75% of the seafloor in certain photographs, whereas epifauna were seen in widely scattered patches. The sponges and solitary hard corals may have been attached to a hard substrate, but their occurrence was so limited that these areas could not be categorized as live bottom. Sand waves, ripple marks, and evidence of bioturbation were sometimes present.

Inner Shelf Live Bottom Assemblage I. This assemblage was distinguished by the presence of large gorgonians (Eunicea spp., Muricea spp., Plexaurella spp., Pseudoplexaura spp., and Pseudopterogorgia spp.) occurring on a substrate of exposed or thinly covered hard bottom. Associated biota included various algae (Caulerpa spp., Halimeda spp., and Udotea spp.), ascidians, hard corals (Siderastrea spp.), hydrozoans, and sponges [Geodia gibberosa, Haliclona spp. (finger sponges), Ircinia campana (vase sponge), and Sphaeciospongia vesparium (loggerhead sponge)]. Individual sponges and gorgonians generally were larger, and epifaunal biomass apparently greater, than in the Inner and Middle Shelf Live Bottom Assemblage II. The assemblage was found in water depths of 10 to 27 m.

Inner and Middle Shelf Live Bottom Assemblage II. This assemblage was typified by a large variety of sponges, including *Cinachyra alloclada*, *Geodia gibberosa*, *G. neptuni*, *Ircinia campana*, *I. strobilina*, *Placospongia melobesioides*, and *Spheciospongia vesparium*. The large gorgonians and seagrass seen near shore were absent, and biomass appeared to be lower than in the Inner Shelf Live Bottom Assemblage I. Associated biota included algae (*Cystodictyon pavonium*, *Halimeda* spp., and *Udotea* spp.), ascidians (*Clavelina gigantea*), bryozoans (*Celleporaria* spp. and *Stylopoma spongites*), hard corals (*Cladocora arbuscula*, *Scolymia lacera*, *Siderastrea* spp., and *Solenastrea hyades*), small gorgonians, and hydrozoans. The assemblage occurred in water depths of 25 to 71 m.

Middle Shelf Algal Nodule Assemblage. This assemblage was distinguished by a substrate consisting of coralline algal nodules formed by two genera of algae, *Lithophyllum* spp. and *Lithothamnium* spp., combined with sand, silt, and clay particles. Other calcified (*Peyssonnelia rubra*, *P. simulans*) and fleshy (*Halimeda* spp., *Udotea* spp., and, in certain areas, *Anadyomene menziesii*) algae were abundant in the algal nodule areas. Hard corals and small sponges (*Cinachyra alloclada* and *Ircinia* spp.) were also present. During the Year 3 survey, this assemblage was seen only on Transects E and L. The depth range was 62 to 108 m.

Agaricia Coral Plate Assemblage. This assemblage was associated with a dead, hard coral-coralline algae substrate. Conspicuous epibiota included living algae (*Anadyomene menziesii* and *Peyssonnelia* spp.), live hard corals (*Agaricia* spp. and *Madracis* spp.), gorgonians, and sponges. The coral plate assemblage was seen only on a portion of Transect E (64 to 80 m water depth) during Years 1, 2, and 3.

Outer Shelf Sand Bottom Assemblage. The deepwater (74 to 200 m) sand-bottom biological assemblage was distinguished from the Inner and Middle Shelf Sand Bottom Assemblage by a lack of macroalgae. Characteristically, the macroepifauna consisted of asteroids (*Echinaster* spp.), crinoids (*Comactinia meridionalis*, *Leptonemaster venustus*, and *Neocomatella pulchella*), echinoids (including *Clypeaster ravenelli*, *Echinolampas depressa*, and *Stylocidaris affinis*), ophiuroids, sea pens, various anemones and crustaceans, and occasional hexactinellid sponges.

Outer Shelf Prominences Live Bottom Assemblage. This assemblage seen along portions of Transect C during Years 1 and 2 and Transect L during Year 3 was typified by the octocoral Nicella guadalupensis, the antipatharian corals Antipathes spp., Aphanipathes abietina, A. filix, and A. humilis, the hard coral Madrepora carolina, crinoids, hydrozoans (Stylaster sp.), and medium to large hexactinellid sponges in the order Dictyonina. All of these organisms were attached to "rock" prominences, which typically emerged from a thick sand covered bottom in water depths of 135 to 170 m and had a vertical relief of up to 3 m.

Outer Shelf Low-Relief Live Bottom Assemblage. This assemblage consisted of various octocorals (including Nicella guadalupensis), the antipatharian corals Antipathes spp., Aphanipathes abietina, A. filix, and A. humilis, occasional hard corals (including Madrepora carolina), crinoids, the hydrozoan Stylaster sp., and small sponges in the order Dictyonina. It was seen in water depths of 105 to 200 m. In contrast to the "prominences" assemblage, this assemblage was associated with low-relief rock surfaces partially covered by a thin sand veneer.

Outer Shelf Crinoid Assemblage. During Year 1 and 2 surveys, some outer shelf areas characterized by large numbers of crinoids (primarily Comactinia meridionalis, Neocomatella pulchella, and Leptonemaster venustus) living on a coarse sand or rock rubble substrate were seen. Small hexactinellid sponges also were typically associated with this assemblage. During Years 1 and 2, this assemblage was noted in water depths of 118 to 168 m on Transects B, C, and D, but it was not seen on any of the Year 3 transects.

4.4 RESULTS

4.4.1 Distribution of Substrates

Table 4.2 lists the percent incidence of different substrate types along the Year 3 transects based on television/still camera observations. Generally, soft bottom and thin sand over hard substrate predominated on the nearshore transects (B, C, D, and G); rock outcrops were rarely seen (or geophysically detected). The incidence of soft bottom was higher, and that of thin sand over hard substrate correspondingly lower, on the mid-shelf transects (H, I, J, and K), although outcrops were more common (especially on Transect I). Coralline algal nodules over sand and algal nodule pavement predominated on the small portion of Transect E revisited during Year 3; the occurrence of these unusual substrates was the primary reason for including this area in the Year 3 survey. Rock outcrops,

TABLE 4.2. SUBSTRATE TYPES ALONG THE YEAR 3 SURVEY TRANSECTS, BASED ON TELEVISION/STILL CAMERA OBSERVATIONS.

Transect	Water Depth (m)	Substrate Type (Percent Incidence*)				Geologic Features (Occurrence†)	
		Soft Bottom	Thin Sand Over Hard Substrate	Algal Nodule Layer Over Sand	Algal Nodule Pavement	Rock Outcrop Areas	Prominence Areas
B	13-20	65	35	0	0	0	0
C	10-19	37	63	0	0	0	0
D	10-20	55	45	0	0	0	0
G	13-19	59	41	0	0	4	0
H	50-51	97	3	0	0	2	0
I	50-51	74	26	0	0	12	0
J	51-52	79	21	0	0	1	0
K	44-50	77	23	0	0	0	0
E	68-73	0	0	66	34	0	0
L	102-165	36	62	2	0	72	12

*Incidence values were calculated as total linear extent of each substrate type along each transect divided by total transect length, times 100.
†Number of rock outcrop areas or prominence areas observed. Each area consisted of several features that were not continuous enough to be mapped in terms of areal extent.

prominences, and thin sand over hard substrate were more common near the shelf edge (Transect L) than elsewhere.

Figure 4.10 summarizes the shelfwide distribution of substrates based on combined Year 1, 2, and 3 television/still camera observations. (The map omits some detail due to the great scale reduction from the Marine Habitat Atlases.) The following paragraphs briefly summarize substrate distribution patterns on the shelf based on the combined data set.

Soft bottom and thin sand over hard substrate were the most widely distributed substrate types on the shelf. Inner to middle shelf (10- to 60-m water depths) substrates were typically soft bottom with patches of thin sand over hard substrate and occasional, widely scattered rock outcrops. Thin sand over hard bottom became generally less common with increasing water depth along the cross-shelf transects. The major exception was seen on Transect E, where inner shelf substrates were entirely soft bottom; small patches of thin sand over hard substrate were noted only in the 40- to 60-m depth range. The opposite extreme was exemplified by Transect A, where most of the inner shelf was characterized by thin sand over hard substrate (Figure 4.10).

Soft bottom and patches of thin sand over hard substrate occurred on the middle to outer shelf out to the end of Transect A and (with the exception of bands of algal nodules over sand in 60 to 85 m depth) Transect B (Figure 4.10). However, other substrates predominated on the middle to outer shelf in the southwestern portion of the study area. Coralline algal nodules over sand was a common substrate type in water depths of 75 to 95 m on Transect D, 66 to 125 m on Transect E, and 75 to 91 m on Transect F. The nodules grade into a fused algal pavement in 64- to 80-m depths along Transect E. The algal nodule pavement area appears to be unique, as it was not seen in similar water depths along either Transect D or F. On Transect E, the algal pavement area was bounded landward and seaward by substrates characterized as algal nodules over sand.

Rock outcrops were common near the shelf edge in the southwestern part of the study area (e.g., along most of Transect L and the outer ends of Transects C, D, and E) (Figure 4.10). For the most part, these were low-relief (<1 m) features, but larger outcrops (prominences) were seen on Transect C and on the northern portion of Transect L. In general, low-relief rock outcrops were seen where the substrate was characterized

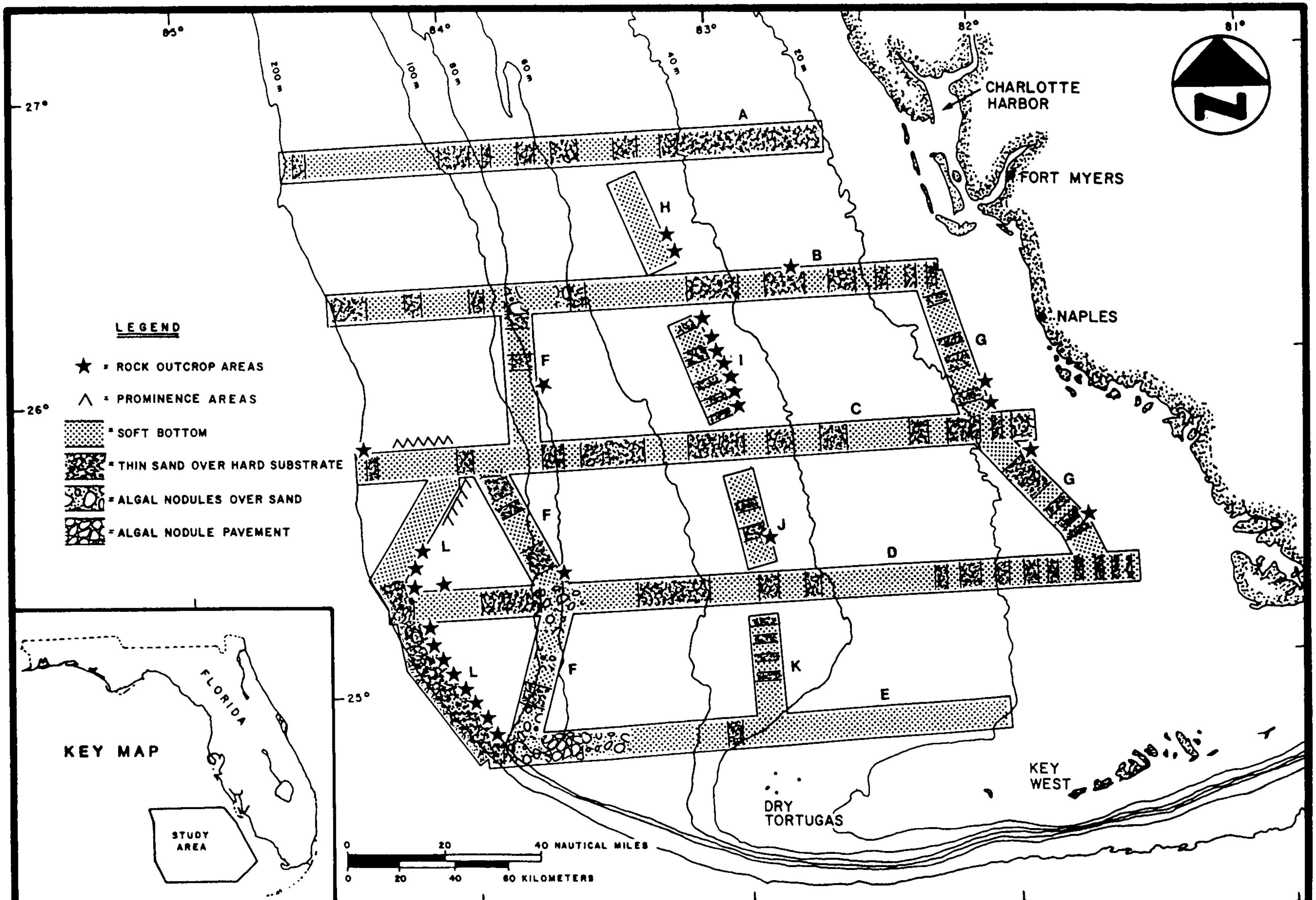


FIGURE 4.10. DISTRIBUTION OF SUBSTRATE TYPES AND GEOLOGIC FEATURES IDENTIFIED FROM TELEVISION/STILL CAMERA SURVEYS DURING YEARS 1, 2, AND 3.

as thin sand over hard substrate, whereas prominences were seen protruding through thick sand. Little or no exposed rock was evident near the shelf edge on the northern Transects A and B.

4.4.2 Distribution of Biological Assemblages

Table 4.3 summarizes the percent incidence and types of live bottom seen along the Year 3 survey transects. These data are combined with Year 1 and 2 data in Table 4.4, which lists the average percentage incidence of live bottom within 10-m depth intervals across the shelf, and Figure 4.11, which summarizes biological assemblage distribution on the survey transects. The following paragraphs summarize patterns in the incidence and composition of live bottom on the shelf.

The incidence of live bottom was high along the nearshore (10 to 20 m depth) transects surveyed during Year 3. The Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage (depth range: 11 to 20 m) and the gorgonian-sponge Inner Shelf Live Bottom Assemblage I (depth range: 10 to 27 m) were typical of the live-bottom habitats seen. The latter was also encountered along the inner shelf portions of Transects C and D during Year 1 surveys, and two live-bottom stations (13 and 19) were sampled in this area during Years 1 and 2. All of the Year 3 live-bottom stations (see Chapter 5) were characterized by this type of biota.

The incidence of live bottom was generally lower in 20- to 60-m depths than at <20-m depths (Table 4.4). Where live bottom occurred, it typically consisted of small patches of epibiota inhabiting thin sand over hard bottom with little exposed rock. The Inner and Middle Shelf Live Bottom Assemblage II (depth range: 25 to 71 m), recognized in part by the absence of the large gorgonians seen farther inshore, was characteristic of these live-bottom habitats. Live bottom was more common in the central portion of the study area (Transects C, D, I, J, and the northern part of K) than on the northern or southern transects (A, E, H, and the southern part of K).

The overall incidence of live bottom was high in the 60- to 90-m depth range, particularly in the southwestern part of the study area where 100% incidence of live bottom was common. Coralline algal nodules and/or algal nodule pavement substrates were the basis for live-bottom habitats in this depth range. Loose algal nodules over sand in the central portion of the study area (Transects B, D, and F) supported the Middle Shelf Algal Nodule Assemblage (water depth: 62 to 108 m). To the

TABLE 4.3. PERCENT INCIDENCE AND TYPES OF LIVE BOTTOM OBSERVED ALONG THE YEAR 3 SURVEY TRANSECTS.

Transect	Water Depth (m)	Percent Incidence of Live Bottom	Type(s) of Live Bottom
B	13-20	34	Inner Shelf Live Bottom Assemblage I
C	10-19	79	Inner Shelf Live Bottom Assemblage I Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage
D	10-20	77	Inner Shelf Live Bottom Assemblage I Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage
G	13-19	50	Inner Shelf Live Bottom Assemblage I Inner Shelf Seagrass/Algal Bed Live Bottom Assemblage
H	50-51	3	Inner and Middle Shelf Live Bottom Assemblage II
I	50-51	26	Inner and Middle Shelf Live Bottom Assemblage II
J	51-52	24	Inner and Middle Shelf Live Bottom Assemblage II
K	44-50	19	Inner and Middle Shelf Live Bottom Assemblage II
E	68-73	100	Middle Shelf Algal Nodule Assemblage *Agaricia* Coral Plate Assemblage
L	102-165	81	Outer Shelf Low-Relief Live Bottom Assemblage Outer Shelf Prominences Live Bottom Assemblage

TABLE 4.4. AVERAGE INCIDENCE OF LIVE BOTTOM WITHIN 10-m DEPTH INTERVALS, BASED ON COMBINED YEAR 1, 2, AND 3 TELEVISION/STILL CAMERA SURVEYS.

Depth Range (m)	Average Percent Incidence of Live Bottom*	Transects Included	
		Years 1 and 2	Year 3
10-20	58	---	B,C,D,G
20-30	17	A,B,C,D,E	---
30-40	13	A,B,C,D,E	---
40-50	25	A,B,C,D,E	K
50-60	17	A,B,C,D,E	H,I,J
60-70	30	A,B,C,D,E	E
70-80	46	A,B,C,D,E	E
80-90	76	A,B,C,D,E,F	---
90-100	8	A,B,C,D,E,F	---
100-110	15	A,B,C,D,E,F	L
110-120	37	A,B,C,D,E,F	L
120-130	55	A,B,C,D,E,F	L
130-140	82	A,B,C,D,E	L
140-150	57	A,B,C,D,E	L
150-160	65	A,B,C,D,E	L
160-170	23	A,B,C,D,E	L
170-180	20	A,B,C,D,E	---
180-190	3	A,B,C,D,E	---
190-200	10	A,B,C,D,E	---

*Values were calculated as the sum of the linear extent of live-bottom patches divided by total transect length within the stated depth range, times 100.

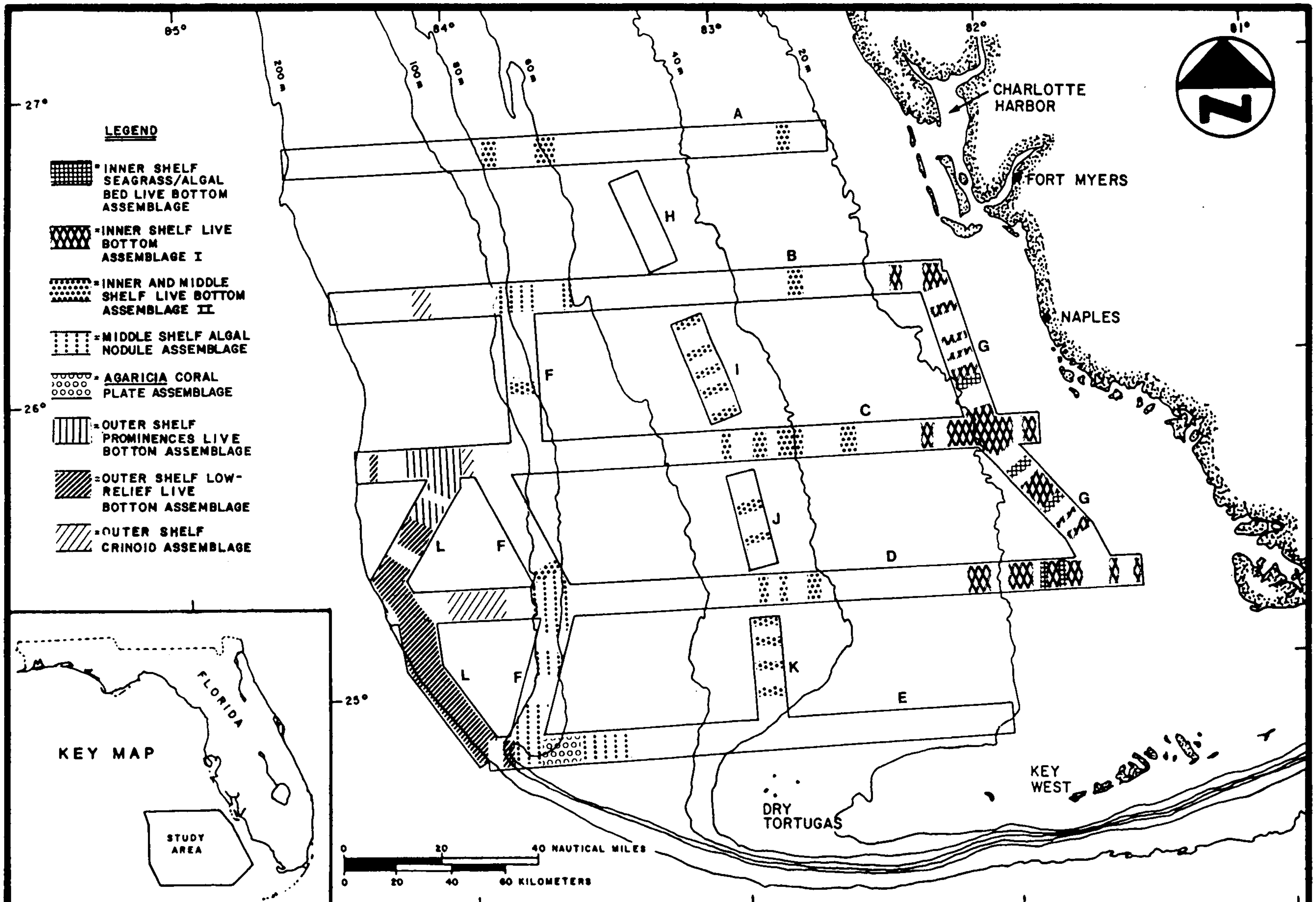


FIGURE 4.11. DISTRIBUTION OF LIVE-BOTTOM ASSEMBLAGES IDENTIFIED FROM TELEVISION/STILL CAMERA SURVEYS DURING YEARS 1, 2, AND 3.

north, nodules were increasingly sparse; the Middle Shelf Algal Nodule Assemblage was not seen along Transect A. To the south, the nodules graded into a fused pavement (crust) along Transect E, where the Agaricia Coral Plate Assemblage was noted in water depths of 64 to 80 m. The Agaricia Coral Plate Assemblage occurred only near the end of Transect E; the Middle Shelf Algal Nodule Assemblage predominated both landward and seaward of this area. The latter assemblage was also seen at the southern end of Transect L, which overlapped with the end of Transect E (Figure 4.11).

Beyond about 90 to 100 m depth, the coralline algal nodules and associated biota became increasingly rare, and most of the outer shelf was typified by a low incidence of live bottom. Exceptions were: (1) the shell rubble areas along portions of Transects C and D where dense crinoid groupings [Outer Shelf Crinoid Assemblage (depth range: 118 to 168 m)] were seen during Years 1 and 2; and (2) along the shelf edge where live-bottom epibiota inhabited low-relief rock outcrops [Outer Shelf Low-Relief Live Bottom Assemblage (depth range: 105 to 200 m)] and prominences [Outer Shelf Prominences Live Bottom Assemblage (depth range: 135 to 170 m)]. Because the Year 3 survey Transect L was expressly selected to examine these outer shelf live-bottom areas, the incidence of live bottom in the 100- to 160-m depth range given in Table 4.4 is probably atypically high; most of the outer shelf along Transects A and B was characterized by soft-bottom biota. In the 160- to 200-m depth range, live bottom was more common in the southern part of the study area (Transects C, D, and E) than in the northern part (Transects A and B) due to the irregularity of the seafloor and the higher incidence of exposed rock. Because of the steepness of the shelf-edge terrain on the southern transects, linear coverage of the 160- to 200-m depth range was much less than on the northern transects, and consequently the average incidence of live bottom was low (Table 4.4).

4.5 DISCUSSION

Remote photographic and geophysical mapping conducted during Year 3, in combination with more extensive coverage obtained during the preceding two study years, provides a broad picture of substrate and epibiotal assemblages of the southwest Florida shelf. To put the results in perspective, we first review the geologic setting.

Holmes (1981) has discussed the geomorphology and likely geologic history of the southwest Florida shelf and slope. The modern shelf consists of a karstic platform of probable Miocene age overlain by wedges of late Tertiary-Quaternary sediments. Partially buried, north-trending reef complexes mark the present shelf edge and separate the inner from the outer shelf (Figure 4.12). The youngest of these, a 10-km wide central reef complex in 70 to 90 m depth, probably was formed about 10,000 yr BP during a sea-level standstill and apparently provided the environment for the production and impoundment of unconsolidated biogenic surface sediments on the inner and middle shelf (Holmes, 1981). Due to this impounding effect, the wedge of unconsolidated sediments overlying the Miocene bedrock increases in thickness from 5 m to 20 m between the 40- and 70-m isobaths (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Seaward of the central reef complex, the seafloor is covered by a thickening wedge of late Tertiary-Quaternary sediments and marked by wave-cut terraces formed during hiatuses in sea level rise (Holmes, 1981). A second, double reef complex occurs near the modern shelf edge. The inner reef crests at approximately 130 to 150 m depth and veers landward north of 25°10' to form the feature known as Howell Hook. This feature was interpreted by Jordan and Stewart (1959) and Ballard and Uchupi (1970) as a spit-and-lagoon, but Holmes (1981) suggests that it was a bioherm. Howell Hook was seen on Transect D during Year 1 and 2 surveys and on Transect L during Year 3. The outer reef forms a 40-m steep west-facing scarp at the modern shelf edge in a water depth of about 210 to 235 m (Holmes, 1981).

Surface sediments on the shelf, sampled during all three study years, are predominantly calcareous sands [see Chapter 5 in Woodward-Clyde Consultants and Continental Shelf Associates, Inc. (1985) and Chapter 6 of this report]. With the exception of some nearshore (10 to to 20 m water depth) stations sampled during Year 3 and one station at 25 m water depth off Charlotte Harbor sampled during Years 1 and 2, sediment carbonate content was consistently >75%. Carbonate muds predominate on the nearshore end of Transect E, where a thick layer of fine sediments has accumulated due to the sheltering influence of southern shelf-edge banks bordering the Florida Straits (Holmes, 1981).

Shelf geomorphology is not the only determinant of live-bottom presence and species composition--but it is probably very influential. Sessile epibiota such as sponges, gorgonians, and hard corals require a hard substrate for attachment; dense aggregations of these organisms presumably develop only where the underlying rock is occasionally exposed. Other types of live bottom defined here are not specifically associated with exposed or thinly covered hard substrate: (1) the

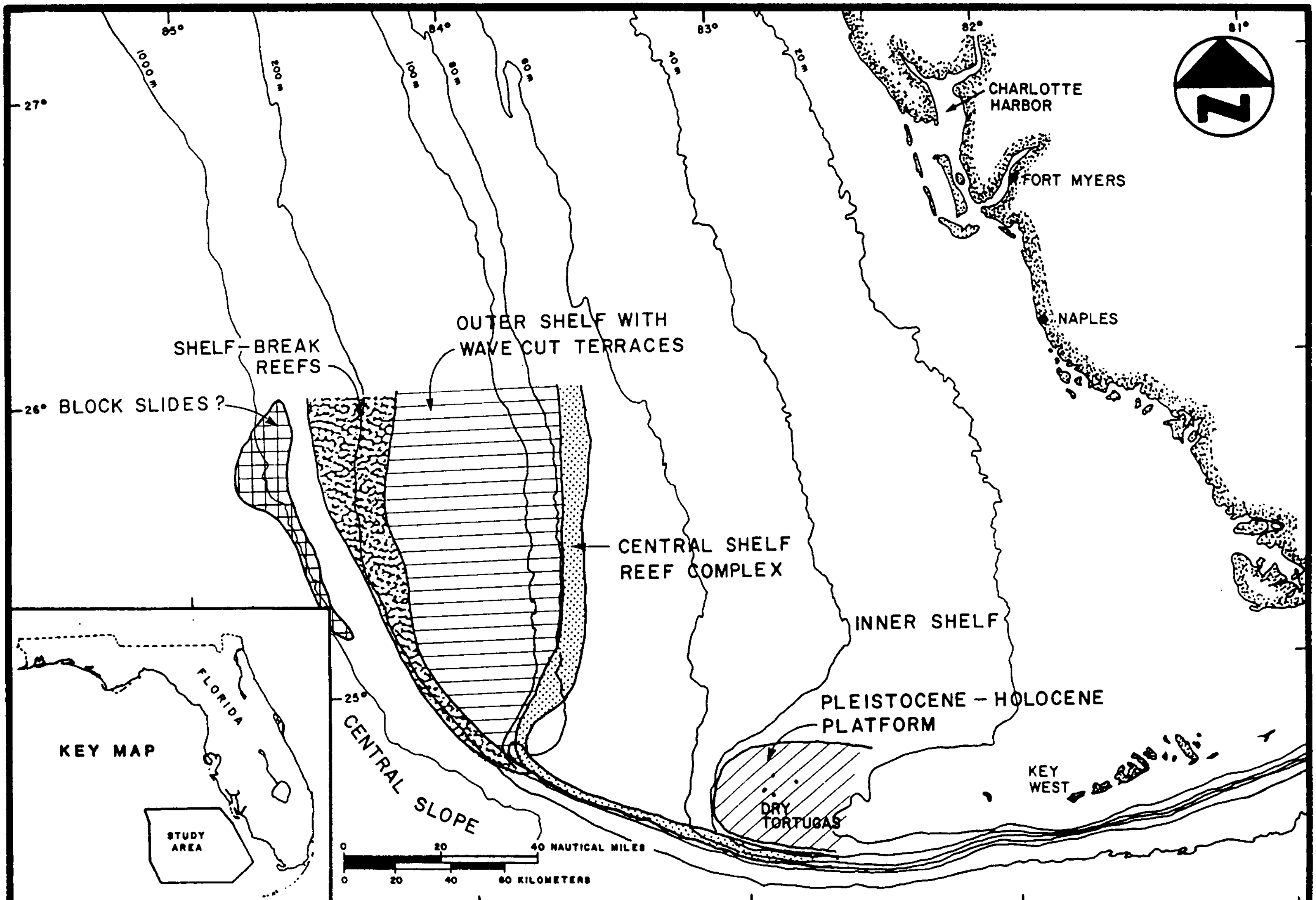


FIGURE 4.12. MAJOR GEOLOGIC FEATURES OF THE SOUTHWEST FLORIDA SHELF (FROM: WOODWARD-CLYDE CONSULTANTS AND CONTINENTAL SHELF ASSOCIATES, INC., 1985, AFTER HOLMES, 1981).

seagrass/algal assemblage associated with soft-bottom areas on the inner shelf; (2) assemblages associated with coralline algal nodules or algal pavement over sand on the middle shelf; and (3) dense crinoid groupings seen on shell rubble over thick sand on the outer shelf.

On the inner shelf, the sand veneer overlying hard substrate is thin. Shallow-water epibiota such as gorgonians and sponges colonize occasional patch reefs (Smith, 1975, 1979) and more extensive areas of thin sand over hard bottom (this study). Areas of thick sand bottom on the inner shelf may be colonized by dense growths of seagrasses and algae--also defined as live bottom for the purposes of this study. Seagrass beds are common farther inshore in the Florida Bay region (Iverson and Bittaker, in press). The presence of the larger gorgonians and seagrass/algal beds landward of the 20-m isobath makes inner shelf epibiota visually distinct from those in greater water depths.

The lower incidence of live bottom and thin sand over hard substrate in the 40- to 60-m depth range (e.g., Transects H, I, J, and K) than in shallower depths (e.g., Transect G and inshore portions of Transects B, C, and D) presumably reflects the thickening wedge of inner shelf sediments impounded by the buried central shelf reef complex. The northward decline of the influential topographic feature may explain in part the higher incidence of thin sand over hard bottom on the inner shelf portion of Transect A in comparison with Transects B, C, and D.

The central reef complex may also be related to the presence of live bottom in its depth range. Little rock or thin sand over hard substrate was evident in 70- to 90-m depths, but the presence of the underlying reef feature was evidenced by irregular seafloor topography on Transects B, C, D, E, and F (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Coralline algae and other perennial algae (e.g., Peyssonnelia spp., Halimeda spp.) are abundant in approximately 60- to 100-m depths, more so on the southern Transects D and E and the southern portion of Transect F than on Transects B and C. The abundance of the coralline and other crustose algae in this depth range may simply reflect a coincidence of favorable environmental conditions (sufficient light, moderate and relatively constant near-bottom temperatures, and elevated near-bottom inorganic nutrient concentrations due to geostrophic upwelling). The development of algal nodules and algal nodule pavements probably requires particular hydrodynamic conditions. These possible environmental influences are discussed in Section 8.2 of the Year 2 final report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985).

Live bottom on the outer shelf was primarily associated with protruding rock outcrops such as those seen near the shelf edge (prominences and low-relief rock outcrops). Most of the outer shelf is covered by a thick sand wedge which precludes establishment of widespread live bottom. The algal nodules and associated crustose perennial algae seen on the middle shelf become increasingly rare with depth, presumably due to changes in environmental variables such as light intensity and near-bottom temperature.

4.6 COMPARISON OF GEOPHYSICAL AND REMOTE PHOTOGRAPHIC MAPPING TECHNIQUES FOR DETECTION OF LIVE BOTTOM

Geophysical and remote photographic methods have different advantages and disadvantages for mapping live bottom. One objective of the mapping surveys was to compare these methodologies for live-bottom detection.

Geophysical techniques cannot detect live bottom (defined by the presence of indicator epibiota); rather, they can be used to infer possible live bottom if exposed or thinly covered hard substrate is present. This is not adequate for recognition of some live-bottom areas, such as seagrass/algal beds or coralline algal nodules/pavement, that may overlie thick sand substratum. In addition, the resolution of the subbottom profiler used here is about 60 cm, whereas the thickness of the sand veneer at live-bottom stations was 0 to 18 cm (Section 5.3.5). Thus, what geophysical instruments show to be a thin sand veneer may not necessarily be thin enough for development of live bottom.

The geophysical mapping has an advantage over remote photographic methods in breadth of coverage. The towed television/still camera system can view only a small area along the towing path, whereas geophysical profiling extends to tens of meters on either side.

Table 4.5 compares live-bottom incidence from photographic interpretation with the predicted incidence from geophysical interpretation. There was generally good agreement, with some notable exceptions:

1) On the nearshore transects, soft-bottom areas characterized by seagrass/algal beds were not consistently mapped as potential live bottom (thin sand over hard substrate) based on geophysical data.

TABLE 4.5. COMPARISON OF REMOTE PHOTOGRAPHIC AND GEOPHYSICAL DATA FOR DETECTION OF LIVE BOTTOM OR POTENTIAL LIVE BOTTOM.

Transect	Percent Incidence of Live Bottom (TV/still camera)	Percent Incidence of Potential Live Bottom (geophysical)	Comments
B	34	70	TV showed no live bottom in some areas where geophysical data indicated thin sand over hard substrate.
C	82*	79	None.
D	77	56	Some seagrass/algal bed areas interpreted geophysically as soft bottom.
G	50	49	As for Transect D; also, some rock outcrop areas seen on TV but not detected geophysically.
H	3	6	None.
I	36	19	Some live bottom areas seen on TV interpreted geophysically as soft bottom with light and dark banding. Also, several rock outcrop areas seen on TV but not detected geophysically.
J	24	0	As for Transect I.
K	19	0	As for Transects I and J.
E	100	18	Side-scan sonar showed coarse bottom and few possible outcrops; no distinctive geophysical signature associated with live bottom.
L	90*	95	Geophysical data showed more widespread pinnacles than TV data (northern part of transect).

Percent incidence values calculated as linear extent of live bottom (TV/still camera data) or potential live bottom (geophysically detected rock outcrops plus thin sand over hard substrate) divided by total transect length, times 100.

*On Transects C and L, geophysical coverage was less than photographic coverage. The values are for comparable portions of the transects and therefore differ slightly from those given in Table 4.3.

2) Small live-bottom areas associated with localized outcrops and patches of thin sand over hard substrate were often seen on the television videotapes but not detected geophysically. This problem was especially noticeable on the midshelf Transects I, J, and K. Conversely, rock outcrops were sometimes detected geophysically, but if none occurred within the narrow field of view of the television camera, the area was characterized as soft bottom. This situation was noted on the northern portion of Transect L, for example, where prominences protruded through thick sand.

3) The algal nodule layer over sand and algal nodule pavement areas were not specifically recognizable from geophysical records. Both substrate types had been seen during Year 1 and 2 television surveys, but not detected geophysically; a portion of Transect E was included in the Year 3 geophysical mapping to evaluate the possibility of recognizing a specific side-scan sonar signature for these substrates. Although the side-scan sonar and subbottom profiler data from Transect E indicated the presence of coarse substrate and possible hard substrate (rock outcrops), no positive identifiers for the algal nodule layer or algal nodule pavement were noted in the geophysical records, regardless of the range and scale settings used.

These results serve to emphasize the importance of using combined geophysical and remote photographic data in mapping live-bottom habitats on the continental shelf.

CHAPTER 5
LIVE-BOTTOM STATIONS

5.1 INTRODUCTION

Five live-bottom stations were chosen following Cruise I to be sampled on Cruises II and III (Figure 5.1). Water depths and Loran-C and latitude/longitude coordinates are provided in Table 5.1.

Both remote and in situ sampling methods were used. The remote methods were the same as those used during Years 1 and 2, consisting of a television/still camera survey and dredge and trawl sampling at each station. The in situ methods were as follows: (1) diver photography and harvesting of epibiota within 0.5 m^2 quadrats to further characterize the epibiota (especially small and/or cryptic organisms); (2) diver photography of line transects--an alternative method of percent cover estimation that has previously been used at Caribbean reefs and the Flower Garden Banks; and (3) diver fish counts to supplement trawl sampling of fish populations. Relevant environmental data also were collected at these stations, including sediment thickness measurements within the quadrats harvested; sediment deposition rate (from sediment traps deployed on Cruise II and retrieved on Cruise III); and continuous temperature measurements (from recording thermographs deployed on Cruise II and recovered on Cruise III).

5.2 METHODS

5.2.1 Field Methods and Equipment

At each station, the television/still camera tow and hydrographic profiling (see Chapter 3) were completed prior to collection of dredge and trawl samples. The television/still camera tow and dredge and trawl collections were conducted at night (generally the night preceding diver collections) because all diver sampling had to be completed during daylight hours. At Station 52, which was designated as an intensive sampling station, dredge and trawl sampling and the television/still camera tow were repeated during daylight hours on each of the two cruises to evaluate diel differences.

Television/Still Camera Photographic Surveys. Photographic surveys employed a television/still camera sled system similar to the one described in Chapter 4, except that the television camera was mounted in

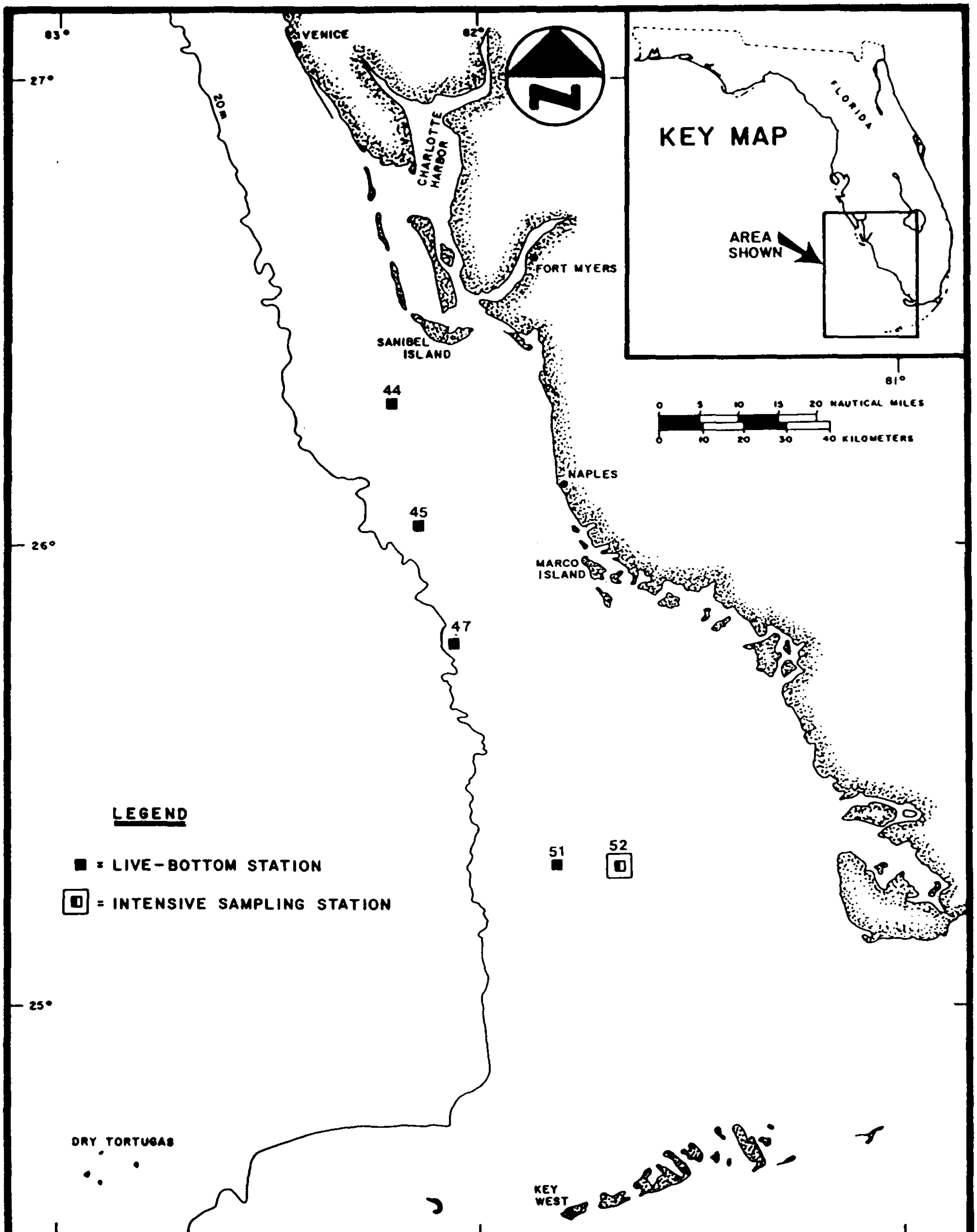


FIGURE 5.1. LOCATIONS OF LIVE-BOTTOM STATIONS SAMPLED DURING CRUISES II AND III.

TABLE 5.1. WATER DEPTHS AND LOCATIONS OF LIVE-BOTTOM STATIONS SAMPLED DURING CRUISES II AND III.

Station	Water Depth (m)	Latitude (N)	Longitude (W)	Loran-C Coordinates	
44	13	26°17.86'	82°12.61'	14078.2	43961.5
45	17	26°03.19'	82°08.45'	14055.9	43888.5
47	19	26°46.02'	82°06.06'	14025.9	43833.5
51	16	25°17.67'	81°48.00'	14008.0	43675.7
52	14	25°17.80'	81°39.80'	14024.3	43625.4

Cruise II: December 1982
Cruise III: May-June 1983.

a position to view the bottom ahead of the sled whereas the still camera and strobe were oriented to provide a field of view directly beneath the sled (Figure 5.2). An iron sash weight suspended from the end of a steel rod extending forward and to the right of the sled appeared in the right side of the television camera's field of view. The bottom end of the sash weight was suspended approximately 0.5 m below the bottom of the television/still camera sled, and the still camera was mounted with its lens at a distance of approximately 0.5 m above the bottom of the sled. During television/still camera tows, the scientist piloting the sled (through an onboard winch system) attempted to maintain the sled at a constant height above the seafloor by keeping the sash weight barely touching bottom. Using this system, slides covering a known area (approximately 0.5 m^2) could be obtained for quantitative comparison of percent cover within and between sampling stations.

At each station, the sled was towed at a speed of 1 to 2 kt within the boundaries of the 1 km^2 station. A typical tow pattern is illustrated in Figure 5.3. A scientist watching the shipboard television monitor took approximately three still photographs per minute (plus additional photographs of items of interest) during the tows. In general, 200 photographs were taken at each station using Ektachrome 200 ASA color slide film. Upon completion of a particular roll of film, the last 0.5 m was developed on board ship to check camera performance. Television data were recorded on 3/4-inch black-and-white tapes. Navigational fixes were recorded on the audio track of the tapes every minute, and areas of dense epibiota were noted in the television log at corresponding navigational fix points.

Dredge and Trawl Sampling. The scientist monitoring the remote television observations selected areas of live bottom to be sampled by dredge and trawl at each station. A typical pattern of dredge and trawl collections in relation to the television/still camera tow is shown in Figure 5.3.

In general, three dredge samples were obtained at each station on each cruise. Exceptions were: (1) Station 51, Cruise II--three dredge samples were obtained in a live-bottom area and three in a soft-bottom area with dense algal growth; (2) Station 45, Cruise III--an extra dredge sample was obtained in lieu of a trawl sample after the trawl net was ripped repeatedly on coral heads; and (3) Station 52, both cruises--three day and three night samples were obtained. The samples were collected using a Kahlsico triangle dredge having a 0.6-m wide mouth opening and

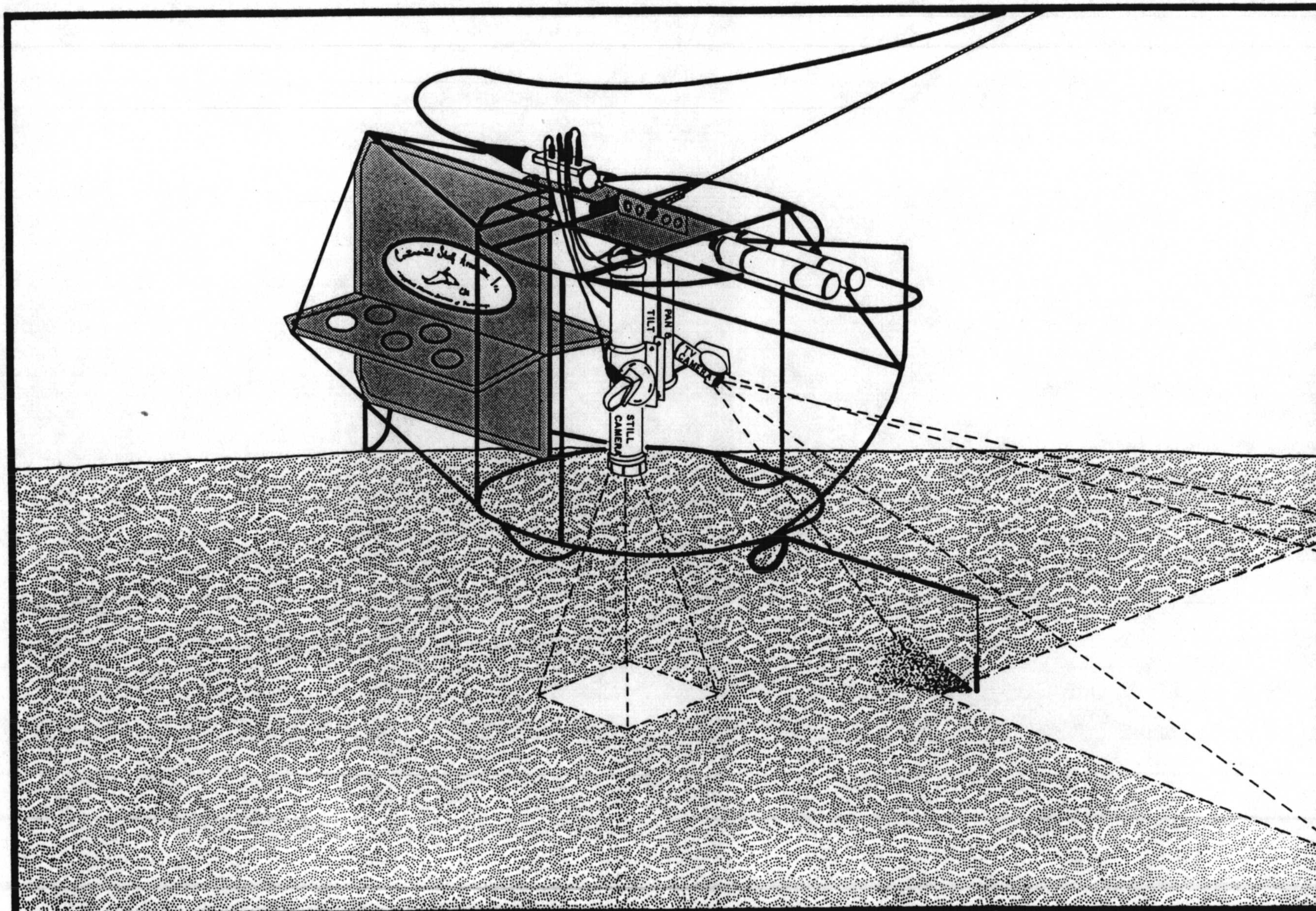


FIGURE 5.2. UNDERWATER TELEVISION/STILL CAMERA SYSTEM.

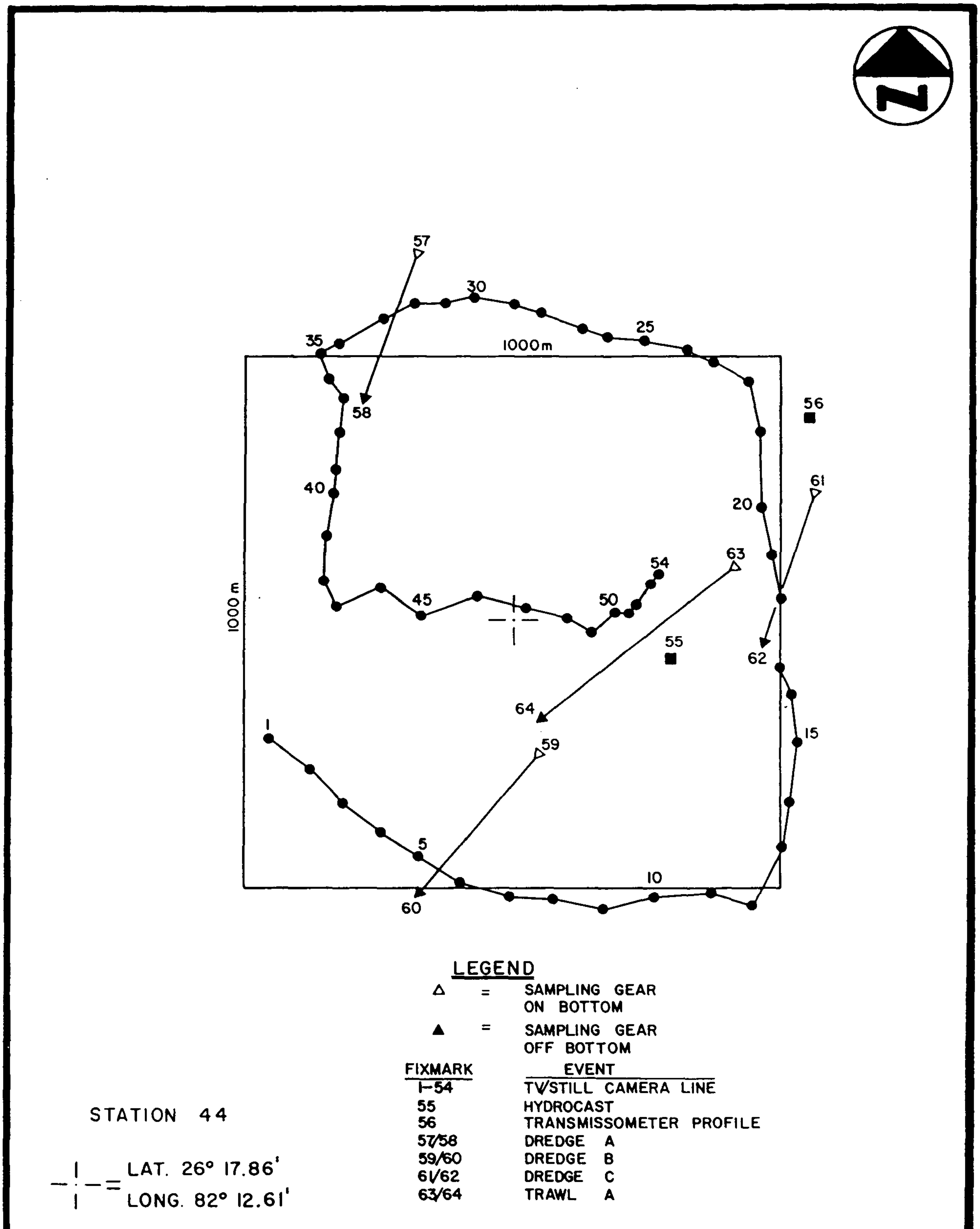


FIGURE 5.3. AN EXAMPLE TELEVISION/STILL CAMERA TOW PATTERN FOR STATION 44, CRUISE III. LOCATIONS OF DREDGE, TRAWL, AND HYDROGRAPHIC SAMPLING ARE ALSO SHOWN.

1.2-cm mesh openings. The dredge was towed at less than 2 kn for a distance of up to 300 m. Navigational fixes were recorded during each tow.

Trawl samples were collected using a Marinovich 7.6-cm semiballoon otter trawl equipped with 12-cm diameter rollers, 3.8-cm stretch mesh in the body of the net, and 1.3-cm mesh in the cod end. One trawl sample was collected at each station on each cruise. Exceptions were: (1) Station 51, Cruise II--one sample was obtained in a live-bottom area and another in a soft-bottom algal area; and (2) Station 52, both cruises--one daytime and one nighttime trawl sample was obtained. The length of trawl tows varied from about 500 to 1,000 m depending on the density of macroepibiota previously observed in the area during the television/still camera tow. Navigational fixes were recorded as for the dredge samples.

Post-plots of dredge, trawl, and television/still camera tow locations at each station are shown in Appendix B.

Quadrat Photography, Quadrat Harvesting, and Sediment Thickness Measurements. At each live-bottom station, divers photographed and harvested epibiota and made sediment thickness measurements within 35 (or more) 0.5 m^2 quadrats. Quadrat positions were determined randomly by tossing 58 x 86 cm rectangular PVC quadrat frames from a height of 2 m above the bottom. A marked tag was then positioned within each frame. The area within each frame was photographed using a Nikonos III underwater 35-mm camera with Subsea 100 underwater strobes attached to a camera jig designed to fit the quadrat frame. Sediment thickness measurements were made by inserting a calibrated (1-cm intervals) 30-cm stainless steel rod into the substrate at three arbitrary locations within each quadrat. These measurements were recorded on diver slates and later transferred to data sheets on board ship. The epibiota within each quadrat was harvested by hand and placed in a canvas bag along with a numbered quadrat tag. On board ship, the contents of the bags were sorted into major phyletic groups (sponges, hard corals, gorgonians, crustaceans, gastropods, bryozoans, macroalgae, etc.) and the total wet weight of epibiota in each group was recorded to the nearest gram. The epibiota was then preserved (70% ethanol for sponges; 10% buffered, neutralized formalin for all others) in labeled containers for onshore taxonomic processing.

Transect Photography. At each live-bottom station, divers photographed the seafloor and epibenthos along a 10-m linear transect during each cruise. The starting point and direction for each transect were determined arbitrarily. Divers first laid out a fiberglass measuring tape to establish the transect. They then used a Nikonos III camera with a 35-mm lens and a pair of Subsea 100 underwater strobes attached to a stainless steel camera jig (the same one used for quadrat photography) to obtain a 58-cm wide photographic mosaic of the entire transect.

Fish Counts. Divers censused fish populations at each live-bottom station during each cruise. At each station, a diver swam an arbitrarily selected 20-min transect within the live-bottom area and recorded all fish species observed. Abundance was noted for each species using the following categories:

A) 100 or more individuals
B) 26 to 100 individuals
C) 11 to 25 individuals
D) 2 to 10 individuals
E) 1 individual

Fish count data initially were recorded on the diver's slate and later were transferred to a data form on board ship.

Sediment Trap and Thermograph Deployment and Recovery. Sediment trap arrays were deployed at all five live-bottom stations on Cruise II. Each array consisted of two sets of triplicate sediment traps positioned so that their mouth openings were 1 and 2 m above the bottom, respectively (Figure 5.4). A Helle Model 2260 pinger was attached to each array to facilitate its relocation. The traps consisted of cylindrical PVC tubes 2.5 cm in diameter and 38 cm in height inserted into 1-l polyethylene jars; each trap had an aspect ratio (height:diameter) in excess of 10:1, which was considered sufficient to ensure that washout of sediment would not occur. At Stations 44 and 52, each array also contained a Ryan Model J-180 recording thermograph (see Appendix A for specifications).

Only three of the sediment trap arrays and one of the thermographs were recovered intact on Cruise III. At Station 44, the array could not be located; it was probably dragged off station by a shrimp trawler. At Station 45, the array was recovered, but it had been knocked over and the

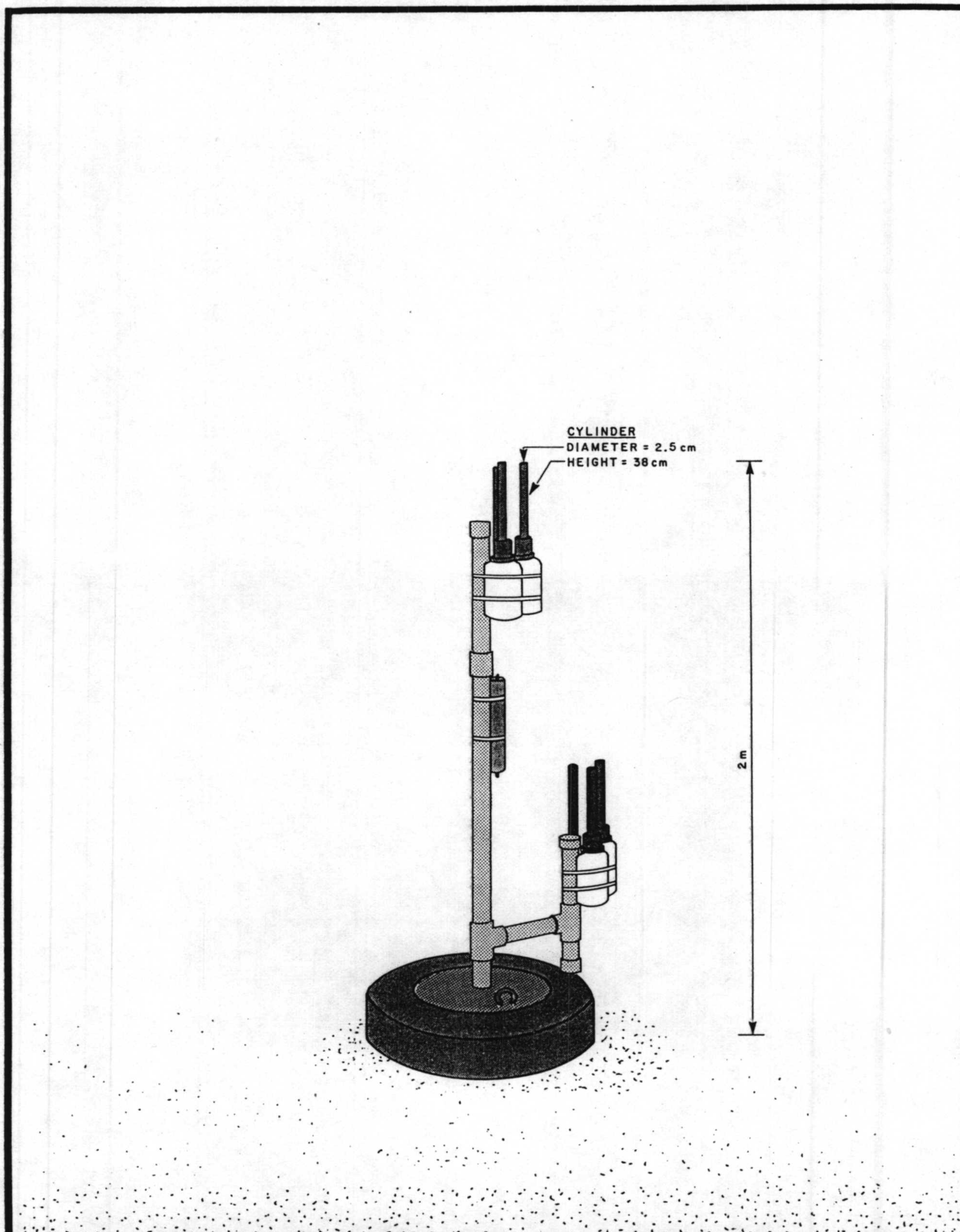


FIGURE 5.4. SEDIMENT TRAP ARRAY.

data were discarded. At Station 52, the upper sediment traps and the thermograph were recovered intact, but the lower traps had been dislodged. The fates of the sediment trap/thermograph arrays at each station are summarized in Table 5.2.

5.2.2 Laboratory Analysis

Sample Processing and Identification. All samples were returned to the laboratory, sorted to the lowest possible taxonomic level, and identified to species, if feasible. Representative specimens were sent to taxonomic experts for identification or verification of identification. Species lists were developed for each station and all data were entered on computer to facilitate statistical analysis. A voucher collection was assembled and forwarded to the U.S. National Museum (Smithsonian Institution). Figure 5.5 shows a flow chart for the processing of live-bottom station biological samples.

Analysis of Videotapes and Photographs. Videotapes from the television tows were reviewed to compile station maps showing bottom type seen along the towing path. Each videotape was viewed and bottom type was recorded for 15-s intervals. Categories were: soft bottom; occasional live bottom (<1 epibiotic individual m^{-2}); thin live bottom (1 to 2 individuals m^{-2}); medium live bottom (2 individuals m^{-2} up to 50% areal coverage); and thick live bottom (>50% areal coverage). Rock outcrops, sand waves, and any other unusual features were noted.

All color 35-mm still photographs initially were reviewed in their original roll form using a Dukane Model 27A25 microreader. Slides having images of epibiota in at least 5% of the area covered (as estimated subjectively) were selected for analysis. Therefore, estimates of the percent coverage of epibiota pertain to the live-bottom patches within a station rather than to the station area as a whole. Also during this initial review, bottom types were identified relative to the navigational fix marks to confirm that the assemblages/bottom types corresponded to the bottom types identified from the television observations and videotapes.

After the initial screening of the slides to meet the 5% coverage criterion, 100 slides per station were chosen arbitrarily from all of the slides containing suitable epifaunal images for quantitative slide analysis. All available slides were analyzed at stations where fewer than 100 acceptable photographs had been taken.

TABLE 5.2. FATES OF SEDIMENT TRAP/THERMOGRAPH ARRAYS DEPLOYED AT LIVE-BOTTOM STATIONS.

Station	Array Type	Fate
44	Sediment Traps/Thermograph	Lost (dragged off station?).
45	Sediment Traps	Knocked over; recovered, but data discarded.
47	Sediment Traps	Recovered intact.
51	Sediment Traps	Recovered intact.
52	Sediment Traps/Thermograph	Lower traps had been dislodged; upper traps and thermograph intact.

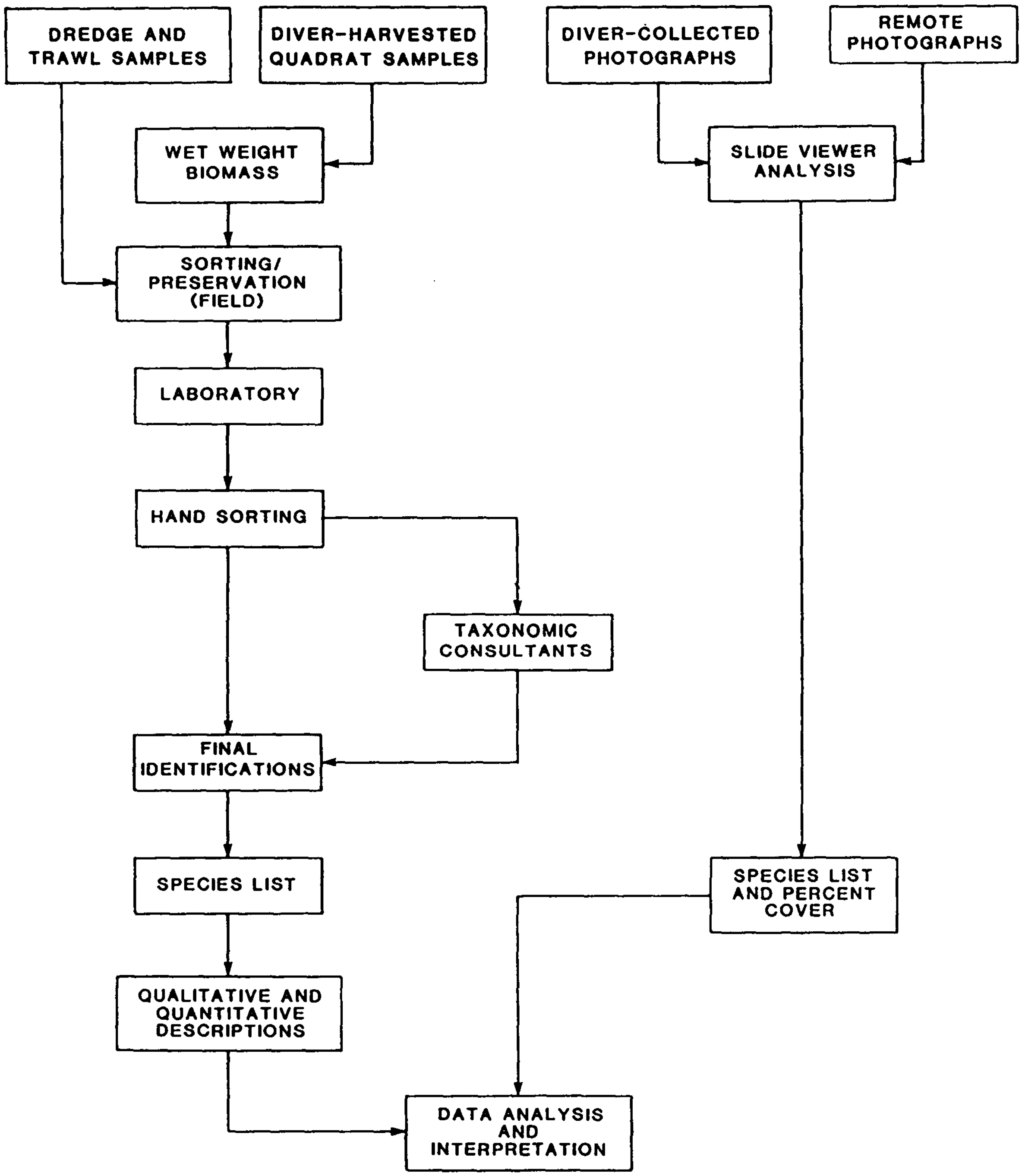


FIGURE 5.5. FLOW CHART FOR PROCESSING OF LIVE-BOTTOM SAMPLES AND DATA.

Quantitative slide analysis (QSA) was performed to estimate the percent cover of the various species, genera, species-groups, and/or substrate types that could be identified at each station. An acetate overlay with 100 randomly selected points was superimposed over each slide while it was projected onto the screen of the microreader. The number (and, by calculation, percentage) of points that covered each type of biota and/or substrate was recorded for every slide. Biota were identified to the lowest possible taxonomic level.

Photographs taken by divers prior to quadrat harvesting were analyzed in exactly the same manner as were the remote still camera photographs. The objective was to determine whether photographic identifications could be improved if the specimens present in a given photograph were collected.

Transect photographs were analyzed using the "intercepted length" method, which has been used at Caribbean reefs (Dodge et al., 1982) and at the Flower Garden Banks in the northwestern Gulf of Mexico (Continental Shelf Associates, Inc., 1985b). The length of each species, genus, or substrate type intersecting the transect line in each photograph was recorded. These intercept lengths were compiled to provide estimates of percent cover, on the premise that the percent of total transect length intercepted by each taxon is proportional to the average percent cover of that taxon.

5.2.3 Data Analysis

Summary tables and descriptive statistics were generated for each data set as needed using SAS (Statistical Analysis System) (SAS Institute Inc., 1982) and EAP (Ecological Analysis Package) (Smith, 1979). Included were species richness tables, ranked abundance tables, and two-way (taxon vs. station/cruise) occurrence tables for dredge, trawl, and quadrat data; biomass and sediment thickness summary tables for harvested quadrats; and percent cover summaries and lists of cover dominants from analysis of photographic data. Sediment trap data and fish counts were tabulated by hand.

Dredge, trawl, and quadrat harvesting data were explored further using normal and inverse classification (cluster) analysis. We used agglomerative, hierarchical clustering (EAP procedure DENDRO) with flexible sorting ($\beta = -0.25$). Because only one trawl sample was collected at each station/cruise, the binary (presence/absence)

Czekanowski (Dice) index was used as the similarity measure for these data. Dredge and quadrat data consist of replicated collections at each station/cruise, and we used the Bray-Curtis index as the similarity measure, with weighting by relative frequency of occurrence. Data were not transformed Procedure DENDRO uses a "step across" method to recalculate high dissimilarity values; therefore, on some dendrograms, distances greater than 1.0 are displayed.

Many more species were collected by each sampling method than could be included in cluster analyses (due to computer program limitations). Therefore, each data set was truncated to exclude infrequently collected species. Truncation criteria and their effect on data set size are summarized in Table 5.3.

Regression analyses also were performed to investigate interrelationships among variables measured in harvested quadrats. Sediment thickness was used as the independent variable, and percent cover (all biota and various groups) and biomass (all biota and various groups) were used as dependent variables. Both within- and between-station analyses were conducted.

5.3 RESULTS

5.3.1 Station Descriptions

Live-bottom station descriptions were compiled by reviewing (1) videotapes, photographs, and field notes from television/still camera tows and (2) field notes summarizing diver observations.

Table 5.4 summarizes live-bottom station characteristics. Station maps showing habitat features observed during television/still camera tows are presented in Appendix D. Figure 5.6 shows an example of a station map for Station 52, Cruise II.

The seafloor at the live-bottom stations was typically flat, and little exposed rock was evident. The substrate commonly consisted of a thin sand veneer overlying hard bottom. This substrate type was inferred during television/still camera surveys from the presence of numerous sessile epibiota (such as sponges and gorgonians) that require hard substrate for attachment. Divers measured the thickness of the sand veneer near the station centers during quadrat harvesting (see Quadrat Collections); the values ranged from 0 to 18 cm. The underlying hard bottom was irregular and pocked with holes and crevices. Patches of thicker sand (inferred from the absence of attached epibiota) were interspersed with thin sand substrate to various degrees at all stations;

TABLE 5.3. NUMBERS OF SPECIES INCLUDED IN CLUSTER ANALYSES.

Cruise	Dredge			Trawl			Quadrats		
	Inclusion Criterion (No. dredges/ total)	No. Species		Inclusion Criterion (No. trawls/ total)	No. Species		Inclusion Criterion (Mean relative frequency of occurrence)*	No. Species	
		Total	Included in Analysis		Total	Included in Analysis		Total	Included in Analysis
II†	2/15	413	233	1/5	186	186	0.009	355	250
II§	3/21	456	207	1/7	221	221			
III†	2/15	322	221	1/4	161	161	0.010	314	218
III¶	2/18	337	238	1/5	177	177			
II + III†	3/30	496	245	1/9	231	231	0.009	449	245
II + III¶	4/36	516	227	1/12	254	254			

Explanation: Because more species were collected in dredge and quadrat samples than could feasibly be included in cluster analyses, the data sets were truncated by including only species having a specified minimum frequency of occurrence. Trawl data did not require truncation, as the total number of species was less than 255 in each case.

*Mean relative frequency of occurrence = $\left[\sum \frac{\text{no. quadrats species occurred in}}{\text{total no. quadrats/station}} \right] /5.$

†Analysis conducted using Stations 44, 45, 47, 51 (live-bottom area), and 52 (night).
§Analysis conducted using Stations 44, 45, 47, 51 (live-bottom area), 51 (soft-bottom area), 52 (day), and 52 (night).
¶Analysis conducted using Stations 44, 45, 47, 51 (live-bottom area), 52 (day), and 52 (night).

TABLE 5.4. STATION CHARACTERISTICS FROM TELEVISION/STILL CAMERA AND DIVER OBSERVATIONS.

Station No.	Water Depth at Station Center* (m)	Water Depth Range† (m)	Percent Incidence of Live Bottom§ Cruise II	Cruise III	Mean	Habitat Description¶
44	13	11 - 13.5	90	93	92	Substrate: thin sand over hard bottom with few patches of thick sand; low-relief rock ledge located about 400 m NNE of the station center. Medium to thick live-bottom coverage; gorgonians and sponges abundant. Stone crabs and cryptic fishes seen in rock holes and crevices.
45	17	16 - 18.5	100	100	100	Substrate: thin sand over hard bottom. Thick live-bottom coverage dominated by gorgonians and sponges.
47	19	19 - 20.5	95	80	88	Substrate: thin sand over hard bottom with patches of thick sand bottom. Sand waves (15 cm height, 50 cm wavelength) seen over a wide area during Cruise II TV tow. Occasional to medium live-bottom coverage typified by gorgonians and sponges.

TABLE 5.4. (CONTINUED).

Station No.	Water Depth at Station Center[*] (m)	Water Depth Range[†] (m)	Percent Incidence of Live Bottom[§]			Habitat Description[¶]
			Cruise II	Cruise III	Mean	
51	15.5	13 - 16	100	68	84	Substrate: thin sand over hard bottom with patches of thick sand bottom. Western half of station characterized by soft bottom with abundant algae, especially during Cruise II; eastern half characterized by medium to thick live-bottom coverage typified by sponges and gorgonians.
52	13.5	11.5 - 13.5	86	72	79	Substrate: thin sand over hard bottom with patches of thick sand bottom. NW half of station predominantly sand bottom and scattered thin live bottom; SE half of station predominantly medium to thick live bottom typified by sponges, gorgonians, and algae.

[*]Depth at station center is average from diver depth gauges, both cruises.
[†]Depth range is from fathometer records compiled during television/still camera tows.
[§]Incidence of live bottom is from television/still camera observations. Estimates were compiled by classifying the seafloor within 15-s intervals of videotape (approximately 15 m linear distance) over a total transect length of several kilometers per station.
[¶]Habitat descriptions are from television/still camera and diver observations.

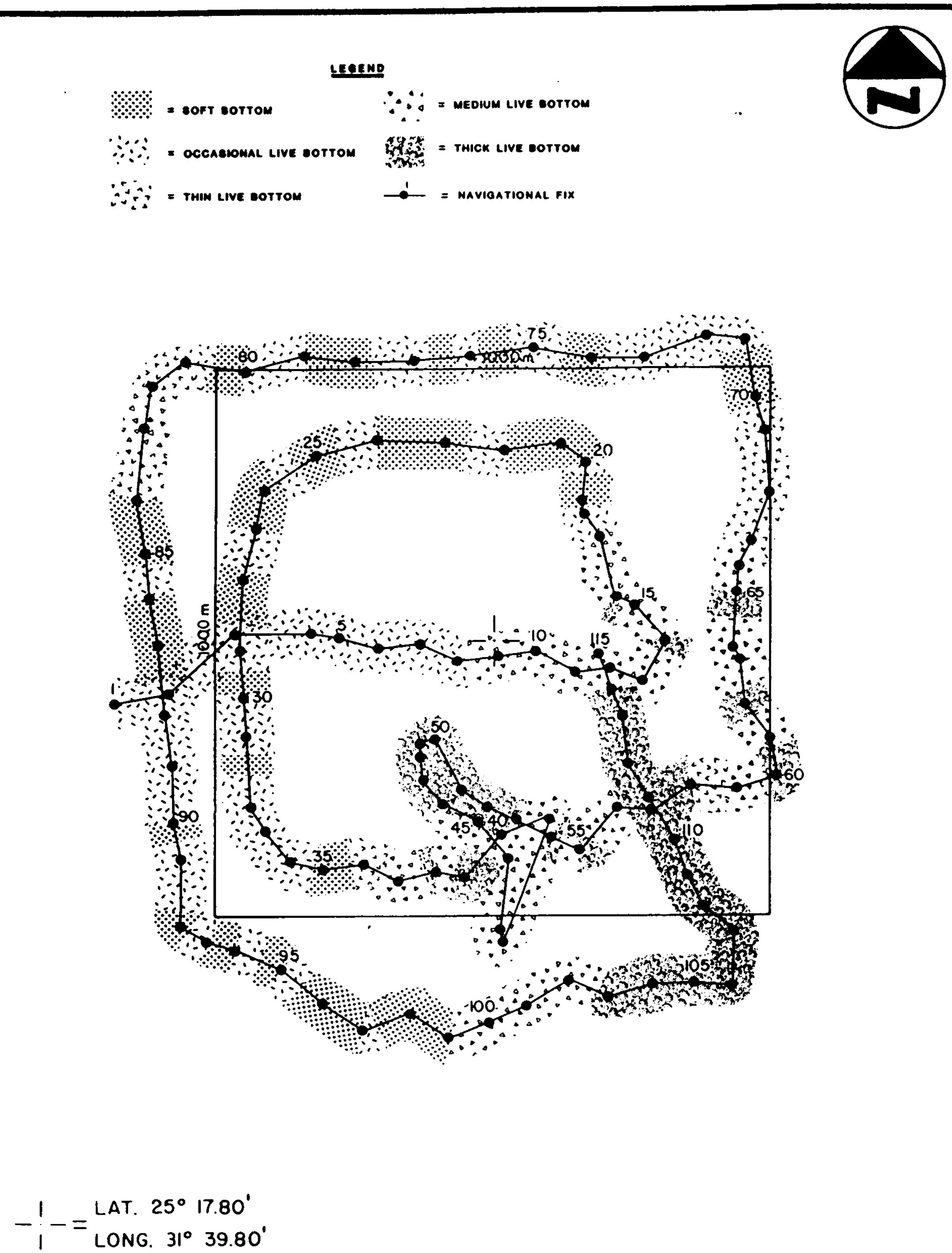


FIGURE 5.6. EXAMPLE HABITAT MAP FOR STATION 52, CRUISE II.

thick sand substrate was rare at Station 45 but covered about half of the area surveyed at Station 52 (Figure 5.6).

The incidence and thickness of live bottom varied among stations (Table 5.4). Incidence refers to the percentage of television videotape time, analyzed in 15-s intervals, over which the habitat was characterized as live bottom. Thickness refers to the density of epibiota within live-bottom areas: occasional ($\leq$1 individual or colony m^{-2}), thin (1 to 2 individuals or colonies m^{-2}), medium (>1 individual m^{-2} up to about 50% areal coverage), or thick (>50% areal coverage). Station 45 exhibited 100% incidence of live bottom, with thick epibiotic coverage. In contrast, the incidence of live bottom at Station 47 was high, but epibiota were sparse (occasional) within live-bottom patches. At Stations 51 and 52, epibiotic coverage was medium to thick within live-bottom areas, but portions of the stations were predominantly soft bottom (e.g., Figure 5.6).

The visually conspicuous epibiota were similar among live-bottom stations. Common epibiota seen included various gorgonians (*Eunicea* spp., *Muricea* spp., *Pseudoplexaura* spp., and *Pseudopterogorgia* spp.), sponges (*Geodia gibberosa*, *Haliclona* spp., *Ircinia* spp., and *Spheciospongia vesparium*), and algae (*Caulerpa* spp., *Halimeda* spp., and others). With the exception of a portion of Station 51 which fits the description of the Seagrass/Algal Bed Live Bottom Assemblage, all of the stations would be characterized as Inner Shelf Live Bottom Assemblage I according to the classification scheme presented in Chapter 4.

5.3.2 Remote Photography

Table 5.5 summarizes percent cover data from quantitative slide analysis (QSA) of photographs taken during the television/still camera tow at each station/cruise. Species with cover values of 1% or more are listed in Table 5.6.

Total biotic cover ranged from 14.7% to 48.8% (Table 5.5). Cover was consistently high (about 40%) at Station 45 and low (about 15% to 20%) at Stations 44 and 47. Values also were high at Stations 51 and 52 during Cruise II, when algae (primarily *Dictyopteris jamaicensis*) contributed over 50% of the total. Algae were much less abundant in the Cruise III photographs from these two stations, and total biotic cover was correspondingly lower (Table 5.5). The seagrass *Halophila decipiens*

TABLE 5.5. QUANTITATIVE SLIDE ANALYSIS OF REMOTE STILL PHOTOGRAPHS: PERCENT COVER SUMMARY.

Group	Cruise II Stations						Cruise III Stations				
					52*						52*
	44	45	47	51	(N)	(D)	44	45	47	51	(N)
Algae	2.0	0.8	1.9	28.5	24.6	26.0	1.5	3.6	0.3	5.0	0.2
Seagrasses	0.0	0.0	1.0	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sponges	9.8	8.1	3.2	2.5	8.6	5.5	7.6	6.2	7.0	5.3	9.5
Hydrozoans	0.9	0.2	1.3	0.4	0.4	0.3	0.0	0.1	0.3	0.3	0.0
Gorgonians	3.0	27.3	5.3	0.4	2.5	3.5	1.9	20.8	10.2	3.8	7.0
Hard Corals	0.7	1.7	0.1	0.0	0.1	0.2	0.5	1.0	0.0	0.1	0.0
Bryozoans	0.4	0.3	0.2	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.0
Echinoderms	0.7	1.8	0.0	0.0	0.0	0.0	0.3	1.7	0.0	0.0	0.2
Ascidians	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.3	0.0
Other	0.6	0.7	4.2	1.2	2.7	2.7	2.8	5.4	2.9	5.8	5.6
TOTAL BIOTA	18.3	41.0	17.3	48.8	39.1	38.4	14.7	39.0	20.8	20.7	22.5

*At Station 52, separate day (D) and night (N) television/still camera tows were conducted during both cruises. High turbidity (low visibility) prevented analysis of the Cruise III day photographs.

TABLE 5.6. QUANTITATIVE SLIDE ANALYSIS OF REMOTE STILL PHOTOGRAPHS: SPECIES WITH COVER VALUES OF 1.0% OR MORE.

Cruise	Station	Species	Percent Cover
II	44	*Placospongia melobesioides* (S)	1.1
		Anthosigmella varians (S)	1.0
	45	*Muricea laxa* (Cn)	2.6
		Pterogorgia guadalupensis (Cn)	2.4
		Placospongia melobesioides (S)	1.7
		Spirastrella sp. A (S)	1.5
		Muricea elongata (Cn)	1.2
	47	*Spheciospongia vesparium* (S)	1.3
		Halophila decipiens (SG)	1.0
	51	*Dictyopteris jamaicensis* (A)	21.2
		Halophila decipiens (SG)	15.6
	52(N)*	*Dictyopteris jamaicensis* (A)	24.2
		Placospongia melobesioides (S)	1.9
III	44	*Spirastrella* sp. A (S)	1.5
	45	*Muricea laxa* (Cn)	1.7
		Spirastrella sp. A (S)	1.7
		Ophiothrix suensonii (E)	1.6
		Pterogorgia guadalupensis (Cn)	1.5
		Placospongia melobesioides (S)	1.3
	47	*Geodia gibberosa* (S)	3.1
		Spheciospongia vesparium (S)	1.7
	51	*Pterogorgia guadalupensis* (Cn)	1.6
		Spheciospongia vesparium (S)	1.2
	52(N)*	*Placospongia melobesioides* (S)	3.4
		Ircinia campana (S)	1.4
		Pterogorgia guadalupensis (Cn)	1.1

A = alga
Cn = cnidarian
E = echinoderm
S = sponge
SG = seagrass.

*See note to Table 5.5.

also contributed significantly to the total at Station 51 during Cruise II (Table 5.6) but was not seen in the Cruise III photographs.

High cover values at Station 45 on both cruises reflect a large contribution by gorgonians, which were far more abundant at Station 45 than at any other station on either cruise. Most of the gorgonians seen were not identifiable to species; Pseudopterogorgia sp. was a major contributor. Of the gorgonians identified to species, Muricea elongata, M. laxa, and Pterogorgia guadalupensis were the main contributors (Table 5.6).

Sponges accounted for about half of total biotic cover at Station 44 on both cruises and at Station 52 on Cruise III; they were also significant secondary contributors at the other stations. Commonly seen species included Placospongia melobesioides, Anthosigmella varians, and Spirastrella sp. A (all encrusting forms); the loggerhead Sphecio-spongia vesparium; the vase sponge Ircinia campana; and Geodia gibberosa (Table 5.6).

Comparison of data from the two television/still camera tows conducted at Station 52 on Cruise II indicates the percent cover estimates were repeatable (Table 5.5) even though the tow tracks were not identical (Appendix B). Precision can also be evaluated by using within-tow variability to construct statistical confidence intervals for percent cover estimates (Table 5.7). In general, 95% confidence limits for mean percent cover values (total biota) were within $\pm$15% of the mean.

5.3.3 Dredge Collections

Five hundred and thirty-nine species were identified from dredge collections with molluscs, crustaceans, sponges, and algae contributing 21%, 19%, 15%, and 12% of the total, respectively (Table 5.8). Gastro-pods and bivalves accounted for most of the mollusc species (62 and 48 species, respectively). Among the algae, red algae were the most speciose (43 species) and brown algae the least (6 species). Species collected by dredge are listed in Appendix F.

Table 5.9 summarizes numbers of species (within major groups) collected by triangle dredge at each station [excluding day collections at Station 52 (both cruises) and those from the soft-bottom, algal area at Station 51 (Cruise II)]. Species richness of dredge collections was fairly consistent across stations (200 to 250 species were collected at

TABLE 5.7. QUANTITATIVE SLIDE ANALYSIS OF REMOTE STILL PHOTOGRAPHS: CONFIDENCE LIMITS FOR TOTAL BIOTIC COVER VALUES.

Cruise	Station	No. of Slides Analyzed	Mean Percent Cover	Standard Deviation	95% Confidence Interval	95% Confidence Interval as Percent of Mean
II	44	100	18.3	10.86	16.1 - 20.5	±12
	45	100	41.0	12.09	38.6 - 43.4	± 6
	47	100	17.3	12.84	14.7 - 19.9	±15
	51	100	48.8	18.13	45.2 - 52.4	± 7
	52(N)*	100	39.1	19.45	35.2 - 43.0	±10
	52(D)*	100	38.4	20.03	34.4 - 42.4	±10
III	44	100	14.7	7.12	13.3 - 16.1	±10
	45	100	39.0	13.18	36.4 - 41.6	± 7
	47	100	20.8	13.84	18.0 - 23.6	±13
	51	100	20.7	10.59	18.6 - 22.8	±10
	52(N)*	50	22.5	8.52	20.1 - 24.9	±11

*See note to Table 5.5.

TABLE 5.8. TRIANGLE DREDGE DATA, CRUISES II AND III COMBINED: SPECIES RICHNESS.

Group	Total No. of Species Collected
ALGAE (total)	67
- green	18
- brown	6
- red	43
SEAGRASSES	1
SPONGES	81
CNIDARIANS (total)	53
- hydrozoans	17
- gorgonians	22
- scleractinian corals	13
MOLLUSCS (total)	113
- gastropods	62
- bivalves	48
CRUSTACEANS (total)	104
- cirripedes	3
- decapods	98
- stomatopods	3
ECHINODERMS (total)	27
- asteroids	7
- echinoids	7
- holothuroids	4
- ophiuroids	9
BRYOZOANS	28
UROCHORDATES	27
FISHES	35
OTHER	3
TOTAL	539

Values represent numbers of species collected at Stations 44, 45, 47, 51 (including algal area sampled during Cruise II), and 52 (including both day and night samples from both cruises).

TABLE 5.9. TRIANGLE DREDGE DATA: SPECIES RICHNESS BY STATION, CRUISE, AND TAXONOMIC GROUP.

Group	Station 44			Station 45			Station 47			Station 51 (LB)*			Station 52 (night)†		
	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises
Algae	2	7	8	13	21	26	16	11	22	20	12	25	14	16	25
Sponges	41	41	53	44	46	55	16	28	31	40	42	52	36	43	48
Hydrozoans	3	2	3	1	1	1	5	4	7	5	4	5	7	3	7
Gorgonians	10	10	14	10	12	13	6	7	9	5	10	11	8	9	10
Hard Corals	6	4	6	10	9	10	2	3	4	7	3	7	3	4	4
Molluscs	28	20	38	30	30	43	40	24	52	25	22	36	20	32	42
Crustaceans	35	30	47	24	23	35	48	34	60	34	27	41	31	28	43
Bryozoans	4	3	4	6	9	10	9	9	13	6	7	9	13	4	13
Echinoderms	13	12	16	10	9	12	13	9	17	7	6	10	6	9	12
Ascidians	12	8	15	11	13	14	6	8	10	17	16	20	12	10	18
Fishes	8	2	9	4	3	5	14	11	22	5	0	5	9	3	10
Other	2	1	2	0	0	0	3	1	3	3	1	3	2	1	2
TOTAL	164	140	215	163	176	224	178	149	250	174	150	224	161	162	234

*At Station 51, samples were collected from a live-bottom (LB) area and a soft-bottom algal area during Cruise II. For purposes of inter-station comparisons, only the live-bottom data are included here.
†At Station 52, both day and night samples were collected on both cruises. Because all other dredge samples were collected at night, only the night data are included here.

each), but the phyletic breakdown varied somewhat. Algal species richness was low at Station 44 in comparison with the other stations. Fewer sponge and ascidian species and more crustacean, mollusc, and fish species were collected at Station 47, characterized by sparse live bottom, than at the other stations.

Tables 5.10 and 5.11 list species frequently collected in dredges during Cruises II and III, respectively. Frequently collected representatives of major taxonomic groups in the combined (pooled over cruises) data set are presented in Table 5.12.

Cluster Analyses. Results of separate cluster analyses of Cruise II and III data were similar and are not presented here. Figure 5.7 shows the dendrogram and station map emerging from cluster analysis of the combined data set for each station [data from day collections at Station 52 (both cruises) and the soft-bottom, algal area at Station 51 (Cruise II) were omitted]. The analysis indicates Station 47 differed distinctly in species composition from the other stations. Stations 51 and 52 were similar in species composition, with both Stations 44 and 45 differing by about the same degree from each other as from Stations 51 and 52.

Table 5.13 lists species characteristic of cluster analysis station groupings. Species characteristic of Stations 44, 45, 51, and 52 include several sessile invertebrates--several sponges, a bryozoan, a gorgonian, and a bivalve mollusc (Table 5.13). Species characteristic of Station 47 were primarily motile invertebrates--crustaceans, a gastropod, an ophiuroid--and a sand-bottom flatfish. Station 47 appeared to exhibit less live-bottom character than the other stations. Station 45 exhibited the most speciose assemblage of hard corals and gorgonians. Coral species collected exclusively or almost exclusively at Station 45 include Porites porites divaricata, Manicina areolata, Isophyllia sinuosa, and Stephanocoenia michelinii (Appendix F).

The degree of between-cruise variation in species composition of the dredge collections was low (Figure 5.8). With the exception of Stations 51 and 52 (which were similar in species composition within cruises), between-station differences were more pronounced than between-cruise differences. Between-cruise (and probably seasonal) differences at Stations 51 and 52 included presence of several species of Gracilaria (red alga) in the Cruise III samples (both stations); presence of the seagrass Halophila decipiens in Cruise II samples (Station 51);

TABLE 5.10. TRIANGLE DREDGE DATA, CRUISE II: SPECIES COLLECTED IN 14 OR MORE OF 21 TOTAL DREDGE SAMPLES.

Species	No. of Dredges	No. of Stations
Anthosigmella varians (S)	19	5
Mithrax (*Mithrax*) *pleuracanthus* (C)	19	5
Geodia gibberosa (S)	18	5
Petrolisthes galathinus (C)	18	5
Pilumnus sayi (C)	18	5
Schizoporella unicornis (B)	17	5
Haliclona compressa (S)	16	5
Phyllangia americana (Cn)	16	5
Solenastrea hyades (Cn)	16	5
Spirastrella sp. A (S)	16	5
Ophiothrix angulata (E)	15	5
Crepidula aculeata (M)	14	5
Eunicea calyculata (Cn)	14	5
Ircinia felix (S)	14	5
Pterogorgia guadalupensis (Cn)	14	5
Celleporaria magnifica (B)	14	4
Cinachyra kuekenthali (S)	14	4
Paguristes tortugae (C)	14	4

B = bryozoan
C = crustacean
Cn = cnidarian
E = echinoderm
M = mollusc
S = sponge.

TABLE 5.11. TRIANGLE DREDGE DATA, CRUISE III: SPECIES COLLECTED IN 14 OR MORE OF 19 TOTAL DREDGE SAMPLES.

Species	No. of Dredges	No. of Stations
Anthosigmella varians (S)	19	5
Geodia gibberosa (S)	19	5
Pilumnus sayi (C)	19	5
Spheciospongia vesparium (S)	19	5
Cinachyra alloclada (S)	18	5
Ophiothrix angulata (E)	18	5
Axinella bookhouti (S)	17	5
Paguristes tortugae (C)	17	5
Schizoporella unicornis (B)	17	5
Solenastrea hyades (Cn)	17	5
Igernella notabilis (S)	16	5
Udotea conglutinata (A)	16	5
Euryspongia rosea (S)	15	5
Mithrax (*Mithrax*) *pleuracanthus* (C)	15	5
Celleporaria albirostris (B)	15	4
Placospongia melobesioides (S)	15	4
Pseudaxinella lunaecharta (S)	15	4
Spirastrella sp. A (S)	15	4
Botryocladia occidentalis (A)	14	5
Clavelina gigantea (U)	14	5
Epipolasis lithophaga (S)	14	5
Haliclona compressa (S)	14	5
Petrolisthes galathinus (C)	14	5
Pilumnus dasypodus (C)	14	5
Plexaurella fusifera (Cn)	14	5
Chama macerophylla (M)	14	4
Celleporaria magnifica (B)	14	4
Cinachyra kuekenthali (S)	14	4
Didemnum candidum (U)	14	4
Ircinia campana (S)	14	4
Phyllangia americana (Cn)	14	4
Pterogorgia guadalupensis (Cn)	14	4

A = alga
B = bryozoan
C = crustacean
Cn = cnidarian
E = echinoderm
M = mollusc
S = sponge
U = urochordate (ascidian).

TABLE 5.12. TRIANGLE DREDGE DATA, CRUISES II AND III COMBINED: FREQUENTLY COLLECTED REPRESENTATIVES OF MAJOR TAXONOMIC GROUPS.

ALGAE

Udotea conglutinata	(28)
Botryocladia occidentalis	(22)
Dictyopteris jamaicensis	(20)
Laurencia intricata	(13)
Halimeda incrassata	(11)
Halimeda scabra	(11)

CRUSTACEANS

Pilumnus sayi	(37)
Mithrax (Mithrax) pleuracanthus	(34)
Petrolisthes galathinus	(32)
Paguristes tortugae	(31)
Pilumnus dasypodus	(27)

ASCIDIANS

Clavelina gigantea	(27)
Didemnum candidum	(26)
Clavelina picta	(21)
Aplidium lobatum	(19)
Eudistoma capsulatum	(16)

ECHINODERMS

Ophiothrix angulata	(33)
Arbacia punctulata	(17)
Lytechinus variegatus carolinus	(16)
Clypeaster subdepressus	(16)
Ophiothrix suensonii	(15)

BRYOZOANS

Schizoporella unicornis	(34)
Celleporaria magnifica	(28)
Celleporaria albirostris	(26)
Stylopoma spongites	(16)
Amathia convoluta	(14)

MOLLUSCS

Chama macerophylla	(27)
Crepidula aculeata	(25)
Anadara notabilis	(21)
Arca zebra	(20)
Pteria colymbus	(18)

CNIDARIANS

Solenastrea hyades	(33)
Phyllangia americana	(30)
Pterogorgia guadalupensis	(28)
Campanularia marginata	(25)
Eunicea calyculata	(24)

SPONGES

Anthosigmella varians	(38)
Geodia gibberosa	(37)
Spirastrella sp. A	(31)
Spheciospongia vesparium	(31)
Cinachyra alloclada	(30)
Haliclona compressa	(30)

Values in parentheses are numbers of dredge occurrences out of 40 possible.

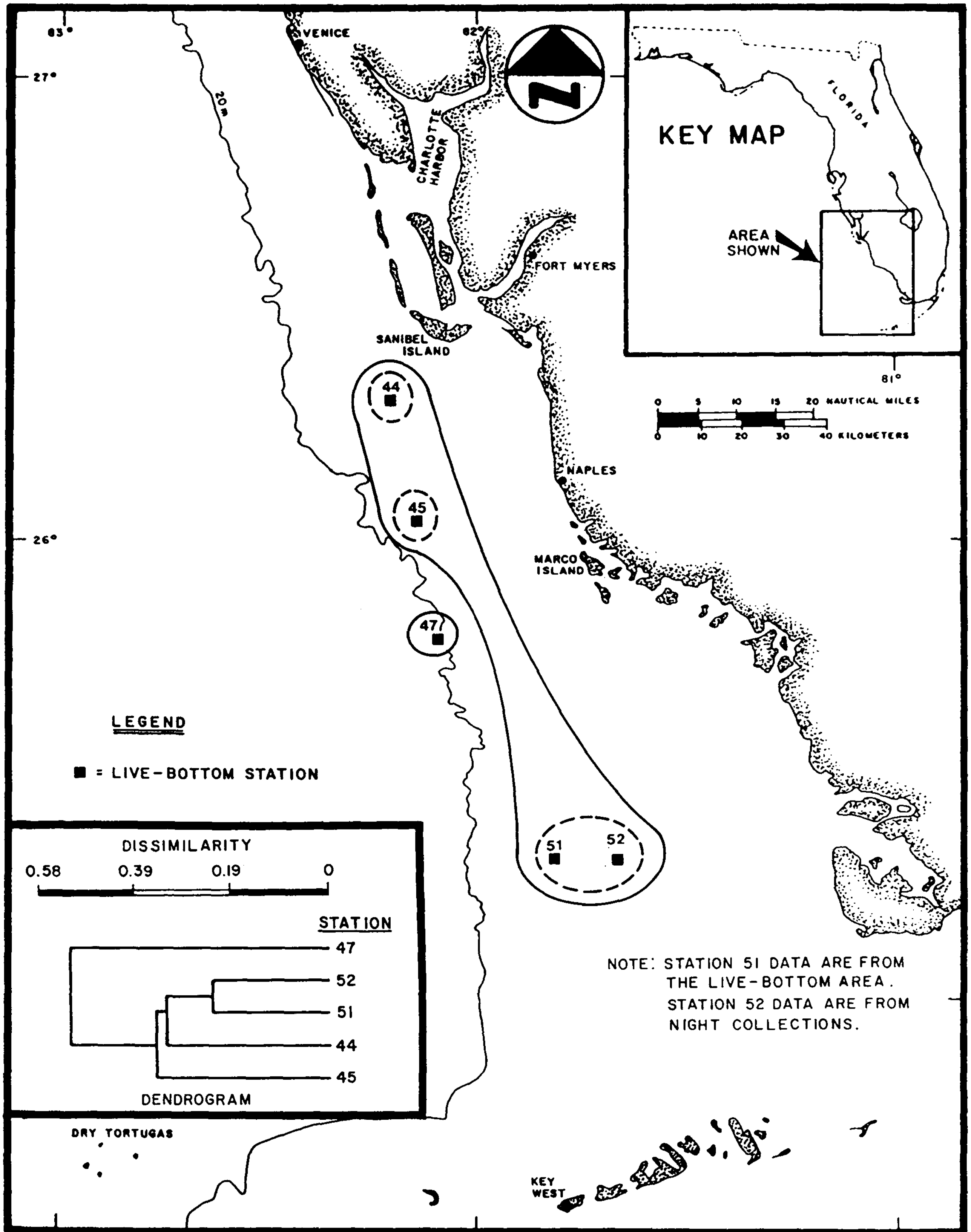


FIGURE 5.7. TRIANGLE DREDGE DATA, CRUISES II AND III COMBINED: CLUSTER ANALYSIS RESULTS.

TABLE 5.13. TRIANGLE DREDGE DATA, CRUISES II AND III: SPECIES CHARACTERISTIC OF CLUSTER ANALYSIS STATION GROUPINGS.

MAJOR CLUSTERS:

Station 47

Conus floridanus (M)
Cupuladria biporosa (B)
Iliacantha intermedia (C)
Lobopilumnus agassizi (C)
Lophogorgia cardinalis (Cn)
Ophiolepis elegans (E)
Rhabdopleura compacta (H)
Synalpheus longicarpus (C)
Symphurus urospilus (F)

Stations 44, 45, 51, and 52

Celleporaria magnifica (B)
Chama macerophylla (M)
Chondrilla nucula (S)
Cinachyra kuekenthali (S)
Ircinia campana (S)
Haliclona sp. D (S)
Microciona sp. B (S)
Microciona sp. C (S)
Placospongia melobesioides (S)
Pseudaxinella lunaecharta (S)
Pseudoplexaura wagenaari (Cn)

MINOR CLUSTERS:

Station 44

Leptogorgia virgulata (Cn)
Lophogorgia hebes (Cn)

Station 45

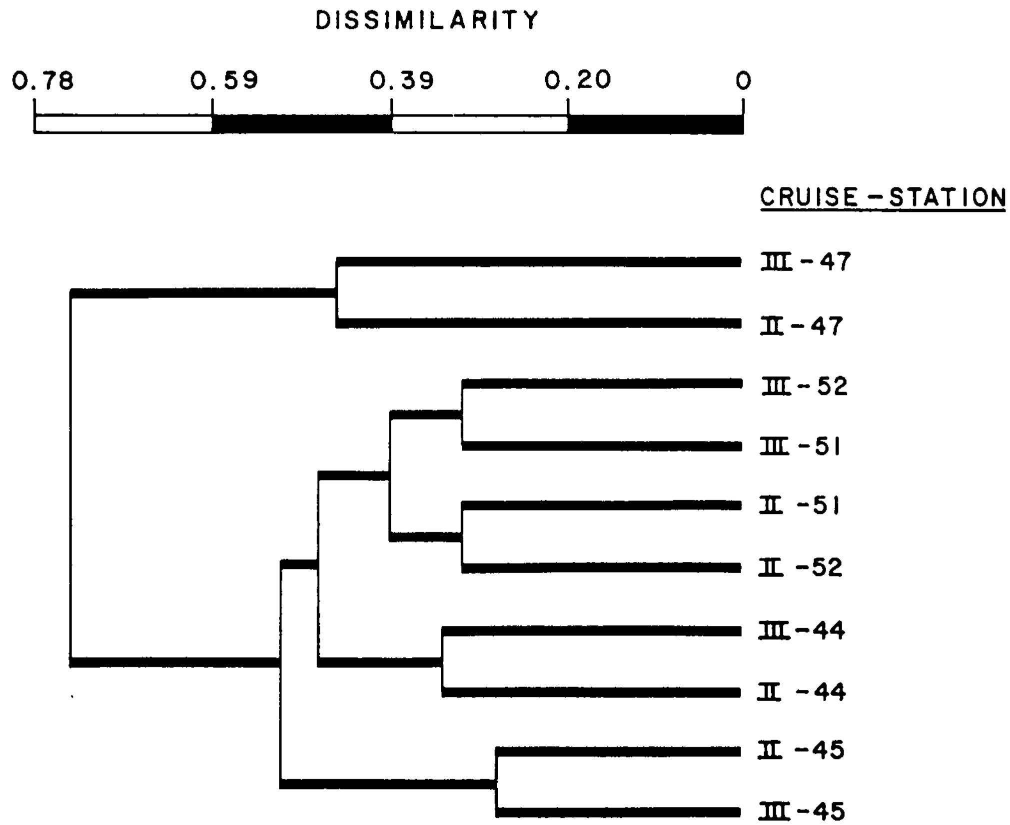
Acarnus sp. B (S)
Manicina areolata (Cn)
Millepora alcicornis (Cn)
Porites porites divaricata (Cn)
Rhipocephalus oblongus (A)
Terpios fugax (S)

Stations 51 and 52

Chicoreus dilectus (M)
Conus jaspideus (M)
Dictyopteris jamaicensis (A)
Dyshasia digitalis (Cn)
Myrmekioderma sp. A (S)

Species listed are those having a high degree of fidelity (i.e., occurring primarily at stations in a group) and constancy (occurring at most or all stations in a group on each cruise) for particular station groupings.

A = alga
B = bryozoan
C = crustacean
Cn = cnidarian
E = echinoderm
F = fish
H = hemichordate
M = mollusc.



NOTE: STATION 51 DATA ARE FROM THE LIVE-BOTTOM AREA. STATION 52 DATA ARE FROM NIGHT COLLECTIONS.

FIGURE 5.8. TRIANGLE DREDGE DATA, CRUISES II AND III: CLUSTER ANALYSIS DENDROGRAM SHOWING BETWEEN-CRUISE DIFFERENCES IN SPECIES COMPOSITION.

and presence of the fishes *Monacanthus ciliatus* (fringed filefish), *Serranus subligarius* (belted sandfish), and *Serraniculus pumilio* (pygmy sea bass) in the Cruise II samples (both stations).

Selected Comparisons. Two sets of dredge samples were collected for within-station comparisons. During Cruise II, three dredge samples were collected from a soft-bottom, algal area within Station 51 (in addition to the regular samples from the live-bottom area). During both cruises, daytime dredge samples (in addition to those collected at night as at all other live-bottom stations) were collected at Station 52.

The soft-bottom, algal area at Station 51 was typified by far fewer sponge, gorgonian, hard coral, and ascidian species than the live-bottom area at the same station (Table 5.14). Comparable numbers of algal species were collected in the two areas; the most notable difference was the presence of several more green algae, including *Caulerpa cupressoides*, *C. mexicana*, *C. prolifera*, *Halimeda gracilis*, *H. goreauii*, *Penicillus pyriformis*, and *P. dumentosus*, in the soft-bottom area. The seagrass *Halophila decipiens* was collected in all three dredge samples from the soft-bottom area but in only one of three from the live-bottom area. Cluster analysis revealed that the soft-bottom algal area was more similar in species composition to Station 47 (also a sparse live-bottom station) than to Station 51 or the other live-bottom stations (Figure 5.9). Species common to Station 47 and the algal area at Station 51 included the crustaceans *Iliacantha intermedia*, *Lobopilumnus agassizi*, *Portunus ordwayi*, and *Scyllarus chacei*; the echinoderms *Encope michelini* and *Ophiolepis elegans*; the scaphopod *Dentalium eboreum*; and the bryozoan *Cupuladria biporosa*.

At Station 52, Cruise III day and night dredge collections were similar in species richness (Table 5.14) and species composition (Figure 5.10). However, during Cruise II, fewer species were collected during the daytime, and the day and night catches did not cluster as closely as those from Cruise III (Figure 5.10). Some of the day/night difference is due to spatial variability and inadequate replication, as one would not expect diel differences in the availability of algae, bryozoans, corals, gorgonians, sponges, etc.; however, differences for some fish and crustacean collections could be attributable to diel activity patterns. Species collected in night dredge samples (at Station 52 and other stations) but not in day samples included the penaeids *Metapenaeopsis goodei*, *Sicyonia laevigatus*, and *S. typica*; the lesser sponge crab (decorator crab) *Dromidia antillensis*; the arrow crab

TABLE 5.14. TRIANGLE DREDGE DATA: COMPARISON OF NUMBERS OF SPECIES COLLECTED FROM LIVE-BOTTOM VS. ALGAL AREAS AT STATION 51 AND DURING DAY VS. NIGHT SAMPLING PERIODS AT STATION 52.

Group	Station 51		Station 52			
	Cruise II		Cruise II		Cruise III	
	Live-Bottom Area	Algal Area	Day	Night	Day	Night
Algae	20	24	7	14	11	16
Sponges	40	5	41	36	45	43
Hydrozoans	5	4	4	7	2	3
Gorgonians	5	0	9	8	10	9
Hard Corals	7	1	5	3	4	4
Molluscs	25	19	20	20	30	32
Crustaceans	34	30	21	31	25	28
Bryozoans	6	9	6	13	5	4
Echinoderms	7	7	8	6	9	9
Ascidians	17	1	16	12	14	10
Fishes	5	5	5	9	7	3
Other	3	1	1	2	1	1
TOTAL	174	106	143	161	163	162

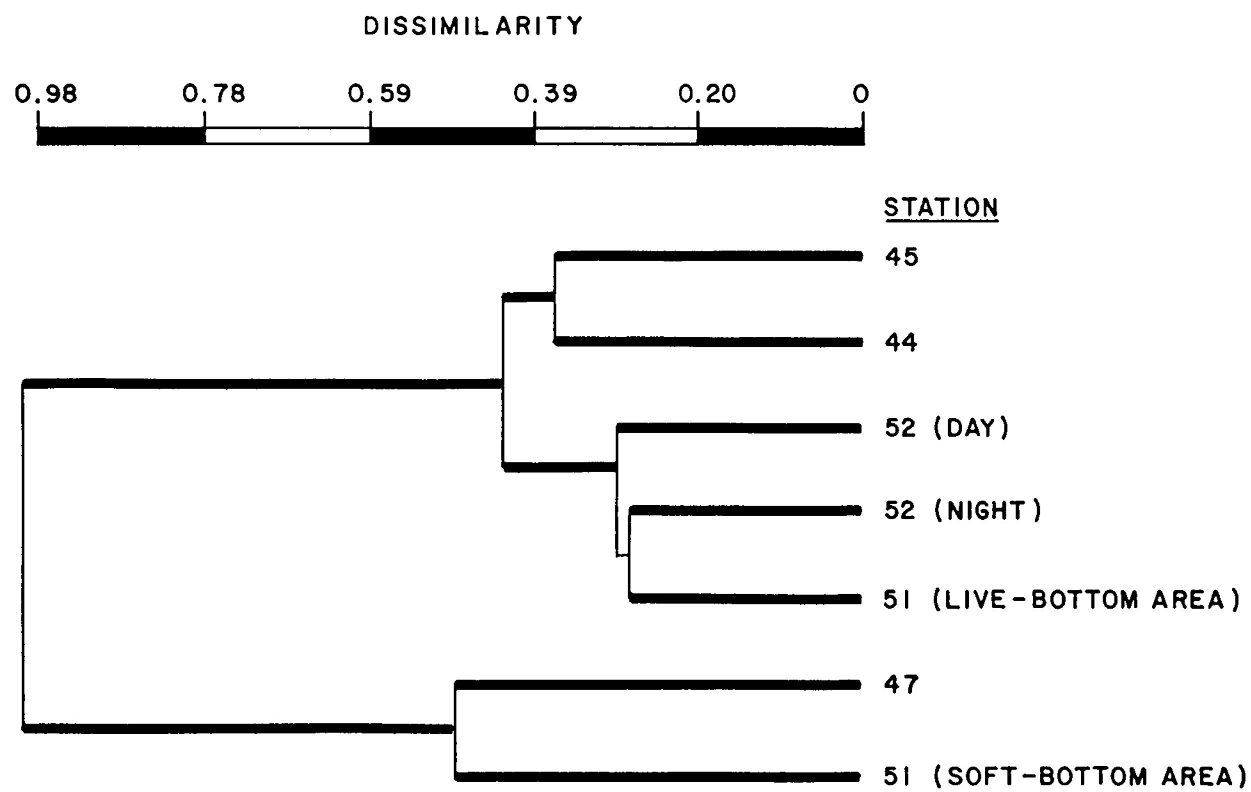
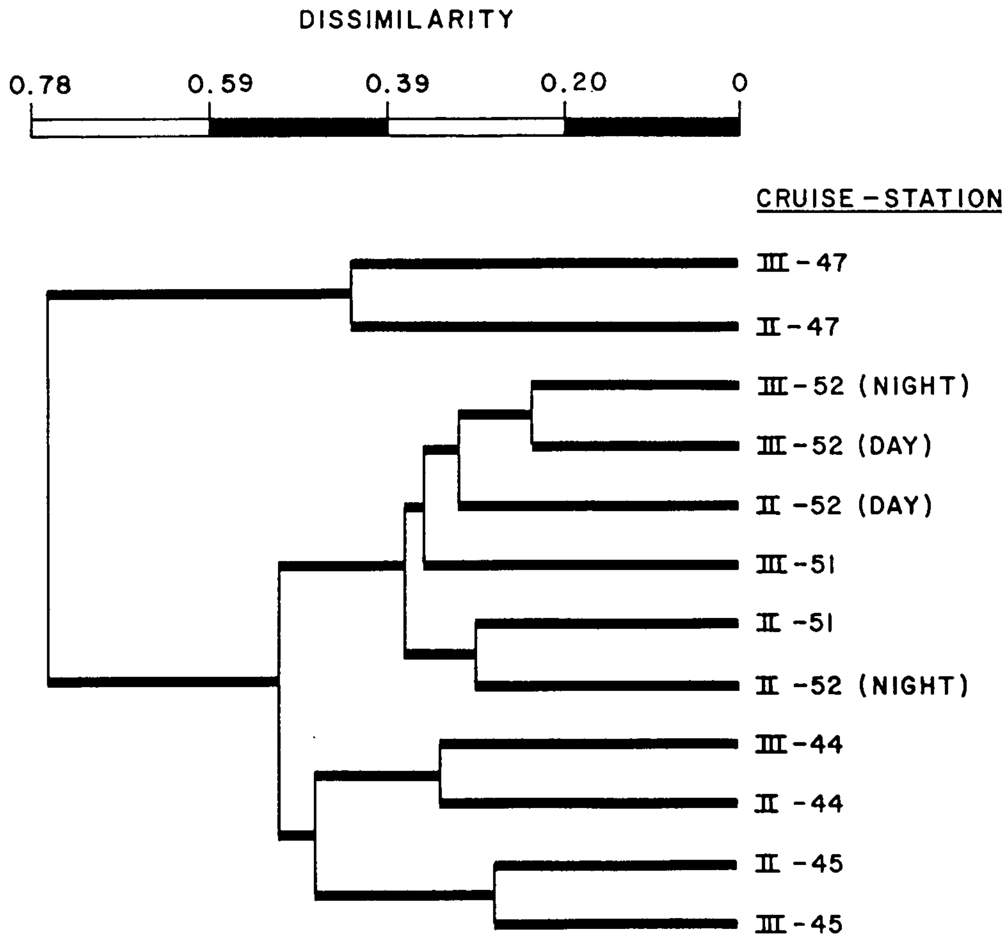


FIGURE 5.9. TRIANGLE DREDGE DATA, CRUISE II: CLUSTER ANALYSIS DENDROGRAM INCLUDING SOFT-BOTTOM ALGAL AREA AT STATION 51.



NOTE: STATION 51 DATA ARE FROM THE LIVE – BOTTOM AREA.

FIGURE 5.10. TRIANGLE DREDGE DATA, CRUISES II AND III: CLUSTER ANALYSIS DENDROGRAM INCLUDING DAY AND NIGHT SAMPLES AT STATION 52.

Stenorhynchus seticornis; the conch hermit crab Petrochirus diogenes; and the snapping shrimp Alpheus normanni. Too few fishes were collected by dredge to allow an evaluation of day/night differences for particular species.

5.3.4 Trawl Collections

Two hundred and eighty species were collected in otter trawl samples with sponges, fishes, crustaceans, algae, and molluscs contributing 19%, 18%, 18%, 10%, and 10% of the total, respectively (Table 5.15). About 60 to 70 species were collected from each station on each cruise, and about 100 species were collected from each of the four stations sampled on both cruises (Table 5.16). Species collected by trawl are listed in Appendix G.

The taxonomic composition of trawl catches differed among stations (Table 5.16). Only one bryozoan species and no algae were collected from Station 44, and few sponges were obtained from Station 47. Stations 44 and 47 exhibited a relatively high number of crustacean species. Stations 51 and 52 were characterized by more sponge and ascidian species but generally fewer fish species than the other stations.

Tables 5.17 and 5.18 list frequently collected species for each cruise, and Table 5.19 presents common species within major taxonomic groups for the overall (combined over cruises) data set.

Of 51 fish species collected by trawl, only 20 can be considered primary reef dwellers--fishes typically associated with reefs (Starck, 1968). The rest are secondary reef dwellers (species that are equally or more characteristic of non-reef habitats) or sand bottom dwellers. (Section 5.3.6 presents a complete listing with habitat affinities for each species). The list of frequently collected fishes includes both primary reef dwellers such as white grunt (Haemulon plumieri), jackknifefish (Equetus lanceolatus), and dusky cardinalfish (Phaeoptyx pigmentaria), as well as secondary reef dwellers such as scrawled cowfish (Lactophrys quadricornis), filefishes (Monacanthus ciliatus and M. hispidus), and bandtail puffer (Sphoeroides spengleri). The relatively large number of secondary reef dwellers and sand bottom species reflects the inherent difficulties of trawling in areas of dense live bottom; peripheral live-bottom areas and mixed live/soft bottom areas were the most successfully sampled by trawl. Primary reef species that were obtained by trawl included several (e.g., white grunt, dusky

TABLE 5.15. OTTER TRAWL DATA, CRUISES II AND III COMBINED: SPECIES RICHNESS.

Group	Total No. of Species Collected
ALGAE (total)	28
- green	8
- brown	4
- red	16
SEAGRASSES	1
SPONGES	52
CNIDARIANS	28
- hydrozoans	11
- gorgonians	13
- scleractinian corals	3
MOLLUSCS (total)	27
- gastropods	15
- bivalves	12
CRUSTACEANS (total)	49
- cirripedes	1
- decapods	47
- stomatopods	1
ECHINODERMS (total)	16
- asteroids	3
- echinoids	5
- holothuroids	1
- ophiuroids	7
BRYOZOANS	10
UROCHORDATES	17
FISHES	51
OTHER	1
TOTAL	280

Values represent numbers of species collected at Stations 44, 45 (Cruise II only), 47, 51 (including algal area sampled during Cruise II), and 52 (including both day and night samples from both cruises).

TABLE 5.16. OTTER TRAWL DATA: SPECIES RICHNESS BY STATION, CRUISE, AND TAXONOMIC GROUP.

	Station 44			Station 45	Station 47			Station 51 (LB)*			Station 52 (night)†		
Group	Cruise II	Cruise III	Both Cruises	Cruise II Only	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises
Algae	0	0	0	3	4	1	5	7	5	10	4	6	8
Sponges	14	18	23	20	4	14	14	22	26	33	22	18	29
Hydrozoans	3	1	3	1	3	4	6	1	3	3	2	2	4
Gorgonians	1	3	3	4	2	1	2	0	2	2	2	4	6
Hard Corals	0	1	1	0	0	0	0	0	0	0	1	0	1
Molluscs	1	0	1	8	7	2	8	6	7	12	2	3	4
Crustaceans	20	10	25	6	22	15	29	13	5	16	12	6	14
Bryozoans	1	0	1	2	3	2	4	3	3	4	2	4	4
Echinoderms	3	6	8	5	3	6	9	3	3	6	3	3	5
Ascidians	3	3	5	4	4	3	5	7	7	11	6	6	11
Fishes	12	16	22	13	9	25	27	10	9	15	14	5	14
Other	2	1	2	0	1	1	2	1	1	1	1	1	1
TOTAL	60	59	94	66	62	74	111	73	71	113	71	58	101

*At Station 51, trawl samples were collected in a live-bottom (LB) area and in a soft-bottom algal area during Cruise II. For purposes of inter-station comparisons, only the live-bottom data are included here.

†At Station 52, both day and night trawl samples were collected during both cruises. For purposes of inter-station comparisons, only the night data are included here.

TABLE 5.17. OTTER TRAWL DATA, CRUISE II: SPECIES COLLECTED IN 5 OR MORE OF 7 TOTAL TRAWL SAMPLES.

Species	No. of Trawls	No. of Stations
Campanularia marginata (Cn)	7	5
Monacanthus hispidus (F)	7	5
Lactophrys quadricornis (F)	6	5
Anthosigmella varians (S)	5	4
Cinachyra alloclada (S)	5	4
Geodia gibberosa (S)	5	4
Haliclona compressa (S)	5	4
Metapenaeopsis goodei (C)	5	4
Mithrax (Mithrax) pleuracanthus (C)	5	4
Paguristes tortugae (C)	5	4
Periclimenes longicaudatus (C)	5	4
Petrolisthes galathinus (C)	5	4
Phaeoptyx pigmentaria (F)	5	4
Podochela riisei (C)	5	4
Spirastrella sp. A (S)	5	4
Synalpheus townsendi (C)	5	4
Haemulon plumieri (F)	5	3
Sphoeroides spengleri (F)	5	3

Five live-bottom stations were sampled by trawl during Cruise II. One trawl sample was collected at each station except at Station 51, where an extra sample was obtained in a soft-bottom algal area, and at Station 52, where single day and night samples were collected.

C = crustacean
Cn = cnidarian
F = fish
S = sponge.

TABLE 5.18. OTTER TRAWL DATA, CRUISE III: SPECIES COLLECTED IN 4 OR MORE OF 5 TOTAL TRAWL SAMPLES.

Species	No. of Trawls	No. of Stations
Haliclona compressa (S)	5	4
Ircinia campana (S)	5	4
Lactophrys quadricornis (F)	5	4
Anthosigmella varians (S)	4	4
Campanularia marginata (Cn)	4	4
Haemulon plumieri (F)	4	4
Paguristes tortugae (C)	4	4
Arbacia punctulata (E)	4	3
Axinella bookhouti (S)	4	3
Carejoa riisei (Cn)	4	3
Cinachyra alloclada (S)	4	3
Epipolasis lithophaga (S)	4	3
Euryspongia rosea (S)	4	3
Microciona sp. A (S)	4	3
Petrolisthes galathinus (C)	4	3
Spheciospongia vesparium (S)	4	3
Styela plicata (U)	4	3

Four live-bottom stations were sampled by trawl during Cruise III (no trawl sample was obtained at Station 45). Single day and night samples were obtained at Station 52.

C = crustacean
Cn = cnidarian
E = echinoderm
F = fish
S = sponge
U = urochordate (ascidian).

TABLE 5.19. OTTER TRAWL DATA, CRUISES II AND III COMBINED: FREQUENTLY COLLECTED REPRESENTATIVES OF MAJOR TAXONOMIC GROUPS.

ALGAE		ECHINODERMS	
Dictyopteris jamaicensis	(7)	*Isostichopus badionotus*	(6)
Udotea conglutinata	(6)	*Arbacia punctulata*	(5)
Botryocladia occidentalis	(4)	*Ophiothrix angulata*	(5)
Halimeda incrassata	(3)	*Ophiothrix suensonii*	(4)
Halimeda scabra	(3)	*Astrophyton muricatum*	(3)
BRYOZOANS		**FISHES**	
Schizoporella unicornis	(7)	*Lactophrys quadricornis*	(11)
Celleporaria magnifica	(6)	*Haemulon plumieri*	(9)
Celleporaria albirostris	(4)	*Monacanthus hispidus*	(9)
Antropora tincta	(2)	*Equetus lanceolatus*	(7)
Cupuladria biporosa	(2)	*Phaeoptyx pigmentaria*	(7)
CNIDARIANS		**SPONGES**	
Campanularia marginata	(11)	*Haliclona compressa*	(10)
Carejoa riisei	(8)	*Anthosigmella varians*	(9)
Pseudopterogorgia acerosa	(6)	*Cinachyra alloclada*	(9)
Eudendrium carneum	(5)	*Ircinia campana*	(8)
Dyshasia digitalis	(4)	*Microciona* sp. A	(8)
CRUSTACEANS		**UROCHORDATES**	
Petrolisthes galathinus	(9)	*Clavelina gigantea*	(7)
Paguristes tortugae	(9)	*Clavelina picta*	(6)
Mithrax (Mithrax) pleuracanthus	(8)	*Didemnum candidum*	(6)
Metapenaeopsis goodei	(6)	*Styela plicata*	(5)
Pilumnus sayi	(6)	*Botrylloides nigrum*	(4)

Values in parentheses are number of trawl occurrences out of 12 possible.

cardinalfish) that forage away from dense live bottom during the night and consequently were susceptible to night trawling.

Cluster Analyses. Figure 5.11 summarizes cluster analysis results for Cruises II and III. During Cruise II, the two major groupings included Stations 44 and 47 on the one hand and Stations 51, 52, and 45 on the other. Station 45 was not sampled by trawl on Cruise III, but the station groupings otherwise appeared similar. Species characteristic of the cluster analysis station groupings are listed in Table 5.20.

Several of the species characteristic of Stations 44 and 47 are associated primarily with sand bottom--for example, fishes such as sand perch (Diplectrum formosum), barred searobin (Prionotus martis), and barbfish (Scorpaena brasiliensis), as well as the sand dollar Clypeaster subdepressus and the seastar Echinaster spinulosus. In contrast, species characteristic of Stations 45, 51, and 52 included more live-bottom types such as sponges, bryozoans, and primary or secondary reef fishes such as white grunt (Haemulon plumieri), cubbyu (Equetus umbrosus), hogfish (Lachnolaimus maximus), and bandtail puffer (Sphoeroides spengleri). Stations 45, 51, and 52 exhibited more live-bottom character than Stations 44 and 47.

Between-cruise differences in species composition were more pronounced in trawl than dredge data--a result due, in part, to the lack of trawl replication. The difference was greatest at Station 47 and least at Stations 44 and 51 (Figure 5.12). Contributing to the between-cruise species composition difference at Station 47 was the disparity in numbers of fish and sponge species captured on the two cruises (Table 5.16). Fishes collected at Station 47 during Cruise III but not Cruise II included the flounders Bothus robinsi and Symphurus urospilus; the sea robins Prionotus stearnsi and P. martens; and the haemulids Haemulon aurolineatum, H. plumieri, and the pigfish, Orthopristis chrysoptera. Except for H. aurolineatum and H. plumieri, these are sand bottom species. These data and the smaller number of sponge species collected during Cruise II suggest that a denser patch of live bottom was trawled during Cruise III at this station.

Selected Comparisons. Two sets of trawl samples were collected expressly for within-station comparisons. During Cruise II, an extra trawl sample was obtained at Station 51 in a soft-bottom algal area (in addition to the trawl from the live-bottom area). During both cruises,

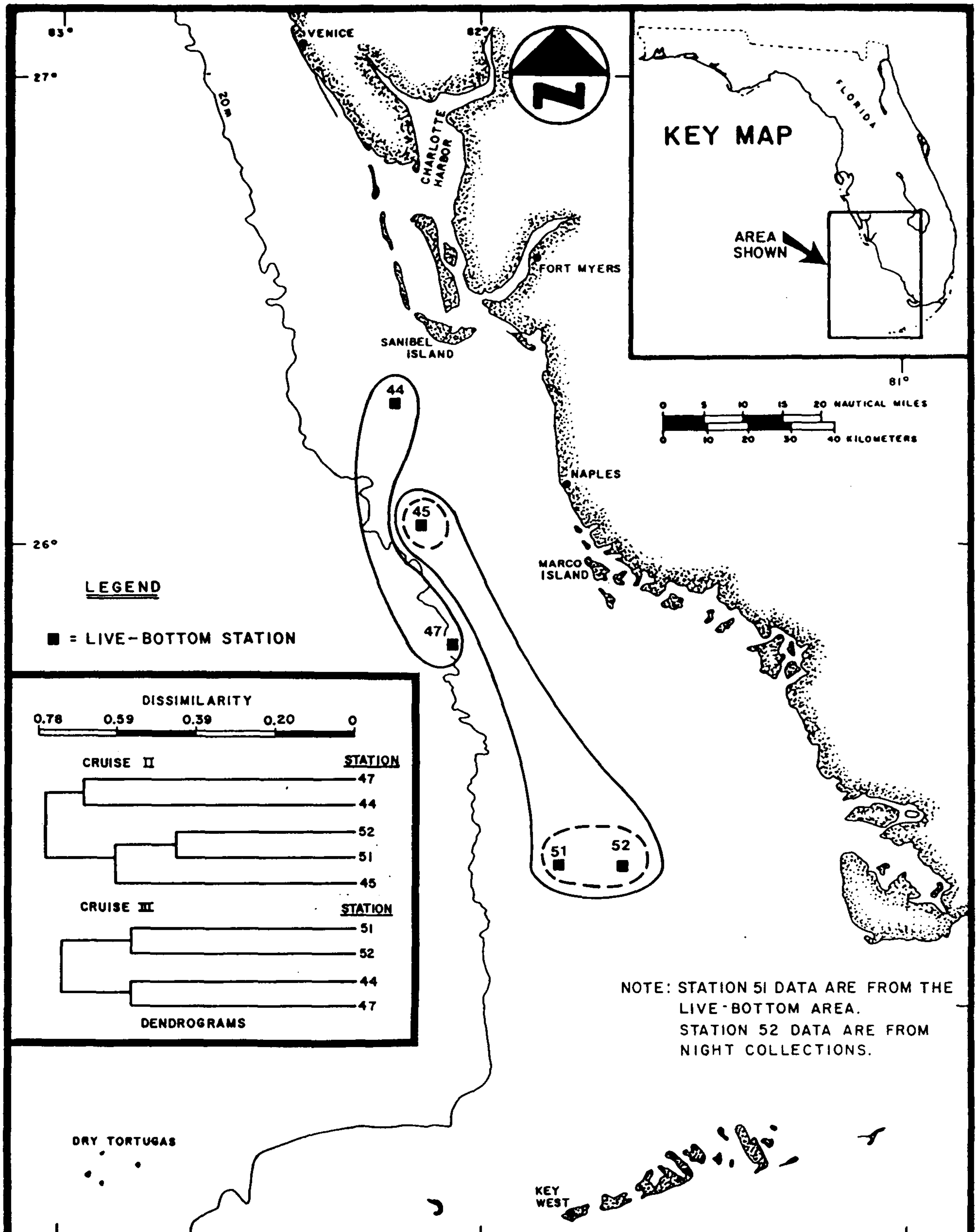


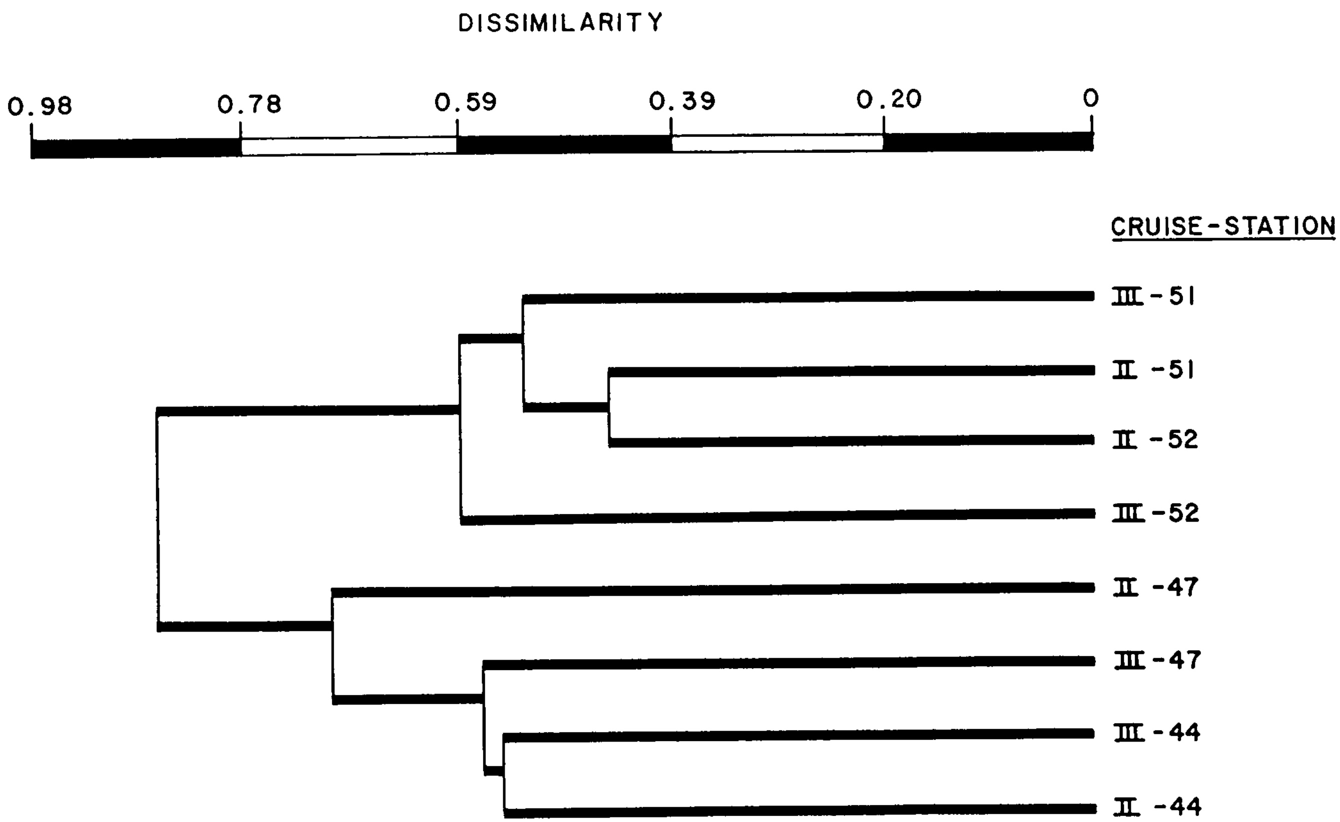
FIGURE 5.11. OTTER TRAWL DATA, CRUISES II AND III : CLUSTER ANALYSIS RESULTS.

TABLE 5.20. OTTER TRAWL DATA, CRUISES II AND III: SPECIES CHARACTERISTIC OF CLUSTER ANALYSIS STATION GROUPINGS.

Stations 44 and 47	Stations 45, 51, and 52
Aiolochroia crassa (S)	*Botryocladia occidentalis* (A)
Anoplodactylus insignis (P)	*Celleporaria magnifica* (B)
Clypeaster subdepressus (E)	*Chama macerophylla* (M)
Diplectrum formosum (F)	*Epipolasis lithophaga* (S)
Dromidia antillensis (C)	*Equetus umbrosus* (F)
Echinaster spinulosus (E)	*Haemulon plumieri* (F)
Lutjanus synagris (F)	*Ircinia strobilina* (S)
Metoporhaphis calcarata (C)	*Lachnolaimus maximus* (F)
Nicholsina usta (F)	*Placospongia melobesioides* (S)
Ophiolepis elegans (E)	*Schizoporella unicornis* (B)
Prionotus martis (F)	*Sphoeroides spengleri* (F)
Scorpaena brasiliensis (F)	
Stenorhynchus seticornis (C)	

Species listed are those having a high degree of fidelity (i.e., occurring primarily at stations in a group) and constancy (occurring at most or all stations in a group on each cruise) for particular station groupings.

A = alga
B = bryozoan
C = crustacean
E = echinoderm
F = fish
M = mollusc
P = pycnogonid
S = sponge.



NOTE: STATION 51 DATA ARE FROM THE LIVE-BOTTOM AREA.
STATION 52 DATA ARE FROM NIGHT COLLECTIONS.

FIGURE 5.12. OTTER TRAWL DATA, CRUISES II AND III: CLUSTER ANALYSIS DENDROGRAMS SHOWING BETWEEN-CRUISE DIFFERENCES IN SPECIES COMPOSITION.

day trawl collections were made at Station 52 for comparison with night trawl collections from the same station.

At Station 51, more species were collected from the live-bottom area than from the soft-bottom algal area (Table 5.21). No sponges were collected from the soft-bottom area, and more crustacean and ascidian species were obtained from the live-bottom area. Twice as many algal species were captured from the soft-bottom area. Algae collected only from the soft-bottom area were the green algae Caulerpa cupressoides v. flabellata, C. sertularioides, C. mexicana, C. prolifera, and Penicillus dumentosus; the brown alga Dictyota cervicornis; and the red algae Eucheuma isiforme, Jania capillacea, and Lithothamnium incertum. In addition, the seagrass Halophila decipiens was collected only from the soft-bottom area.

Cluster analysis results indicate trawl species composition at the soft-bottom area within Station 51 was more similar to that at Station 47 than to that at the other live-bottom stations (including Station 51) (Figure 5.13). Shared common species in the trawl collections from the soft-bottom area and Station 47 included the seagrass Halophila decipiens, the echinoderms Encope aberrans and Ophiolepis elegans, the red alga Jania capillacea, and the emerald parrotfish Nicholsina usta.

At Station 52, slightly more species were collected in day than night trawls on both cruises (Table 5.21). During Cruise II, the difference was primarily due to higher numbers of hydrozoans, gorgonians, and molluscs collected in the day trawl and is not likely to represent a real diel difference. The Cruise III difference reflected higher numbers of sponge species collected during the day--a result attributable to spatial variability within station rather than diel differences. No additional fish species were captured in day trawls. Day/night differences in species composition were less than between-station differences on each cruise (Figure 5.14).

Some day/night trawl catch differences may reflect diel activity patterns. During Cruise II, the penaeid shrimp Metapenaeopsis goodei was captured in night trawls at Stations 44, 47, and 51 (algal area); 15 individuals were also caught in the night trawl at Station 52, but none in the day trawl. White grunt (Haemulon plumieri) was captured in all night trawls during Cruise III but not in the Station 52 day trawl, and during Cruise II, the day catch (2 individuals) was much lower than the night catch (20 individuals) of this species. There were generally too

TABLE 5.21. COMPARISON OF NUMBERS OF SPECIES COLLECTED IN OTTER TRAWL SAMPLES FROM LIVE-BOTTOM VS. ALGAL AREAS AT STATION 51 AND DURING DAY VS. NIGHT SAMPLING PERIODS AT STATION 52.

	Station 51		Station 52			
	Cruise II		Cruise II		Cruise III	
Group	Live-Bottom Area	Algal Area	Day	Night	Day	Night
Algae	7	14	2	4	3	6
Sponges	22	0	22	22	28	18
Hydrozoans	1	2	4	2	3	2
Gorgonians	0	2	6	2	3	4
Hard Corals	0	0	1	1	2	0
Molluscs	6	1	8	2	7	3
Crustaceans	13	7	12	12	6	6
Bryozoans	3	2	3	2	1	4
Echinoderms	3	2	4	3	3	3
Ascidians	7	1	5	6	7	6
Fishes	10	17	10	14	3	5
Other	1	1	1	1	1	1
TOTAL	73	49	78	71	67	58

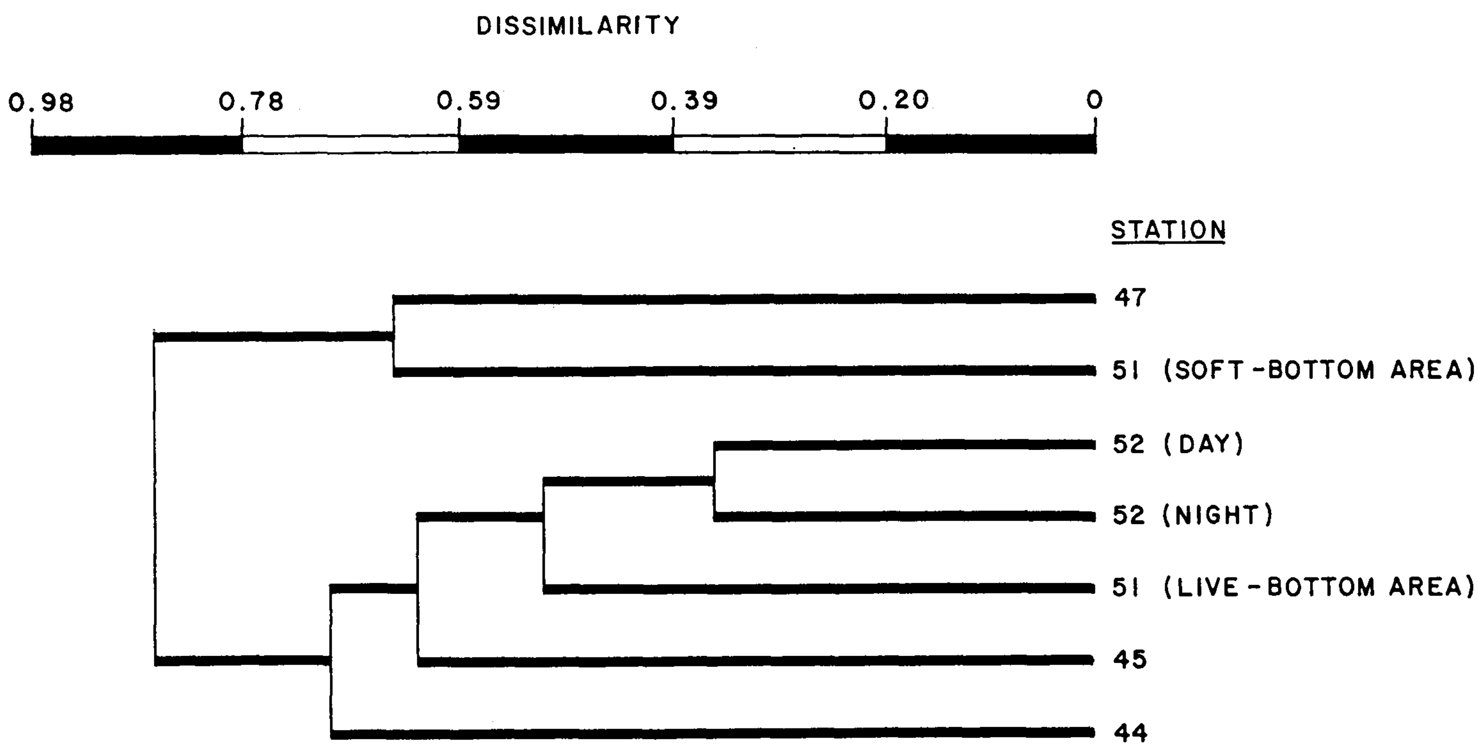


FIGURE 5.13. OTTER TRAWL DATA, CRUISE II: CLUSTER ANALYSIS DENDROGRAM INCLUDING SOFT-BOTTOM ALGAL AREA AT STATION 51.

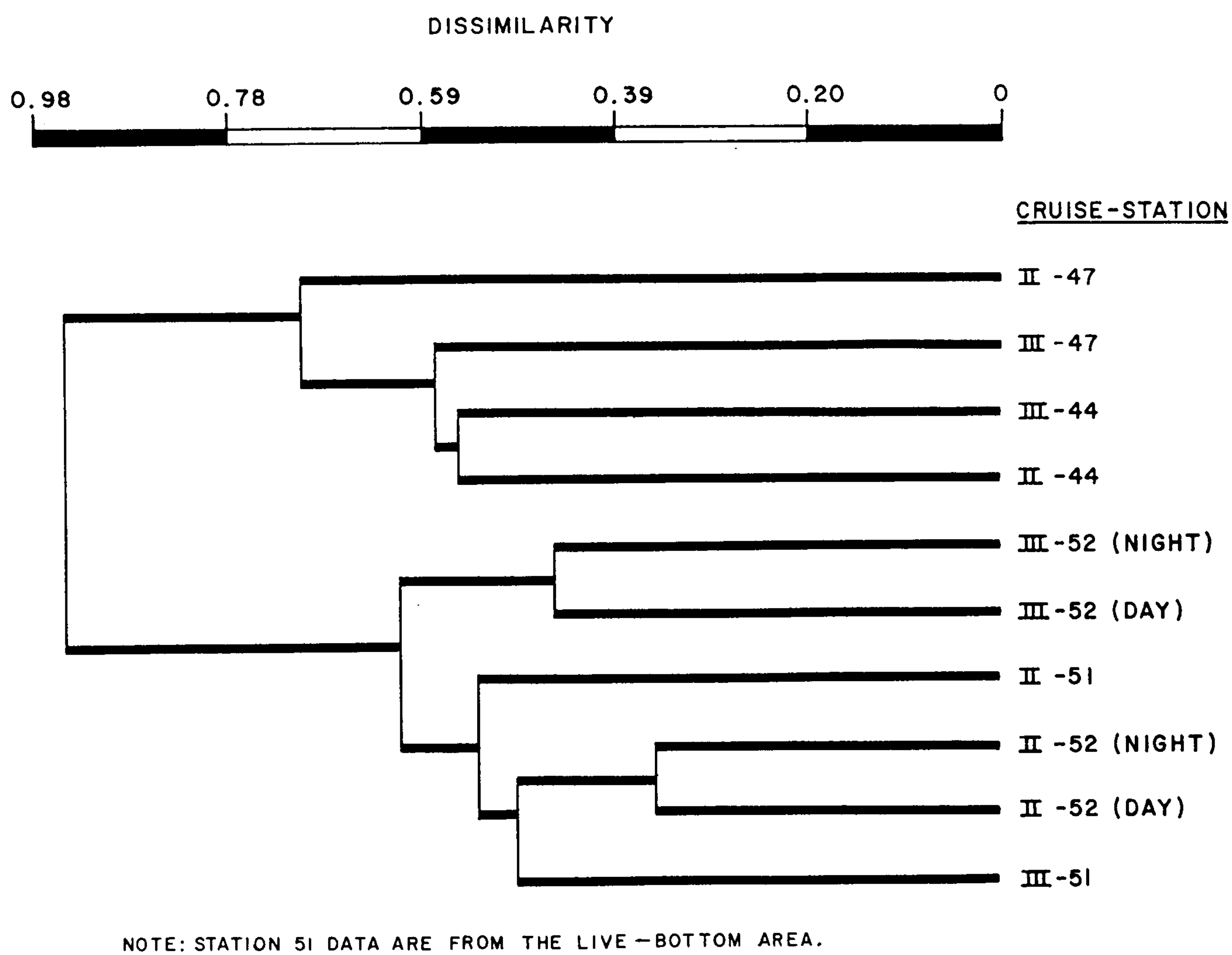


FIGURE 5.14. OTTER TRAWL DATA, CRUISES II AND III: CLUSTER ANALYSIS DENDROGRAM INCLUDING DAY AND NIGHT SAMPLES AT STATION 52.

few individuals of other species captured in a given trawl to allow an evaluation of diel differences.

5.3.5 Quadrat Collections and Diver Photography

Data from each diver-harvested quadrat consist of: (1) biomass measurements; (2) lists of taxa collected, including counts for molluscs, crustaceans, and echinoderms and frequency of occurrence for other groups; (3) percent cover estimates for various epibiota based on quantitative slide analysis; and (4) sediment thickness measurements.

Biomass. Table 5.22 presents the biomass data. Mean wet weight biomass per 0.5 m^2 quadrat ranged from 312 g (Station 47, Cruise II) to 2,162 g (Station 44, Cruise III), with an overall average of 1,051 g. The highest biomass (averaged over cruises) was at Stations 45 and 44 (1,374 and 1,373 g, respectively) and the lowest was at Station 47 (356 g).

Sponges were the primary biomass contributor at all stations on both cruises, averaging 58% of total biomass. Sponge biomass was >70% of the total at Stations 44 and 45, 50% to 70% of the total at Stations 51 and 52, and about 40% of the total at Station 45. Hard corals, bivalves, gorgonians, and (especially on Cruise II) algae were also significant contributors at most stations. Gorgonians contributed 22% to 23% of the total at Station 45. Ascidian and bryozoan biomass was significant at some stations (Table 5.22).

Total biomass values did not change consistently between cruises. The largest change was at Station 44, where much higher sponge, hard coral, and bivalve biomass was measured in the Cruise III quadrats. None of these groups is likely to exhibit dramatic seasonal changes in abundance, and the difference probably reflects spatial variability in density of epibiota within the station. Apparently, a denser patch of live bottom was sampled during Cruise III.

Algal biomass was much lower in the Cruise III quadrats than in those collected during Cruise II (Table 5.22). The difference was most marked at Stations 47, 51, and 52.

Species Richness and Composition. Table 5.23 lists numbers of species identified from quadrat collections. A total of 449 species were identified in all, with about 200 species identified from each station.

TABLE 5.22. QUADRAT BIOMASS DATA.

Group	Mean Biomass (g wet wt/0.5 m^2 quadrat)										
	Station 44 Cruise		Station 45 Cruise		Station 47 Cruise		Station 51 Cruise		Station 52 Cruise		
	II	III	II	III	II	III	II	III	II	III	Mean
Algae	44	19	64	34	31	7	173	42	178	42	63
Sponges	414	1,549	601	523	223	342	529	741	678	519	612
Hydrozoans	2	1	0	0	1	2	4	9	2	0	2
Gorgonians	16	9	328	288	23	34	41	36	54	42	87
Hard Corals	43	298	293	296	3	2	43	77	85	49	119
Bivalves	0	245	168	45	6	0	54	73	181	159	93
Gastropods	4	4	2	1	1	1	0	3	0	2	2
Crustaceans	3	2	1	3	1	1	7	2	1	1	2
Bryozoans	23	3	0	20	4	2	28	72	47	23	22
Echinoderms	27	6	44	16	10	3	0	0	14	4	12
Ascidians	8	26	16	6	7	4	48	32	126	86	36
Other	0	0	0	0	2	1	1	0	0	1	1
TOTAL	584	2,162	1,517	1,232	312	399	928	1,087	1,366	928	1,051
n*	37	35	35	35	44	35	35	35	37	42	

*Number of quadrats harvested.

TABLE 5.23. QUADRAT DATA: SPECIES RICHNESS BY STATION, CRUISE, AND TAXONOMIC GROUP.

Group	Station 44			Station 45			Station 47			Station 51			Station 52			All Stations
	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	Cruise II	Cruise III	Both Cruises	
Algae	5	12	14	21	29	42	24	18	34	15	32	37	18	23	32	80
Sponges	46	46	59	56	50	69	20	19	25	45	46	55	52	54	63	88
Hydrozoans	3	1	3	3	0	3	11	4	12	5	4	6	1	4	4	16
Gorgonians	10	9	13	14	16	18	9	9	11	6	8	9	8	9	13	22
Hard Corals	5	5	6	11	9	11	3	4	4	3	3	3	6	5	6	12
Molluscs	24	31	41	22	16	29	18	11	25	26	15	34	26	25	39	86
Crustaceans	24	18	31	20	10	22	21	10	25	25	14	27	18	16	23	56
Bryozoans	8	5	9	10	7	13	19	15	26	8	12	13	17	7	18	36
Echinoderms	8	9	11	7	10	11	7	5	8	6	6	7	9	6	9	18
Ascidians	8	18	20	13	10	16	8	5	9	17	13	19	20	18	23	27
Other	4	1	5	0	0	0	3	1	3	1	1	1	1	2	2	8
TOTAL	145	155	212	177	157	234	143	101	182	157	154	211	176	169	232	449
(n)*	(37)	(35)	(72)	(35)	(35)	(70)	(44)	(35)	(79)	(35)	(35)	(70)	(37)	(42)	(79)	(370)

*Number of quadrats harvested.

Species richness was highest at Stations 45 and 52, lowest at Station 47, and intermediate at Stations 44 and 51. Species collected in the quadrats are listed in Appendix H.

Sponges, molluscs, algae, and crustaceans were the most speciose groups in the quadrat collections, contributing 20%, 19%, 18%, and 12%, respectively, of the total (Table 5.23). Cnidarians (hydrozoans, gorgonians, and hard corals) contributed another 11%. Station 44 had far fewer algal species and slightly more crustacean and mollusc species than the other stations. Station 45 had the most sponge, algal, gorgonian, and hard coral species. Station 47 had more hydrozoan and bryozoan species and fewer sponge and ascidian species than the other stations.

There was no consistent (across stations) seasonal difference in total species richness in the quadrat collections. However, there were generally more algal species and fewer crustacean species in the Cruise III collections than in those from Cruise II (Table 5.23).

Tables 5.24 and 5.25 list the most frequently occurring species for each station/cruise. The most common species within major taxonomic groups for the combined data set (all stations/cruises) are listed in Table 5.26. The most frequently collected sessile epifauna were sponges (Cinachyra alloclada, Anthosigmella varians) and small hard corals (Phyllangia americana, Siderastrea radians). Common motile epifauna included brittle stars (especially Ophiothrix angulata), crabs (Petrolisthes galathinus, Paguristes tortugae, Mithrax spp.), and snapping shrimp (Synalpheus spp.).

Table 5.27 lists the most abundant non-colonial organisms in the quadrat collections (individual molluscs, crustaceans, and echinoderms were counted, whereas specimens of other groups were not generally amenable to counts). Abundant species included the brittle stars Ophiothrix suensonii and O. angulata, the bivalves Chama macerophylla and Arca zebra, and the porcellanid crab Petrolisthes galathinus.

Figure 5.15 shows results of cluster analysis conducted using combined Cruise II and III data (all biota). Station 47 was dissimilar to the other stations in species composition; among the remaining four, Stations 51 and 52 were very similar to each other. Examination of two-way occurrence tables reveals that the distinctiveness of Station 47 in the cluster analysis reflects partly the presence there of numerous species not collected elsewhere, including the algae Caulerpa

TABLE 5.24. QUADRAT DATA, CRUISE II: SPECIES COLLECTED IN 50 OR MORE OF 188 TOTAL QUADRATS.

Species	No. of Quadrats	No. of Stations
Cinachyra alloclada (S)	122	5
Anthosigmella varians (S)	78	5
Amathia convoluta (B)	74	5
Dictyopteris jamaicensis (A)	69	3
Epipolasis lithophaga (S)	64	5
Ophiothrix angulata (E)	64	5
Siderastrea radians (Cn)	64	5
Phyllangia americana (Cn)	58	4
Pseudopterogorgia acerosa (Cn)	57	4
Spirastrella sp. A (S)	57	4
Geodia gibberosa (S)	52	5
Placospongia melobesioides (S)	52	3
Haliclona compressa (S)	51	5

A = alga
B = bryozoan
Cn = cnidarian
E = echinoderm
S = sponge.

TABLE 5.25. QUADRAT DATA, CRUISE III: SPECIES COLLECTED IN 50 OR MORE OF 182 TOTAL QUADRATS.

Species	No. of Quadrats	No. of Stations
Cinachyra alloclada (S)	137	5
Udotea conglutinata (A)	101	5
Phyllangia americana (Cn)	84	5
Placospongia melobesioides (S)	82	4
Anthosigmella varians (S)	79	5
Geodia gibberosa (S)	74	5
Dictyopteris jamaicensis (A)	72	4
Spirastrella sp. A (S)	67	4
Ophiothrix angulata (E)	65	5
Pseudaxinella lunaecharta (S)	63	5
Epipolasis lithophaga (S)	60	5
Siderastrea radians (Cn)	60	5
Celleporaria albirostris (B)	59	4
Keratosa sp. A (S)	56	4
Chama macerophylla (M)	51	4
Cladocora arbuscula (Cn)	50	4

A = alga
B = bryozoan
Cn = cnidarian
E = echinoderm
M = mollusc
S = sponge.

TABLE 5.26. QUADRAT DATA, CRUISES II AND III COMBINED: FREQUENTLY COLLECTED REPRESENTATIVES OF MAJOR TAXONOMIC GROUPS.

ALGAE		**CRUSTACEANS**	
Dictyopteris jamaicensis	(141)	Petrolisthes galathinus	(76)
Udotea conglutinata	(129)	Synalpheus townsendi	(46)
Halimeda scabra	(74)	Paguristes tortugae	(41)
Lithophyllum bermudense	(55)	Mithrax (Mithrax) pleuracanthus	(40)
Botryocladia occidentalis	(55)	Pilumnus sayi	(40)
ASCIDIANS		**ECHINODERMS**	
Cystodytes dellechiajei	(90)	Ophiothrix angulata	(129)
Didemnum candidum	(71)	Ophiothrix suensonii	(59)
Polycarpa circumarata	(48)	Ophiactis mulleri	(48)
Clavelina gigantea	(35)	Ophiostigma isocantha	(24)
Clavelina picta	(31)	Astrophyton muricatum	(23)
BRYOZOANS		**MOLLUSCS**	
Amathia convoluta	(96)	Chama macerophylla	(96)
Schizoporella unicornis	(93)	Crepidula aculeata	(67)
Celleporaria albirostris	(85)	Arca zebra	(51)
Stylopoma spongites	(81)	Cerithium atratum	(19)
Celleporaria magnifica	(60)	Chicoreus florifer	(19)
CNIDARIANS		**SPONGES**	
Phyllangia americana	(142)	Cinachyra alloclada	(259)
Siderastrea radians	(124)	Anthosigmella varians	(157)
Pseudopterogorgia acerosa	(96)	Placospongia melobesioides	(133)
Cladocora arbuscula	(87)	Geodia gibberosa	(126)
Campanularia marginata	(81)	Spirastrella sp. A	(124)

Values in parentheses are numbers of quadrats in which the species was collected, out of 369 total.

TABLE 5.27. ABUNDANT MOLLUSCS, CRUSTACEANS, AND ECHINODERMS IN THE QUADRAT COLLECTIONS.

Cruise	Station	Species	Abundance
II	44	Ophiothrix angulata (E)	1.94
		Ophiothrix suensonii (E)	1.31
		Cerithium atratum (M)	1.17
		Crepidula aculeata (M)	0.71
		Petrolisthes galathinus (C)	0.63
		Ophiactis mulleri (E)	0.57
	45	Ophiothrix suensonii (E)	1.57
		Arca zebra (M)	0.80
		Lopha frons (M)	0.80
		Chama macerophylla (M)	0.71
		Mithrax (Mithraculus) forceps (C)	0.69
		Synalpheus ?tanneri (C)	0.66
		Ophiactis mulleri (E)	0.60
	47	(none)	
	51	Petrolisthes galathinus (C)	0.71
		Chama macerophylla (M)	0.54
		Pinctada imbricata (M)	0.51
	52	Ophiothrix angulata (E)	0.77
		Chama macerophylla (M)	0.74
		Crepidula aculeata (M)	0.66
III	44	Petrolisthes galathinus (C)	1.43
		Ophiothrix angulata (E)	1.40
		Chama macerophylla (M)	1.31
		Arca zebra (M)	1.14
		Crepidula aculeata (M)	0.94
		Pilumnus dasypodus (C)	0.74
		Synalpheus townsendi (C)	0.74
		Megalobrachium soriatum (C)	0.69
	45	Ophiothrix suensonii (E)	3.77
		Conopea merrilli (C)	1.60
		Ophiothrix angulata (E)	0.74
	47	Astrophyton muricatum (E)	1.43
	51	Chama macerophylla (M)	0.54
	52	Chama macerophylla (M)	1.07
		Ophiothrix angulata (E)	0.71

Species listed are those having a mean abundance $\geq$0.5 individuals per 0.5 m^2 quadrat. Abundance values are mean number of individuals per quadrat.

C = crustacean
E = echinoderm
M = mollusc.

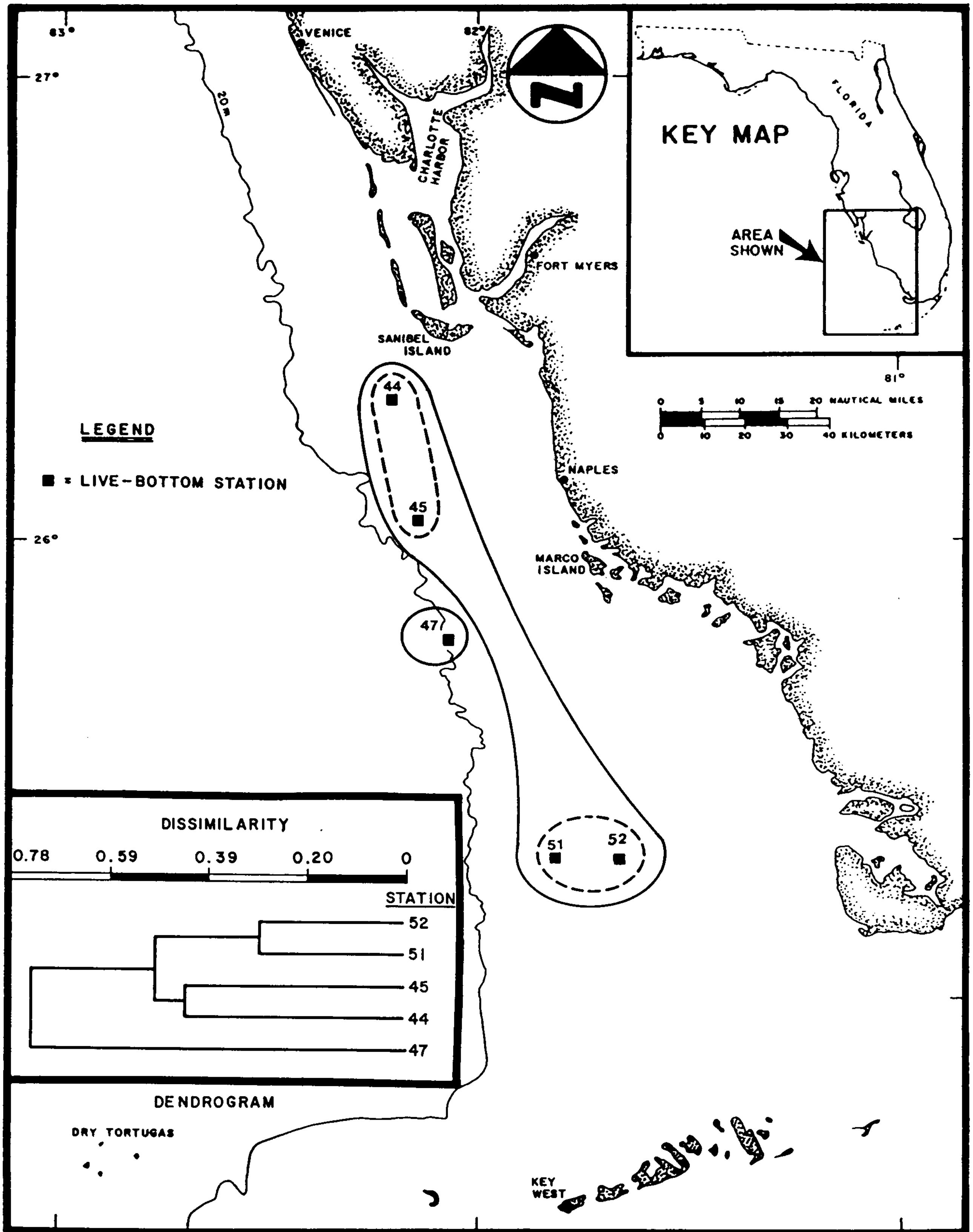


FIGURE 5.15. QUADRAT DATA, CRUISES II AND III COMBINED: CLUSTER ANALYSIS RESULTS.

sertularioides, Udotea cyathiformis, Sargassum filipendula, and Dictyota cervicornis; the gorgonian Lophogorgia cardinalis; hydroids, Synthecium spp.; and the hemichordate (pterobranch) Rhabdopleura compacta. The seagrass Halophila decipiens was also collected only at this station. In addition, species common to several stations generally had a low frequency of occurrence at Station 47. Species collected only at Stations 51 and 52 include the red alga Chondria polyrhiza; the hydroid Dyshasia digitalis; the sponges Haliclona sp. F and Myrmekioderma sp. A; and the decapod Mithrax (Mithrax) hispidus. In addition, the brown alga Dictyopteris jamaicensis was collected in about 90% of the quadrats from these two stations but only rarely collected elsewhere. Table 5.28 summarizes species characteristic of cluster analysis station groupings.

Though not emerging as distinct in the cluster analysis (which included representatives of all phyletic groups), Station 45 clearly exhibited the most well-developed assemblage of hard corals and gorgonians. Hard corals collected only at Station 45 were Isophyllia sinuosa, Porites branneri, P. porites, P. porites divaricata, and Stephanocoenia michelinii (Appendix H). Among the gorgonians, few were collected only at Station 45; however, Muricea elongata, M. laxa, and Pterogorgia guadalupensis were far more frequently collected at Station 45 than at any other station.

Figure 5.16 shows the dendrogram from cluster analysis conducted using each station/cruise as a separate entity. Results indicate that between-cruise variability in species composition was less than between-station variability. The degree of between-cruise difference in species composition was lowest at Stations 51 and 52 and highest at Station 44 Examination of two-way occurrence tables indicates the apparent seasonality at Station 44 reflects differences in frequency of occurrence rather than presence/absence for most species. The Cruise III samples from Station 44 were apparently collected from a denser patch of live bottom than that sampled during Cruise II (see Biomass results).

Diver Photography. Table 5.29 summarizes quadrat photograph QSA results. Mean percent cover ranged from 10.6% to 44.8%, with gorgonians, sponges, and algae the major cover contributors. Station 45 had dense cover (about 40%) on both cruises, with gorgonians contributing two thirds of the total in each case. Dense biotic cover was also noted at Stations 51 and 52 during Cruise II, primarily due to the abundance of the red alga Dictyopteris jamaicensis; algae were much less abundant in the Cruise III photographs at Station 51 (no quadrat photographs were

TABLE 5.28. QUADRAT DATA, CRUISES II AND III: SPECIES CHARACTERISTIC OF CLUSTER ANALYSIS STATION GROUPINGS.

MAJOR CLUSTERS:

Station 47

Astrophyton muricatum (E)
Lophogorgia cardinalis (Cn)
Podochela riisei (C)
Udotea cyathiformis (A)

Stations 44, 45, 51 and 52

Celleporaria magnifica (B)
Chama macerophylla (M)
Euryspongea rosea (S)
Ircinia campana (S)
Ircinia strobilina (S)
Keratosa sp. A (S)
Lithophyllum bermudense (A)
Microciona sp. B (S)
Placospongia melobesioides (S)

MINOR CLUSTERS:

Stations 44 and 45

Cladocora arbuscula (Cn)
Diodora listeri (M)
Diodora sayi (M)
Manicina areolata (Cn)
Microciona sp. D (S)
Rhizochalina oleracea (S)
Spirastrella sp. A (S)

Stations 51 and 52

Chondria polyrhiza (A)
Dictyopteris jamaicensis (A)
Dyshasia digitalis (Cn)
Haliclona sp. F (S)
Mithrax (Mithrax) hispidus (C)
Myrmekioderma sp. A (S)

Species listed are those having a high degree of fidelity (i.e., occurring primarily at stations in the group) and constantly (occurring at most or all stations in a group on each cruise) for particular station groupings.

A = alga
B = bryozoan
C = crustacean
Cn = cnidarian
E = echinoderm
M = mollusc
S = sponge.

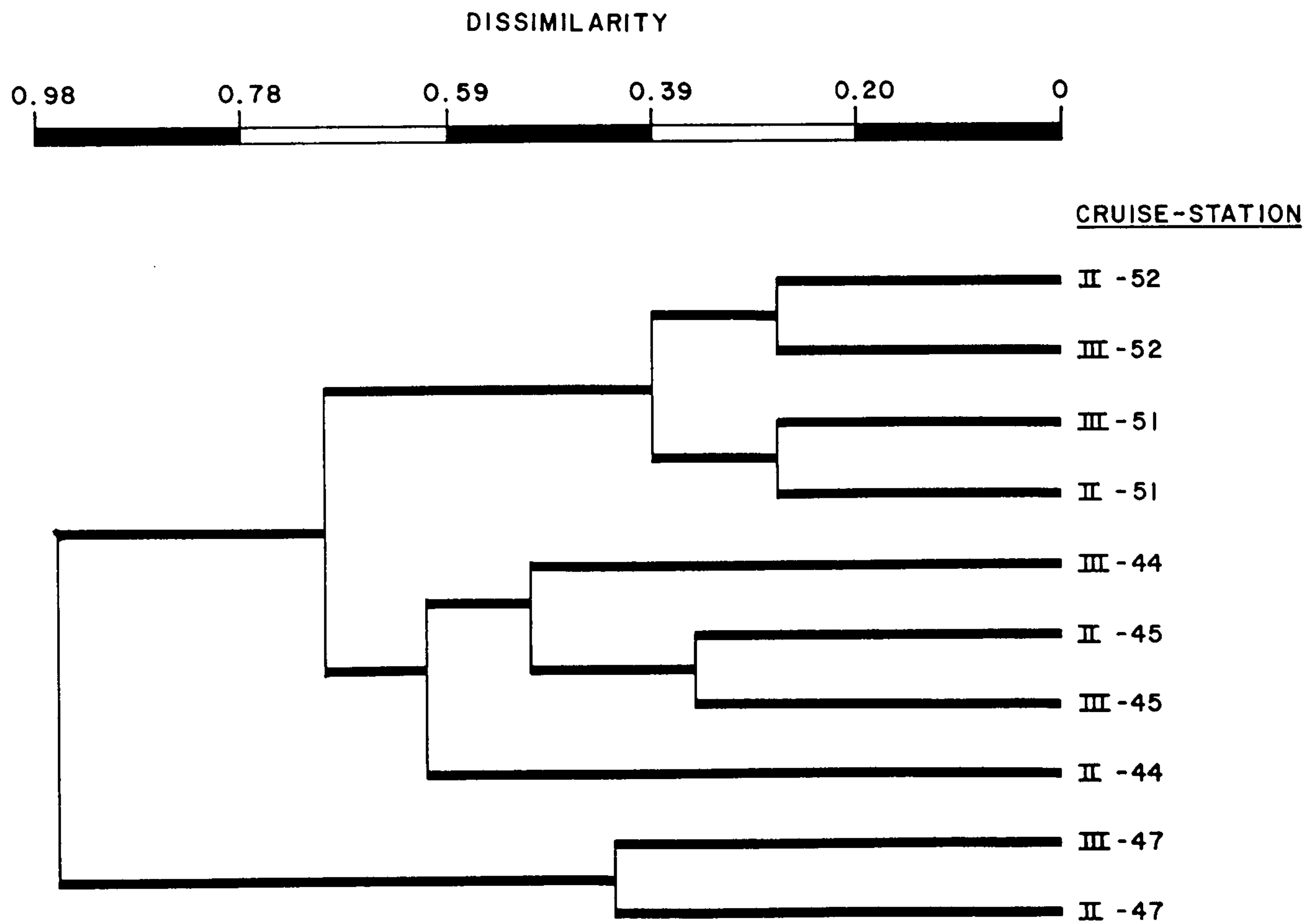


FIGURE 5.16. QUADRAT DATA, CRUISES II AND III: CLUSTER ANALYSIS DENDROGRAM SHOWING BETWEEN-CRUISE DIFFERENCES IN SPECIES COMPOSITION.

TABLE 5.29. PERCENT COVER SUMMARY BASED ON QUANTITATIVE SLIDE ANALYSIS OF STILL PHOTOGRAPHS TAKEN BY DIVERS PRIOR TO QUADRAT HARVESTING.

Group	Cruise II Stations					Cruise III Stations				
	44	45	47	51	52	44	45	47	51	52*
Algae	1.7	1.5	0.4	35.2	32.0	0.8	2.9	0.9	4.9	--
Sponges	4.6	6.9	2.3	3.6	5.0	20.2	4.2	2.8	5.8	--
Hydrozoans	0.0	0.2	0.3	1.5	0.0	0.0	0.2	1.8	1.8	--
Gorgonians	1.8	28.8	8.0	1.7	1.8	0.3	26.5	8.6	1.8	--
Hard Corals	0.2	2.1	0.0	0.1	0.3	0.4	0.9	0.1	0.3	--
Bryozoans	0.4	0.1	0.0	0.0	0.0	0.1	0.2	0.3	0.4	--
Echinoderms	0.3	2.6	0.3	0.0	0.0	0.5	0.9	0.0	0.0	--
Ascidians	0.0	0.0	0.0	0.3	0.2	0.0	0.1	0.1	0.0	--
Other	1.6	1.0	3.2	1.6	5.5	7.5	3.8	0.8	3.0	--
TOTAL BIOTA	10.6	43.2	14.5	44.0	44.8	29.8	39.7	15.4	18.0	--

*No quadrat photographs were taken at Station 52 on Cruise III due to high near-bottom turbidity.

taken at Station 52 due to low visibility). Consistently low values (about 15%) were noted at Station 47, with gorgonians also accounting for over 50% of total biotic cover there. Sparse cover was also noted at Station 44 during Cruise II, but cover was three times higher on Cruise III--reflecting a large difference in sponge cover between cruises.

Quadrat photograph QSA provides percent cover estimates for epibiota within live-bottom patches sampled on each cruise; thus, the data do not necessarily agree with QSA data from the television/still camera tow, which encompassed a much greater area. Comparison of remote and quadrat photographic data (Table 5.30) illustrates this point. Percent cover estimates for Stations 45, 47, 51, and 52 generally were in agreement based on the two data sets. However, at Station 44, percent cover in the photographic quadrats was somewhat lower than overall cover (remote photographs) during Cruise II and higher than overall cover during Cruise III. This suggests a relatively sparse live-bottom patch was sampled during Cruise II and a relatively dense patch was sampled during Cruise III.

Table 5.30 also lists the percentage of total biotic cover identified to species for both remote and quadrat photographs. The remote QSA was able to identify about 25% to 45% of total cover to species; exceptionally high values for Stations 51 and 52 on Cruise II reflect the predominance of a single algal species, Dictyopteris jamaicensis. QSA of quadrat photographs was able to identify a larger percentage of total cover to species in most cases. The improvement is attributable to more favorable photographic conditions (consistent height, light, and camera angle) for the quadrat photography.

Table 5.31 shows data from line-intercept analysis of transect photographs. Because the transect photographs were taken in the same vicinity as the quadrat photographs, the two data sets should be comparable. However, comparison of Tables 5.29, 5.30, and 5.31 shows that the line-intercept results do not agree as closely with the quadrat QSA results as the latter do with remote QSA results. For Station 45, total biotic cover estimates agreed well by the two diver photographic methods, but the relative contribution of gorgonians was lower by the line-intercept method. Station 47 results were in agreement for Cruise II but not for Cruise III. The largest discrepancy between the methods was at Station 51, Cruise II, where higher sponge and algal cover values by line-intercept contributed to a much higher total cover value (60% by

TABLE 5.30. COMPARISON OF REMOTE AND IN SITU (QUADRAT) PHOTOGRAPHY RESULTS.

Station	Mean Percent Biotic Cover		Percent of Total Biotic Cover Identified to Species	
	Remote Photographs	Quadrat Photographs	Remote Photographs	Quadrat Photographs
CRUISE II:				
44	18.3	10.6	44	50
45	41.0	43.2	35	67
47	17.3	14.5	26	33
51	48.8	44.0	81	95
52	39.1	44.8	82	85
CRUISE III:				
44	14.7	29.8	45	66
45	39.0	39.7	30	24
47	20.8	15.4	33	31
51	20.7	18.0	31	60
52	ND*	ND†	ND*	ND†

*No daytime photographs analyzed (too turbid).
†No quadrat photographs taken (too turbid).

TABLE 5.31. PERCENT COVER ESTIMATES FROM LINE-INTERCEPT ANALYSIS OF TRANSECT PHOTOGRAPHS.

Group	Cruise II Stations					Cruise III Stations				
	44*	45	47	51	52	44*	45	47	51	52†
Algae	--	0.2	0.0	43.1	37.5	--	2.7	0.7	3.8	--
Sponges	--	11.2	0.0	13.5	5.4	--	6.9	0.2	6.1	--
Gorgonians	--	24.2	12.0	0.0	0.0	--	19.6	2.6	0.1	--
Hard Corals	--	2.4	0.4	0.3	0.0	--	1.1	0.0	0.8	--
Unidentified	--	7.4	2.6	2.8	5.4	--	10.0	1.2	7.7	--
Other	--	0.9	0.3	0.4	2.0	--	1.3	1.1	4.5	--
TOTAL BIOTA	--	46.3	15.3	60.1	50.3	--	41.6	5.8	23.0	--

*No transect photographs taken at Station 44.
†No transect photographs taken (too turbid).

line-intercept vs. 44% by QSA). Cruise III results for Station 51 and Cruise II results for Station 52 showed general agreement between the two methods, with the line-intercept technique producing slightly higher cover estimates.

Sediment Thickness. Table 5.32 summarizes quadrat sediment thickness values. The individual thickness measurements ranged from 0 to 18 cm, and the average thickness per quadrat ranged from 0 to 14.3 cm. Mean sediment thickness was highest at Station 47 and lowest at Station 45; the rank order of stations was identical on the two cruises. Sediment thicknesses were greater during Cruise III than Cruise II at all stations.

Data were plotted and regression analyses were performed in order to discern possible relationships between sediment thickness and biomass or percent cover. Both within- and between-station analyses were conducted using the following subsets of biomass and cover data:

1) All groups (total biotic cover, total biomass).
2) Algae.
3) Non-algae.
4) Seagrass (Station 47 biomass only).
5) Sponges.
6) Hard corals.
7) Gorgonians.
8) Bivalves (biomass only).
9) Bryozoans (biomass only).
10) Ascidians (biomass only).

In most cases, a simple, linear regression was performed using untransformed data. For some of the between-station analyses where a nonlinear relationship was apparent, several transformations [natural log, square root, and reciprocal of (x) and/or (y) variables] were tried and the one producing the best fit is presented below.

Within-station analyses showed there was no consistent relationship between sediment thickness and percent cover or biomass for any phyletic group at any station on either cruise. Examination of scatter plots did not reveal any noticeable trends, and the overwhelming majority of the (linear) regressions were not significant. Three of 80 biomass regressions and four of 61 cover regressions were significant at $p<0.05$, but they were about evenly divisible into those with positive and

TABLE 5.32. SEDIMENT THICKNESS VALUES.

Station	Sediment Thickness (cm) Overall Mean ± SD (n)*	Range (quadrat means)	Range (individual measurements)
CRUISE II:			
44	1.41 ±1.03 (37)	0.0 - 4.67	0.0 - 12.0
45	0.57 ±0.49 (34)	0.0 - 2.0	0.0 - 5.0
47	3.98 ±2.07 (44)	1.0 - 8.67	0.0 - 14.0
51	2.67 ±1.57 (35)	0.0 - 8.00	0.0 - 15.0
52	2.86 ±1.24 (37)	0.17 - 5.67	0.0 - 10.0
CRUISE III:			
44	1.93 ±1.77 (27)	0.0 - 6.67	0.0 - 12.0
45	1.58 ±1.55 (35)	0.0 - 6.0	0.0 - 13.0
47	5.23 ±1.83 (36)	1.0 - 8.0	0.0 - 18.0
51	3.81 ±2.77 (35)	0.67 - 14.33	0.0 - 18.0
52	4.26 ±2.02 (42)	0.0 - 9.0	0.0 - 16.0

*Three sediment thickness measurements were made in each of (n) quadrats. Means were calculated for each quadrat, and these values were then used to calculate overall mean and standard deviation (SD).

negative slopes. When a large number of analyses is performed, some significant regressions are expected due to chance.

Results of the between-station regression analyses are summarized in Tables 5.33 (biomass) and 5.34 (cover) and discussed below.

Sponge cover decreased significantly with increasing sediment thickness on Cruise II. Negative (but not significant) trends were evident in Cruise III cover data and in biomass data from both cruises (Figure 5.17).

Hard coral biomass showed significant negative relationships to sediment thickness during both cruises. The Cruise II relationship appeared to be nonlinear (Figure 5.18), and a reciprocal transformation of the sediment thickness values produced the best fit; the relationship appeared to be linear for Cruise III biomass data. Cover values from both cruises were negatively, nonlinearly related to sediment thickness values, with the reciprocal transformation producing the best fit. The Cruise II cover vs. sediment thickness relationship was highly significant, whereas that for Cruise III was not.

Gorgonian biomass and cover values exhibited significant negative relationships to sediment thickness on Cruise II but not on Cruise III (Figure 5.19). In all cases, the reciprocal transformation produced the best fit. The extraordinarily high gorgonian biomass at Station 45 (where the sand veneer was thinnest) clearly dominated the relationship; little or no trend was evident among the other stations.

There was no discernible relationship across stations between mean algal cover or biomass and mean sediment thickness on either cruise. Likewise, bivalve, bryozoan, and ascidian biomass and cover did not appear to vary in relation to sediment thickness.

Total biomass and total biotic cover were negatively related to sediment thickness during Cruise III, but only the cover vs. sediment thickness relationship was statistically significant (Figure 5.20). Little or no trend was evident in the Cruise II data (Figure 5.20). Exclusion of algae, which were the dominant cover and biomass contributors at Stations 51 and 52, improved the fit for the Cruise II data (Figure 5.21); the relationship between non-algal cover and sediment thickness was statistically significant.

TABLE 5.33. RESULTS OF BETWEEN-STATION REGRESSION ANALYSES RELATING SEDIMENT THICKNESS AND BIOMASS.

Response Variable	Best-Fit Model	Slope (b)	Intercept (a)	r^2	t-value (degrees of freedom)	Probability Level
CRUISE II:						
Total biomass	y = a + bx	-425.70	2861.06	0.31	1.16(3)	>0.10
Algal biomass	y = a + bx	18.95	152.46	0.03	0.31(3)	>0.10
Non-algal biomass	y = a + bx	-444.65	2708.61	0.38	1.37(3)	>0.10
Sponge biomass	y = a + bx	-128.44	1273.15	0.23	0.95(3)	>0.10
Gorgonian biomass	y = a + b(1/x)	401.05	-91.05	0.88	4.73(3)	<0.05*
Hard coral biomass	y = a + b(1/x)	350.27	-54.12	0.89	4.91(3)	<0.05*
Bivalve biomass	y = a + bx	-44.89	266.75	0.12	0.63(3)	>0.10
Bryozoan biomass	y = a + bx	6.56	25.74	0.05	0.41(3)	>0.10
Ascidian biomass	y = a + bx	18.61	39.22	0.06	0.44(3)	>0.10
CRUISE III:						
Total biomass	y = a + bx	-663.55	4554.07	0.65	2.36(3)	0.05 < p <0.10
Algal biomass	y = a + bx	-3.74	70.18	0.04	0.33(3)	>0.10
Non-algal biomass	y = a + bx	-659.81	4483.89	0.64	2.33(3)	>0.10
Sponge biomass	y = a + bx	-352.43	2654.46	0.33	1.22(3)	>0.10
Gorgonian biomass	y = a + b(1/x)	814.85	-136.18	0.47	1.64(3)	>0.10
Hard coral biomass	y = a + bx	-179.37	891.84	0.97	10.11(3)	<0.01**
Bivalve biomass	y = a + bx	-52.57	385.53	0.18	0.80(3)	>0.10
Bryozoan biomass	y = a + bx	3.44	36.44	0.01	0.16(3)	>0.10
Ascidian biomass	y = a + bx	10.51	26.55	0.06	0.44(3)	>0.10

*Significant.
**Highly significant.

TABLE 5.34. RESULTS OF BETWEEN-STATION REGRESSION ANALYSES RELATING SEDIMENT THICKNESS AND PERCENT COVER.

Response Variable	Best-Fit Model	Slope (b)	Intercept (a)	r^2	t-value (degrees of freedom)	Probability Level
CRUISE II:						
Total cover	y = a + bx	-2.57	37.32	0.04	0.35(3)	>0.10
Algal cover	y = a + bx	3.92	5.16	0.09	0.53(3)	>0.10
Non-algal cover	y = a + b(1/x)	20.39	3.23	0.83	3.88(3)	<0.05*
Sponge cover	y = a + bx	-1.13	7.08	0.78	3.22(3)	<0.05*
Gorgonian cover	y = a + b(1/x)	16.95	-3.24	0.81	3.55(3)	<0.05*
Hard coral cover	y = a + b(1/x)	1.37	-0.40	0.94	6.60(3)	<0.01**
CRUISE III:						
Total cover	y = a + b(1/x)	53.21	4.38	0.97	9.53(2)	<0.05*
Algal cover	y = a + bx	-0.03	2.48	0.00	0.04(2)	>0.10
Non-algal cover	y = a + b(1/x)	54.00	1.69	0.96	7.10(2)	<0.05*
Sponge cover	y = a + bx	-2.43	15.87	0.26	0.85(2)	>0.10
Gorgonian cover	y = a + b(1/x)	31.52	-3.35	0.30	0.92(2)	>0.10
Hard coral cover	y = a + b(1/x)	1.47	-0.17	0.82	3.00(2)	<0.10

*Significant.
**Highly significant.

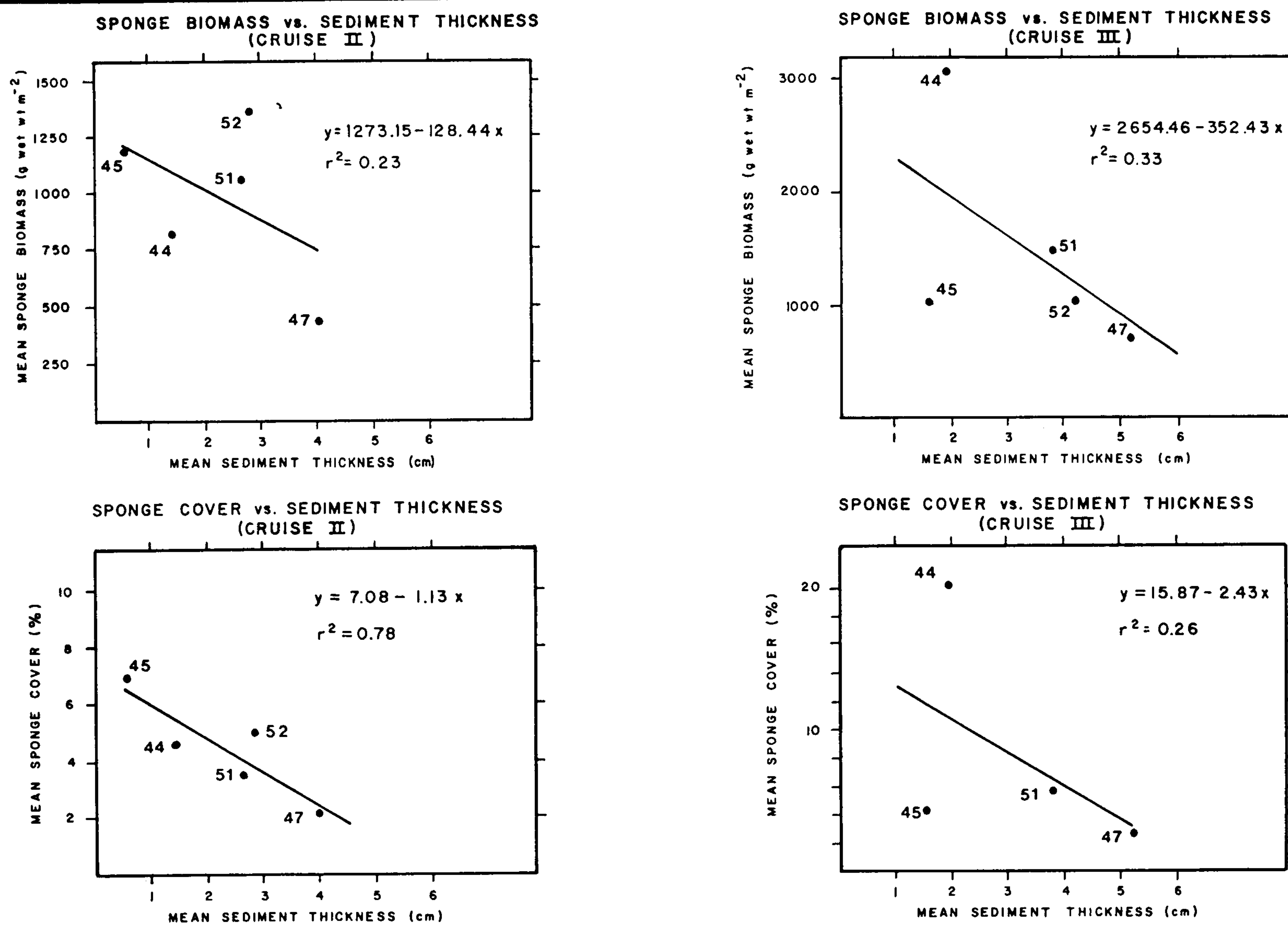


FIGURE 5.17. RELATIONSHIPS BETWEEN SEDIMENT THICKNESS AND SPONGE BIOMASS AND PERCENT COVER.

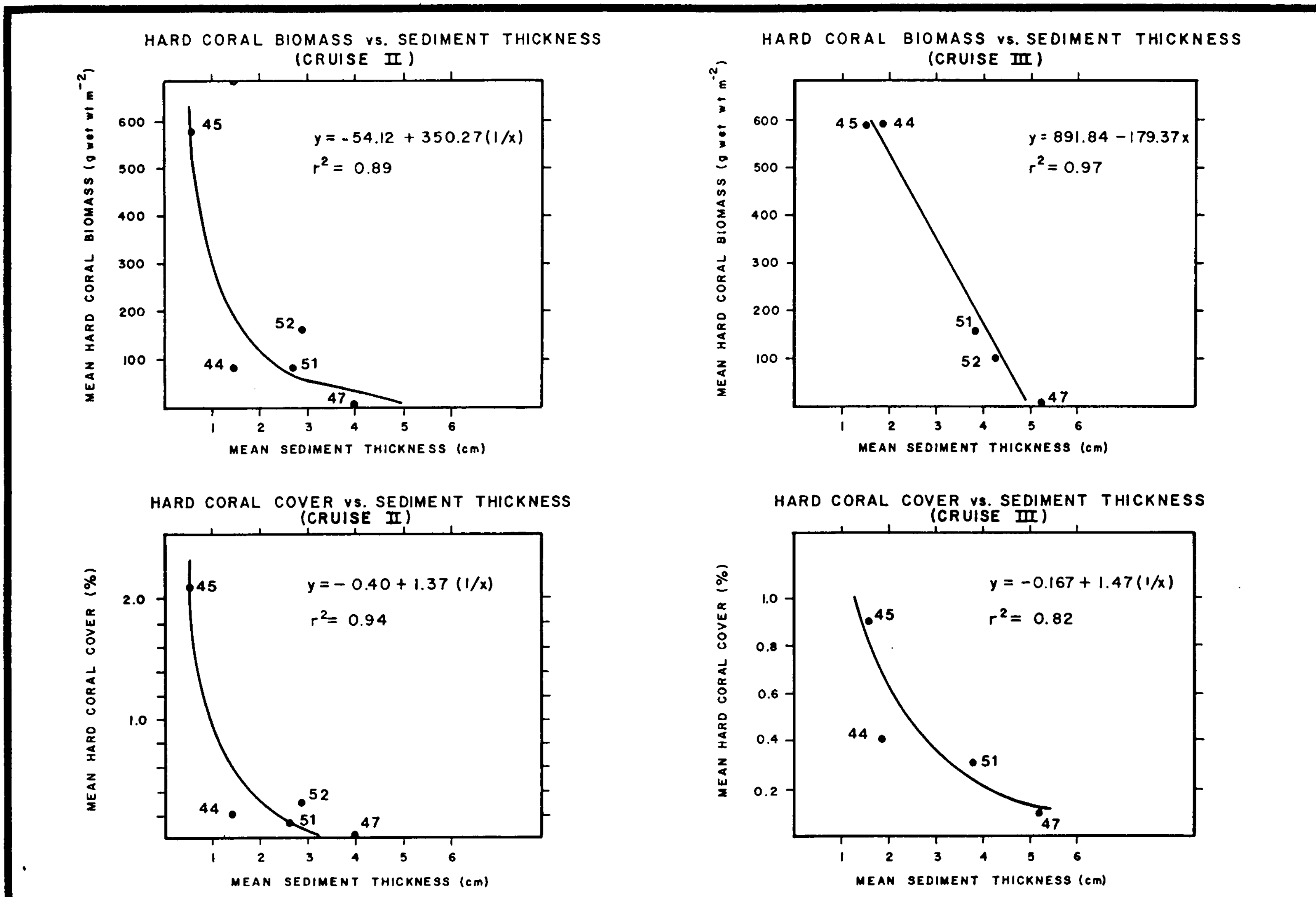


FIGURE 5.18. RELATIONSHIPS BETWEEN SEDIMENT THICKNESS AND HARD CORAL BIOMASS AND PERCENT COVER.

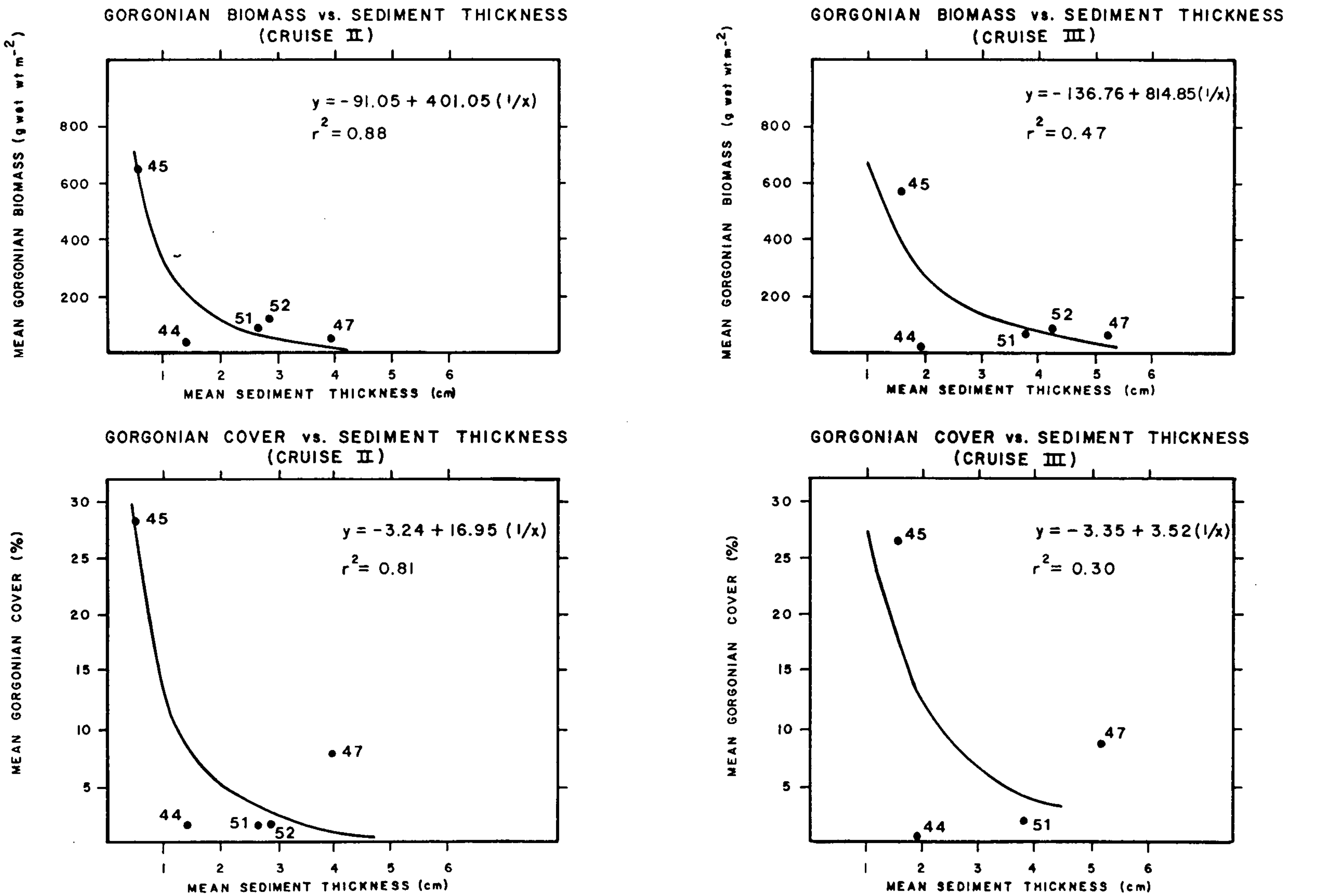


FIGURE 5.19. RELATIONSHIPS BETWEEN SEDIMENT THICKNESS AND GORGONIAN BIOMASS AND PERCENT COVER.

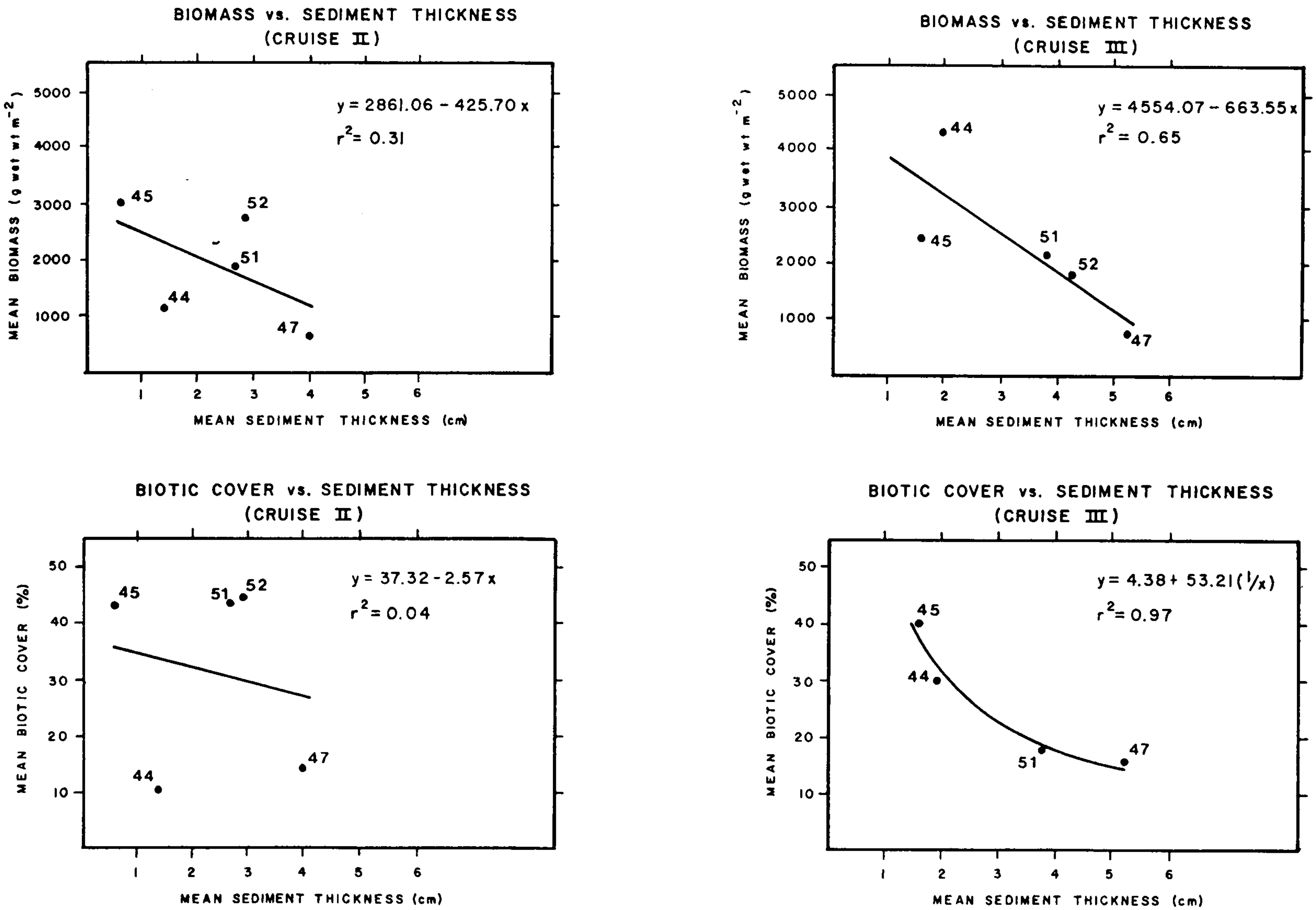


FIGURE 5.20. RELATIONSHIPS BETWEEN SEDIMENT THICKNESS AND TOTAL BIOMASS AND PERCENT COVER.

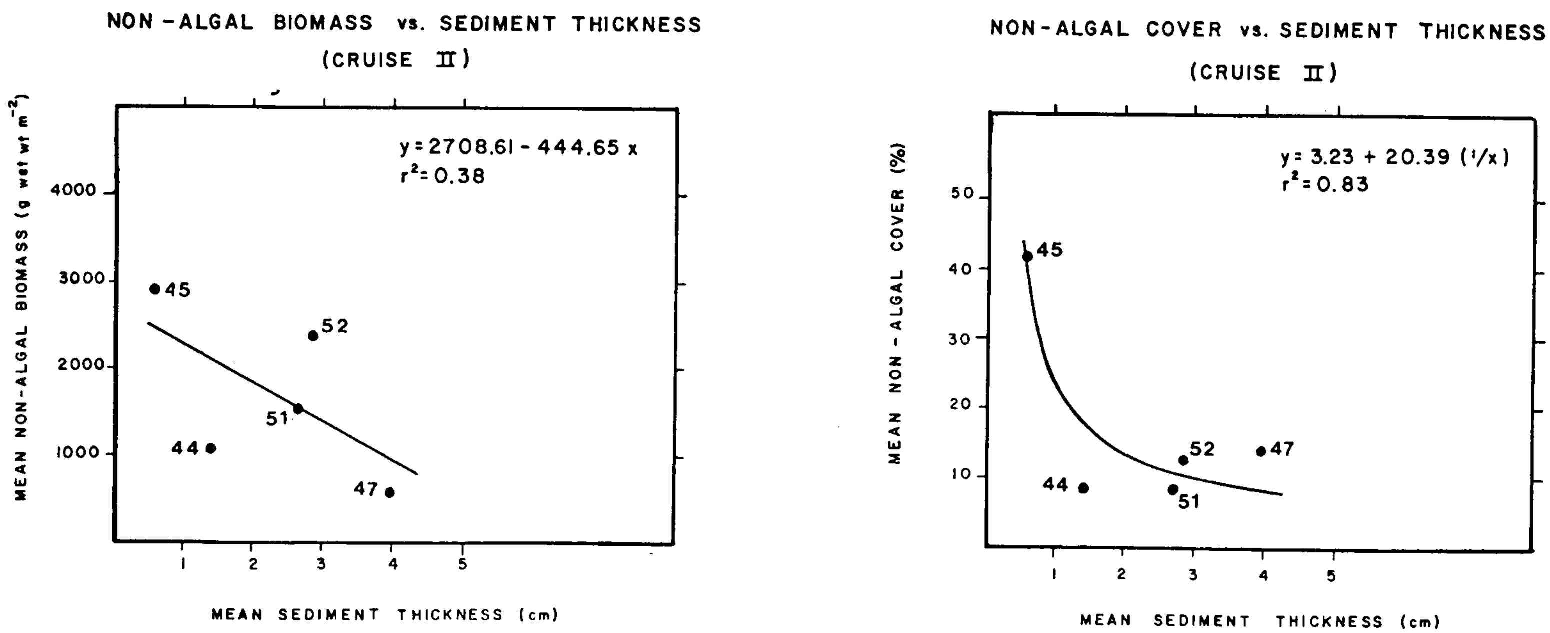


FIGURE 5.21. RELATIONSHIPS BETWEEN SEDIMENT THICKNESS AND NON-ALGAL BIOMASS AND PERCENT COVER.

Results of the between-station analyses are strongly suggestive of negative relationships between sediment thickness and biomass or cover for some groups--particularly sponges, gorgonians, and hard corals. In some cases, a nonlinear (reciprocal) relationship is evident. However, there are too few data points for the results to be conclusive.

5.3.6 Fish Counts

Results of diver fish counts conducted during Cruises II and III are summarized in Tables 5.35 and 5.36, respectively. The main usefulness of the data is to show what species occur at the live-bottom stations; because of the limited sampling effort involved and the known temporal variability of fish populations, relative abundance estimates should be viewed with caution. Likewise, formal comparison among stations or between surveys on the basis of these limited data is not defensible.

Forty-four species were observed during Cruise II (Table 5.35). The number of species seen ranged from 11 at Station 44 to 22 at Station 51. Frequently seen species included red grouper (*Epinephelus morio*), high-hat (*Equetus acuminatus*), tomtate (*Haemulon aurolineatum*), and belted sandfish (*Serranus subligarius*).

Thirty-nine species were observed during Cruise III (Table 5.36). The number of species seen ranged from 10 at Station 52 to 18 at Stations 45 and 47. Frequently seen species included belted sandfish, high-hat, whitespotted soapfish (*Rypticus maculatus*), and white grunt (*Haemulon plumieri*).

Fish Counts vs. Trawls. The main purpose of the fish counts was to supplement trawl data on fish populations associated with live-bottom stations. Table 5.37 shows the combined species lists derived by the the two methods, facilitating comparison of the results. The table includes designations of primary and secondary reef dwellers. Starck (1968) defined primary reef dwellers as those characteristically associated with coral reefs. Secondary reef species are reef residents that are equally or even more characteristic of non-reef habitats (e.g., sand bottom).

A total of 59 species (or distinct taxa) were identified during the fish counts, including 36 species that were not collected by trawl

TABLE 5.35. RELATIVE ABUNDANCE OF FISHES AT LIVE-BOTTOM STATIONS DURING CRUISE II, BASED ON DIVER FISH COUNTS.

		Occurrence				
		Station				
Species	Common Name	44	45	47*	51	52
Epinephelus morio	Red grouper	D	D	D(D)	C	C
Equetus acuminatus	High-hat	D	D	C(C)	D	D
Haemulon aurolineatum	Tomtate	D	D	D(D)	C	D
Serranus subligarius	Belted sandfish	D	D	C(C)	D	D
Lachnolaimus maximus	Hogfish	-	C	D(-)	C	C
Equetus lanceolatus	Jackknife-fish	D	D	C(D)	D	-
Synodus intermedius	Sand diver	E	D	D(E)	E	-
Decapterus punctatus	Round scad	C	B	-(D)	C	-
Halichoeres pictus	Rainbow wrasse	-	-	C(-)	D	D
Calamus calamus	Saucereye porgy	-	D	D(D)	D	-
Haemulon parrai	Sailor's choice	-	-	D(C)	D	D
Rypticus maculatus	Whitespotted soapfish	D	-	-(-)	D	D
Sphoeroides spengleri	Bandtail puffer	-	D	-(-)	D	D
Diplectrum formosum	Sand perch	D	-	E(C)	D	-
Mycteroperca microlepis	Gag	-	E	-(-)	E	E
Haemulon plumieri	White grunt	-	-	-(D)	B	C
Scorpaena plumieri	Spotted scorpionfish	-	D	-(-)	-	E
Lutjanus mahogoni	Mahogany snapper	-	-	-(-)	E	E
Caranx crysos	Blue runner	-	C	-(-)	-	-
Equetus umbrosus	Cubbyu	-	-	-(-)	C	-
Caranx bartholomaei	Yellow jack	-	-	-(-)	-	D
Caranx hippos	Crevalle jack	-	-	-(-)	-	D
Chaetodon ocellatus	Spotfin butterflyfish	-	-	D(-)	-	-
Gobiosoma macrodon	Tiger goby	-	D	-(-)	-	-
Halichoeres bivittatus	Slippery dick	-	-	D(D)	-	-

TABLE 5.35. (CONTINUED).

Species	Common Name	Occurrence Station 44	45	47*	51	52
Hypoplectrus unicolor	Butter hamlet	-	-	-(-)	D	-
Lutjanus griseus	Gray snapper	-	D	-(-)	-	-
Lutjanus synagris	Lane snapper	-	-	D(D)	-	-
Ocyurus chrysurus	Yellowtail snapper	-	D	-(-)	-	-
Pomacentrus leucostictus	Beaugregory	-	-	D(-)	-	-
Pseudupeneus maculatus	Spotted goatfish	-	D	-(-)	-	-
Rypticus saponaceus	Greater soapfish	-	-	D(-)	-	-
Scorpaena brasiliensis	Barbfish	D	-	-(-)	-	-
Seriola dumerili	Greater amberjack	-	-	D(-)	-	-
Aluterus schoepfi	Orange filefish	-	-	-(-)	-	E
Anisotremus virginicus	Porkfish	-	-	-(-)	E	-
Archosargus probatocephalus	Sheepshead	-	-	-(-)	-	E
Balistes capriscus	Gray triggerfish	-	E	-(-)	-	-
Halichoeres spp.	Wrasses	-	E	-(-)	-	-
Holacanthus ciliaris	Queen angelfish	-	E	-(-)	-	-
Lactophrys quadricornis	Scrawled cowfish	-	-	-(-)	E	-
Monacanthus setifer	Pygmy filefish	E	-	-(-)	-	-
Pomacanthus paru (juv.)	French angelfish	-	-	-(-)	E	-
Sphyraena barracuda	Great barracuda	-	E	-(-)	-	-

Abundance categories:

A = 100 or more individuals
B = 26 to 100 individuals
C = 11 to 25 individuals
D = 2 to 10 individuals
E = 1 individual.

*Results of a second fish count conducted at Station 47 are indicated in parentheses.

TABLE 5.36. RELATIVE ABUNDANCE OF FISHES AT LIVE-BOTTOM STATIONS DURING CRUISE III, BASED ON DIVER FISH COUNTS.

Species	Common Name	Occurrence				
		Station				
		44	45	47	51	52
Serranus subligarius	Belted sandfish	C	C	D	E	C
Equetus acuminatus	High-hat	E	C	C	D	D
Rypticus maculatus	Whitespotted soapfish	D	D	D	E	D
Haemulon plumieri	White grunt	-	E	C	B	C
Lachnolaimus maximus	Hogfish	-	C	E	B	E
Equetus lanceolatus	Jackknife-fish	D	-	C	D	D
Caranx crysos	Blue runner	D	D	D	D	-
Epinephelus morio	Red grouper	-	D	D	D	D
Calamus calamus	Saucereye porgy	-	C	E	C	-
Opsanus beta	Gulf toadfish	D	E	-	-	E
Pomacentrus variabilis	Cocoa damselfish	E	-	E	-	E
Haemulon aurolineatum	Tomtate	-	E	D	-	-
Selar crumenophthalmus	Bigeye scad	-	E	D	-	-
Lactophrys quadricornis	Scrawled cowfish	E	-	E	-	-
Lutjanus griseus	Gray snapper	E	E	-	-	-
Lutjanus synagris	Lane snapper	-	-	E	E	-
Sphoeroides spengleri	Bandtail puffer	-	-	-	E	E
Chloroscombrus chrysurus	Atlantic bumper	-	-	-	A	-
Clupeidae sp.	Herrings	-	-	-	A	-
Diplectrum formosum	Sand perch	-	-	D	-	-
Halichoeres maculipinna	Clown wrasse	-	-	D	-	-
Holacanthus bermudensis	Blue angelfish	-	D	-	-	-
Lagodon rhomboides	Pinfish	-	D	-	-	-
Anisotremus virginicus	Porkfish	-	-	-	E	-
Apogon pseudomaculatus	Twospot cardinalfish	-	E	-	-	-
Archosargus probatocephalus	Sheepshead	E	-	-	-	-

TABLE 5.36. (CONTINUED).

Species	Common Name	Occurrence Station 44	45	47	51	52
Balistes capriscus	Gray triggerfish	-	-	-	E	-
Calamus bajonado	Jolthead porgy	E	-	-	-	-
Caranx bartholomaei	Yellow jack	E	-	-	-	-
Chaetodon capistratus	Foureye butterflyfish	E	-	-	-	-
Chaetodon ocellatus	Spotfin butterflyfish	-	-	E	-	-
Diodon holocanthus	Balloonfish	-	-	-	E	-
Halichoeres pictus	Rainbow wrasse	-	-	E	-	-
Holacanthus ciliaris	Queen angelfish	E	-	-	-	-
Lutjanus analis	Mutton snapper	-	E	-	-	-
Narcine brasiliensis	Lesser electric ray	-	-	-	E	-
Ocyurus chrysurus	Yellowtail snapper	-	E	-	-	-
Pomacentrus planifrons	Threespot damselfish	E	-	-	-	-
Pomacanthus arcuatus	Gray angelfish	-	E	-	-	-

Abundance categories:

A = 100 or more individuals
B = 26 to 100 individuals
C = 11 to 25 individuals
D = 2 to 10 individuals
E = 1 individual.

TABLE 5.37. COMPARISON OF FISH COUNT AND TRAWL SPECIES LISTS.

Species Name	Common Name	Habitat Classification*	Occurrence	
			Trawls	Fish Counts
Aluterus heudeloti	Dotterel filefish		X	
Aluterus schoepfi	Orange filefish	(+)	X	X
Anisotremus virginicus	Porkfish	(+)	X	X
Apogon pseudomaculatus	Twospot cardinalfish	(+)		X
Archosargus probatocephalus	Sheepshead			X
Balistes capriscus	Gray triggerfish	(+)		X
Bothus robinsi	Twospot flounder		X	
Calamus arctifrons	Grass porgy	(-)	X	
Calamus bajonado	Jolthead porgy	(+)		X
Calamus calamus	Saucereye porgy	(+)	X	X
Calamus pennatula	Pluma	(+)	X	
Caranx bartholomaei	Yellow jack	(+)		X
Caranx crysos	Blue runner	(-)		X
Caranx hippos	Crevalle jack	(-)		X
Chaetodipterus faber	Atlantic spadefish	(-)	X	
Chaetodon capistratus	Foureye butterflyfish	(+)		X
Chaetodon ocellatus	Spotfin butterflyfish	(+)		X
Chloroscombrus chrysurus	Atlantic bumper			X
Clupeidae spp.	Herrings			X
Decapterus punctatus	Round scad	(-)		X
Diodon holocanthus	Balloonfish	(+)		X
Diplectrum formosum	Sand perch	(-)	X	X
Epinephelus morio	Red grouper	(+)	X	X
Equetus acuminatus	High-hat	(+)		X
Equetus lanceolatus	Jackknife-fish	(+)	X	X
Equetus umbrosus	Cubbyu	(+)	X	X
Eucinostomus argenteus	Spotfin mojarra	(-)	X	
Evermannichthys spongicola	Sponge goby	(+)	X	
Gobiosoma macrodon	Tiger goby	(-)		X
Haemulon aurolineatum	Tomtate	(+)	X	X

TABLE 5.37. (CONTINUED).

Species Name	Common Name	Habitat Classification*	Occurrence	
			Trawls	Fish Counts
Haemulon parrai	Sailor's choice	(+)		X
Haemulon plumieri	White grunt	(+)	X	X
Haemulon sciurus	Bluestriped grunt	(+)	X	
Halichoeres bivittatus	Slippery dick	(+)		X
Halichoeres maculipinna	Clown wrasse	(+)		X
Halichoeres pictus	Rainbow wrasse	(+)		X
Holacanthus bermudensis	Blue angelfish	(+)		X
Holacanthus ciliaris	Queen angelfish	(+)		X
Hypoplectrus puella	Barred hamlet	(+)	X	
Hypoplectrus unicolor	Butter hamlet	(+)		X
Lachnolaimus maximus	Hogfish	(+)	X	X
Lactophrys quadricornis	Scrawled cowfish	(-)	X	X
Lagodon rhomboides	Pinfish		X	X
Lutjanus analis	Mutton snapper	(+)		X
Lutjanus griseus	Gray snapper	(+)		X
Lutjanus mahogoni	Mahogany snapper	(+)		X
Lutjanus synagris	Lane snapper	(-)	X	X
Microgobius carri	Seminole goby	(+)	X	
Monacanthus ciliatus	Fringed filefish	(-)	X	
Monacanthus hispidus	Planehead filefish	(-)	X	
Monacanthus sp.	Filefish	(-)		X
Mycteroperca microlepis	Gag	(+)		X
Narcine brasiliensis	Lesser electric ray	(-)		X
Nicholsina usta	Emerald parrotfish	(-)	X	
Ocyurus chrysurus	Yellowtail snapper	(+)		X
Ogcocephalus radiatus	Polka-dot batfish		X	
Ophidion dromio	Cusk-eel		X	
Ophidion holbrooki	Bank cusk-eel		X	
Opsanus beta	Gulf toadfish			X
Orthopristis chrysoptera	Pigfish		X	
Phaeoptyx pigmentaria	Dusky cardinalfish	(+)	X	

TABLE 5.37. (CONTINUED).

Species Name	Common Name	Habitat Classification*	Occurrence	
			Trawls	Fish Counts
Pomacanthus arcuatus	Gray angelfish	(+)	X	X
Pomacanthus paru	French angelfish	(+)		X
Pomacentrus leucostictus	Beaugregory	(+)		X
Pomacentrus planifrons	Threespot damselfish	(+)		X
Pomacentrus variabilis	Cocoa damselfish	(+)	X	X
Porichthys plectrodon	Atlantic midshipman		X	
Prionotus martis	Barred searobin		X	
Prionotus stearnsi	Shortwing searobin		X	
Pseudupeneus maculatus	Spotted goatfish	(+)		X
Rhinobatos lentiginosus	Atlantic guitarfish		X	
Rypticus maculatus	Whitespotted soapfish	(+)	X	X
Rypticus saponaceus	Greater soapfish	(+)	X	X
Sardinella aurita	Spanish sardine		X	
Scorpaena brasiliensis	Barbfish		X	X
Scorpaena plumieri	Spotted scorpionfish	(+)	X	X
Selar crumenophthalmus	Bigeye scad	(-)		X
Seriola dumerili	Greater amberjack	(-)		X
Serraniculus pumilio	Pygmy sea bass		X	
Serranus subligarius	Belted sandfish	(-)	X	X
Sphoeroides spengleri	Bandtail puffer	(-)	X	X
Sphyraena barracuda	Great barracuda	(+)		X
Syacium papillosum	Dusky flounder		X	
Symphurus urospilis	Spottail tonguefish		X	
Syngnathus pelagicus	Sargassum pipefish		X	
Synodus foetens	Inshore lizardfish		X	
Synodus intermedius	Sand diver	(-)	X	X
Synodus poeyi	Offshore lizardfish	(+)	X	

*(+) indicates primary reef dweller
(-) indicates secondary reef dweller
blank indicates non-reef dweller.

(Table 5.37). Among the latter, twenty-five are primary reef dwellers, seven are secondary reef dwellers, and four are non-reef dwellers. Mid-water foraging carangids such as yellow jack (Caranx bartholomaei), blue runner (C. crysos), crevalle jack (C. hippos), amberjack (Seriola dumerili), bigeye scad (Selar crumenopthalmus), and round scad (Decapterus punctatus) were conspicuously absent from the trawl samples. Other mid-water species seen by divers but not collected in trawls were barracuda (Sphyraena barracuda) and yellowtail snapper (Ocyurus chrysurus). Reef dwellers observed by divers but not collected in trawls included primarily small species with limited home ranges--that is, species that do not stray far from dense live bottom. Examples are butterflyfishes (Chaetodon capistratus, C. ocellatus), wrasses (Halichoeres bivittatus, H. maculipinna, and H. pictus), and damselfishes (Pomacentrus leucostictus, P. planifrons, and P. variabilis). Several snappers (Lutjanus spp.) also were reported by divers but not collected in trawls.

Of 51 fish species collected by trawl, only 21 are primary reef dwellers (Table 5.37). Most of the 28 trawl species not seen by divers are sand dwellers. Examples are lizardfishes (Synodus foetens and S. poeyi), sea robins (Prionotus martis and P. stearnsi), cusk eels (Ophidion holbrooki and O. dromio), flatfishes (Bothus robinsi, Syacium papillosum, and Symphurus urospilis), polka-dot batfish (Ogcocephalus radiatus), Atlantic midshipman (Porichthys plectrodon), and Atlantic guitarfish (Rhinobatos lentiginosus).

Among the few reef dwellers taken exclusively by trawl were secretive species such as dusky cardinalfish (Phaeoptyx pigmentaria), sponge goby (Evermannichthys spongicola), and seminole goby (Microgobius carri). Dusky cardinalfish hides in crevices by day and forages in the water column by night (Starck and Davis, 1966), often in small groups (Thresher, 1980). Dusky cardinalfish would be invisible to divers during the daytime fish counts and would be most susceptible to capture by trawl during these nocturnal forays. The sponge goby lives as an inquiline within large sponges (Bohlke and Robins, 1969; Livingston, 1979) and probably was dislodged from its host sponge following collection in a trawl. Seminole goby constructs burrows in the bottom near the bases of rock outcrops or coral reefs; individuals tend to hover in the water column a few feet above the bottom (Birdsong, 1981).

5.3.7 Sediment Trap and Thermograph Data

Table 5.38 summarizes sediment trap results (raw data are presented in Appendix A). Mean deposition rates ranged from 576 to 912 g dry wt m^{-2} d^{-1} at 2 m above bottom and from 461 to 822 g dry wt m^{-2} d^{-1} at 1 m above bottom. Kruskal-Wallis testing indicates no significant difference among treatments (locations and heights) in deposition rate (or values are too variable within treatments for a difference to be detected with n=3 observations per treatment).

Data from the recording thermograph at Station 52 have been presented in Chapter 3. Raw data are provided in Appendix A.

5.4 DISCUSSION AND CONCLUSIONS

5.4.1 Summary Characterization

The southwest Florida continental shelf consists of a carbonate platform overlain by a variably thin veneer of primarily carbonate sand. Sessile, hard-bottom epibiota occur where the platform is exposed, where the sand veneer is thin enough to allow attachment of sessile epibiota to hard bottom exposed by periodic sand movement, and where surface rubble layers provide hard substratum for attachment. Within the depth range of the Year 3 stations, there is little exposed rock; most of the conspicuous sessile epibiota occur in association with a thin sand veneer over hard bottom rather than with rock outcrops. Where the sand veneer is thicker (and underlying hard bottom probably is infrequently exposed), the attached, sessile epifauna become less common and soft-bottom epibiota (including macroalgae and seagrasses) predominate.

The Year 3 stations were chosen as representative of inner shelf live-bottom areas. Table 5.39 summarizes several types of data from the live-bottom stations. Similarities and differences among stations are discussed in the following paragraphs.

The nearshore live-bottom areas in which the Year 3 stations were located are similar in appearance when compared with other live-bottom habitats seen on the southwest Florida shelf (see Chapter 4). The overall incidence of live bottom also was fairly consistent across stations (70 to 100%), although Station 45 stands out in having 100% incidence on both cruises (Table 5.39). Large, photosynthetic gorgonians and sponges were the most conspicuous elements of the epifauna at all stations. Sponges were the primary biomass contributors at all stations; only at Station 45 did gorgonians account for 20% to 25% of total

TABLE 5.38. SEDIMENT TRAP DATA.

Station	Deployment Interval (d)	Mean Deposition Rate (g dry wt m^{-2} d^{-1}) 1 m Above Bottom	2 m Above Bottom
44*	ND	ND	ND
45*	ND	ND	ND
47	168	461	576
51	173	822	912
52†	175	ND	691

ND = no data.

*Station 44 and 45 trap arrays were not recovered.
†The lower traps at Station 52 had been dislodged from the array.

TABLE 5.39. SUMMARY CHARACTERIZATION OF YEAR 3 LIVE-BOTTOM STATIONS.

Station	Water Depth (m)	Mean Sediment Thickness (cm)	Live-Bottom Incidence (%)	Live-Bottom Density	Mean Percent Cover		Mean Biomass (g wet wt m^{-2})	Species Richness		
					Total	Nonalgal		Dredge	Trawl	Quadrat
CRUISE II:										
44	13	1.41	90	Med/thick	18	16	1,168	164	60	145
45	17	0.57	100	Thick	41	40	3,034	163	66	177
47	19	3.98	95	Occ/Med	17	15	624	178	62	143
51	15.5	2.67	100	Med/Thick	49	20	1,856	174	73	157
52	13.5	2.86	86	Med/Thick	39	14	2,732	161*	71*	176
CRUISE III:										
44	13	1.93	93	Thin/Med	15	13	4,324	140	59	155
45	17	1.58	100	Thick	39	35	2,464	176	--	157
47	19	5.23	80	Occ/Med	21	20	798	149	74	101
51	15.5	3.81	68	Occ/Med	21	16	2,174	150	71	154
52	13.5	4.26	72	Med	22	22	1,856	162*	58*	169

Sediment thickness data are from quadrat measurements. Live-bottom incidence and density are from television surveys (Occ = occasional; Med = medium). Percent cover is from quantitative slide analysis of remote still photographs. Biomass data are from harvested quadrats. Species richness = total number of species identified.

*Night samples only.

biomass. Table 5.39 shows that if only epifauna are considered, percent cover estimates for Stations 44, 47, 51, and 52 all are in the 13 to 22% range; only Station 45 had substantially different (higher) cover percentages.

Differences among stations also are apparent. Although the percent incidence of live bottom was fairly consistent across stations, the density of epibiota within live-bottom patches varied from "thick" at Station 45 to "occasional" or "thin" at Station 47. Percent cover and biomass data support these subjective assessments of relative density (Table 5.39). Station 45 was the densest live-bottom area, whereas Station 47 was a mixture of soft bottom and sparse live bottom.

Species richness also differed among stations, although direct comparisons must be qualified because sampling was not adequate to collect all species present (see Methodology Evaluation). The highest number of dredge-collected species was at Station 47, whereas the highest number of quadrat-collected species was at Station 45. The latter result is to be expected, as Station 45 was the densest live-bottom area sampled. The high number of species collected in dredge samples at Station 47 probably is due to more effective sampling of small, motile invertebrates there (e.g., the high number of crustaceans collected in the Cruise II dredges). In dense live-bottom areas where the sand veneer is thin, the dredge bounces along the bottom, whereas in soft-bottom or sparse live-bottom areas, the dredge can dig into the seafloor. The interspersion of live and soft bottom throughout the station also may have contributed to the total species richness, in that species characteristic of both habitat types were collected. Soft bottom also was present at Stations 51 and 52, but the boundary was relatively sharp, and sampling was conducted in predominantly live-bottom areas at those stations.

The species composition of the epibiota varied among stations. Cluster analyses conducted using dredge, trawl, and quadrat data indicate that Station 47 was distinctly different from the other stations in species composition. Analyses of dredge and trawl data also showed that Station 47 epibiota were more similar to those from a soft-bottom area at Station 51 than to any of the live-bottom stations sampled. Cluster analysis results conducted using Year 1, 2, and 3 data (see Section 5.5) show that Station 47 epibiota are more similar to those at stations in water depths of 20 to 30 m than to those at the other Year 3 stations (10 to 20 m depth). Thus, the epibiota of

Station 47 have a greater affinity to soft-bottom areas and deeper live-bottom stations than to the nearshore live-bottom areas.

Other species composition differences were not as apparent from cluster analysis results, probably due to the inclusion of representatives of all phyletic groups and the weighting by frequency of occurrence rather than abundance. For example, Station 45 was distinguished by the striking abundance of gorgonians and the presence of several hard coral species (Isophyllia sinuosa, Manicina areolata, Porites branneri, P. porites divaricata, and Stephanocoenia michelinii) that were rare or absent at the other stations. Also, during Cruise II, Stations 51 and 52 were distinguished by a species of brown algae (Dictyopteris jamaicensis) that contributed a significant percentage of total cover and biomass.

5.4.2 Relationships to Environmental Variables

This has been a descriptive, primarily biological study. Although some environmental variables were measured, for the most part, we can only speculate as to the importance of particular environmental factors.

Abundance vs. Sediment Thickness. The percent cover and biomass of some epibiota (gorgonians, sponges, and hard corals) were negatively related to sediment thickness. Dense live bottom at Station 45 was associated with mean sediment thicknesses of 0.6 cm on Cruise II and 1.6 cm on Cruise III. Sparse live bottom at Station 47 was associated with sediment thicknesses of 4.0 cm on Cruise II and 5.2 cm on Cruise III.

The relationship between sediment thickness and biomass or percent cover may reflect an underlying relationship between sediment thickness and frequency of hard-bottom exposure. Sessile epifauna such as gorgonians, sponges, and hard corals typically require hard substrate for attachment. Where the sand veneer is thin, hard substrate probably is more frequently exposed and colonized by sessile epibiota. One would not expect a relationship between sediment thickness and algal abundance because some algae do not require hard substratum for attachment. Our biomass and percent cover data showed that algae were abundant in thick, soft-bottom areas as well as in areas where the sand veneer was thin.

Significant, negative relationships between sediment thickness and biomass or percent cover were apparent only when analyses were conducted using station means. There was no consistent evidence of such relationships within stations (i.e., using individual quadrats as experimental units). There are several plausible explanations for the lack of correlation between sediment thickness and percent cover or biomass within stations:

1) Sediment movement that occurs on the scale of a station may be sufficient to produce uneven distribution of sediment thicknesses but insufficient to expose new substratum for colonization. If hard bottom is exposed only during infrequent major storms, on a broad scale (across stations) the probability of exposure should be related to the mean thickness at a particular location (station).

2) Three sediment thickness measurements per quadrat may be insufficient to obtain a representative value. The underlying hard bottom was quite irregular and pocked with holes and crevices. However, in order for a significant relationship to be apparent among stations, the mean of measurements taken in all quadrats would have to be fairly representative of the station as a whole.

3) Within stations, we may have been looking at too narrow a range of sediment thicknesses to detect a relationship with biomass or cover. All quadrats within a given station were harvested within a relatively small area or "patch" of live bottom. No effort was made to include a range of sediment thicknesses or densities of epibiota. For example, at Station 45 (a dense live-bottom area), no quadrats with sediment thickness greater than 2 cm were harvested during Cruise II. Conversely, no quadrats with sediment thicknesses of <1 cm were harvested at Station 47 (a sparse live-bottom area) on either cruise.

The relationship between abundance of live-bottom epibiota and sediment thickness has previously been studied in the South Atlantic Bight by Marine Resources Research Institute (1984). Researchers counted selected hard corals, octocorals, and sponges and measured sediment thickness at fixed points within quadrats deployed along a transect traversing a gradient from thick to sparse live bottom. In addition, they measured sediment thickness at the point of attachment of selected species. Counts of several species of octocoral, one species of hard coral, and several species of sponge were negatively correlated with sediment thickness, though the degree of statistical significance varied. Measurements at the base of individual specimens showed that most specimens were attached to hard substratum with 0 to 1 cm cover, and about 95% were attached to hard substratum with $\leq$5 cm cover. No hard corals or sponges were seen in quadrats where sediment was thicker than 21 cm.

Results reported by Marine Resources Research Institute (1984) differ from ours in that they noted significant relationships between sediment thickness and density of epibiota when individual quadrats were used as experimental units. Possible reasons why we did not have been cited above. The methodological difference (we did not place quadrats along a gradient of live-bottom density) appears to be a likely explanation.

Species Composition vs. Environmental Variables. Some variations in species composition shown by cluster analyses may be related to differences in sediment thickness. Station 47, which had the greatest mean sediment thickness (4 to 5 cm) was distinctly different from other stations in species composition. However, the lack of distinctness of Station 45, which had the lowest mean sediment thickness, argues against a general relationship between species composition and sediment thickness. However, the apparent similarity of epibiota at Station 47 and the soft-bottom area at Station 51 suggests that where mean sediment thickness reaches 4 to 5 cm or more, the epibiota can be expected to have substantial soft-bottom character.

Cluster analysis results may also be interpreted as showing the importance of water depth. One reason for the distinctly different species composition at Station 47 is the water depth--19 m, the greatest among Year 3 stations. Cluster analyses conducted using Year 1, 2, and 3 data (see Section 5.5) show that Station 47 epibiota are more similar to those of Year 1 and 2 stations in water depths of 20 to 30 m than to those of the other Year 3 stations in water depths of 10 to 20 m.

Species composition variations with latitude also were apparent, though not as pronounced as those associated with water depth or sediment thickness. Dredge and quadrat cluster analyses showed that Stations 51 and 52, the southernmost stations studied, were somewhat distinct in species composition from the northernmost Stations 44 and 45.

Water depth and latitude are not explanatory variables; rather, they are correlates of variables that may directly affect the abundance and composition of benthos. Influential environmental variables correlated with water depth include light, temperature (mean, range), sediment composition (e.g., percent carbonate, grain size), sediment thickness, susceptibility to sediment movement due to surface waves, and near-bottom nutrient (nitrate, phosphate) concentrations. The deposition rates and composition (grain size, organic constituents, etc.) of sedimenting material also are likely to vary with water depth, though major differences among stations in the 10- to 20-m depth range were not apparent in our sediment trap results. Influential environmental variables correlated with latitude include light and temperature, although these are not likely to vary much within the narrow range of latitudes encompassed by the Year 3 stations. The frequency of sediment resuspension also may vary with latitude, as suggested by the transmissometry results (see Chapter 3); the water column was frequently turbid in the vicinity of Station 52, an observation that has been confirmed by subsequent measurements during Year 4 (Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc., 1985).

Temperature has been mentioned as an important influence on nearshore epibiota. In particular, severe winter cold fronts can kill or injure tropical fishes and invertebrates associated with nearshore reef and live-bottom communities (Bullock and Smith, 1979; Bohnsack, 1983). These can be expected to occur infrequently at this latitude. Live-bottom epibiota in deeper water are buffered against the most severe temperature changes that might occur. Thermograph data presented in Chapter 3 show that bottom temperatures fell below 18°C (the lower limit for many tropical forms) for only a few days during the winter of 1982-1983. There was no evidence for penetration of a major cold front that could cause catastrophic disturbance.

Light is an important factor affecting nearshore live-bottom epibiota. Many nearshore gorgonians harbor symbiotic zooxanthellae, although they are also capable of feeding on animal prey or particulate organic matter (Lasker, 1981). Light levels have been suggested as a factor influencing gorgonian zonation and may be responsible for the general restriction of symbiont-containing gorgonians to relatively shallow water depths (Goldberg, 1973). Reduced feeding rates with increasing water depth may also accentuate the effects of the decline in net photosynthetic rates with depth to restrict gorgonian distribution (Lasker et al., 1983). In our study area, most of the gorgonian species (*Eunicea* spp., *Muricea* spp., *Plexaurella* spp., *Pseudoplexaura* spp., *Pseudopterogorgia* spp., and *Pterogorgia guadalupensis*) present at the nearshore stations are absent or rare at water depths greater than 20 m. During Year 1 and 2, many of the same Year 3 species were collected at Station 13 (water depth: 20 m), but only Lophogorgia cardinalis, L. barbadensis, and Pseudopterogorgia acerosa were collected at Station 19 (water depth: 22 m), and only L. cardinalis was collected at Station 15 (water depth: 32 m).

Red tides are another potential influence on species composition of nearshore live-bottom areas. Blooms of potentially toxic dinoflagellates (Ptychodiscus brevis) occur frequently in the open waters of the eastern Gulf of Mexico (Steidinger and Ingle, 1972), occasionally leading to major inshore outbreaks of red tide typified by major fish kills (Smith, 1979; Steidinger and Haddad, 1981). Smith (1975, 1979) described the effects of a red tide on nearshore patch reefs located in 12 to 18 m water depths near Sarasota. Over 77% of the resident fish species were eliminated by the red-tide kill, and populations of hard and soft corals, echinoderms, crustaceans, molluscs, and benthic algae sustained heavy mortalities. The number of fish species returned to "normal" within about one to two years; however, recovery of benthic epifauna was not complete even three years after the red tide.

There was no evidence of catastrophic mortality or a predominance of opportunistic species that would indicate a red-tide kill at any of the Year 3 stations. Carder and Steward (1985) have since reported a red-tide fish kill that occurred along the coast in the study area during late 1983. No data on benthic effects were presented.

5.4.3 Relation to Previous Studies

Benthic data from a similar depth range as the present study were collected during the Hourglass cruises (Lyons and Camp, 1982). Relevant data also were reported by Smith (1976), who described patch reefs located in 12- to 18-m water depths near Sarasota. During the MAFLA study, some samples were collected at two stations (11 and 18 m depth) located off Sanibel Island near our Station 44 (Hopkins, 1979); however, the data, particularly for epifauna, are not available in a form suitable for station comparisons. Data from deeper southwest Florida shelf stations sampled during Years 1 and 2 of the present study are discussed in Section 5.5.

The Hourglass cruises, so named because of the configuration of sampling transects, were conducted between 1965 and 1967. Figure 5.22

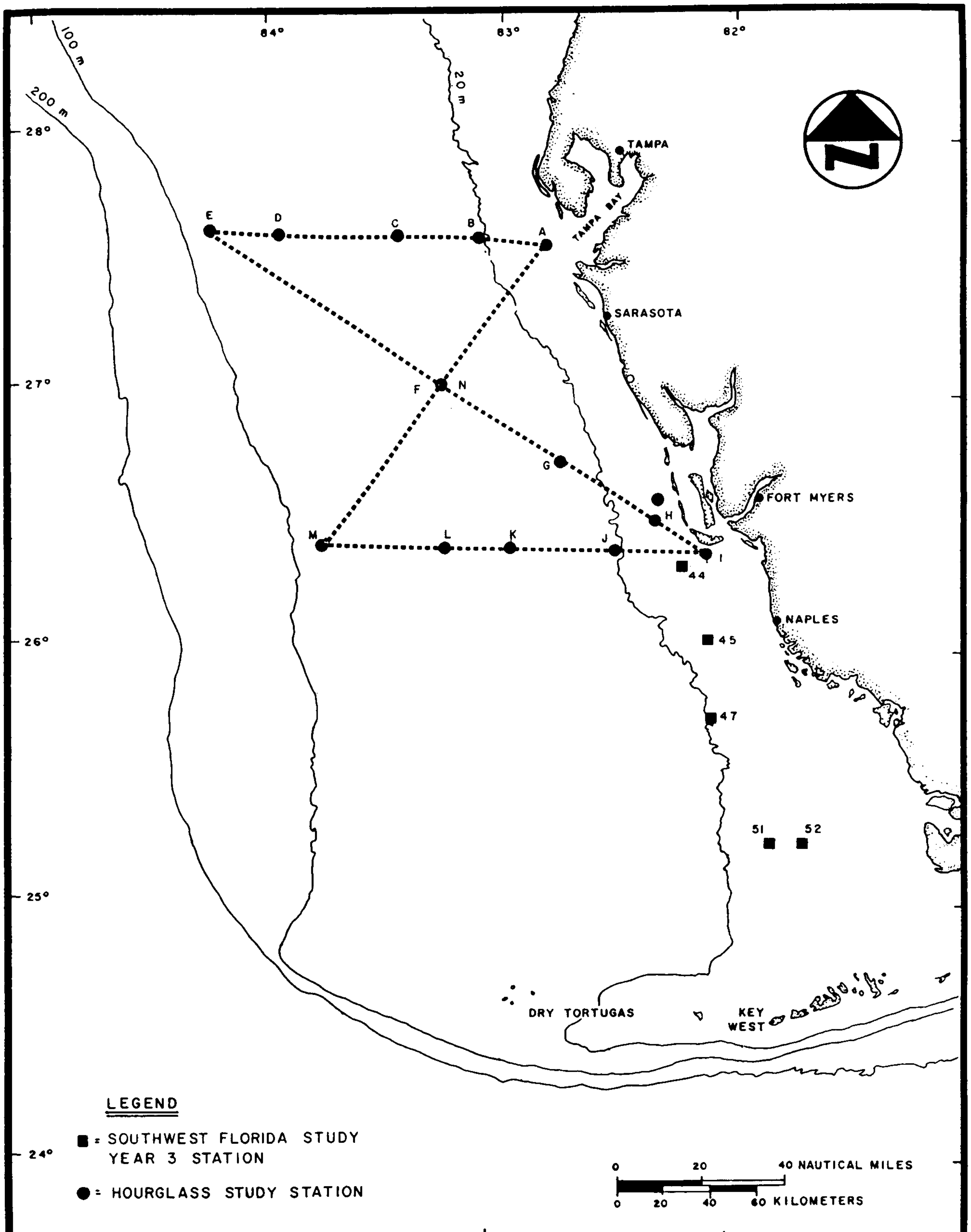


FIGURE 5.22. LOCATIONS OF YEAR 3 STATIONS IN RELATION TO HOURGLASS STUDY STATIONS.

shows the location of stations sampled monthly with dredge and trawl. Stations A and I were in a water depth of 6 m, and Stations B and J were in a water depth of 18 m (Joyce and Williams, 1969). Our Station 44 is located slightly south of and between Stations I and J (Figure 5.22).

Lyons and Camp (1982) present a preliminary summary of results from the Hourglass cruises. Cluster analyses suggest that the two 6-m stations were in a separate faunal "zone" from the 18- and 37-m stations. Although some of our stations are intermediate in water depth between the 6- and 18-m stations, the composition of the epibiota we collected appears more similar to that of the 18-m stations than to that of the 6-m station. For example, of the most commonly collected species which occurred primarily at the 6-m stations (A and I), the bivalve Noetia ponderosa, the coral Astrangia astreiformis, the echinoid Mellita quinquiesperforata, the sergestoid shrimp Lucifer faxoni, and the sea robin Prionotus scitulus were not collected at our Year 3 stations. Conversely, nearly all of the common species occurring primarily at the 18-m Hourglass stations (B and J) were collected at our Year 3 stations. The species include the corals Cladocora arbuscula, Phyllangia americana, Siderastrea radians, and Solenastrea hyades, the crustaceans Trachypenaeus constrictus and Gonodactylus bredini, and the echinoids Arbacia punctulata and Encope michelinii. Comparison of our results with those from the Hourglass cruises lends support to the hypothesis that there is a distinct faunal zone in water depths of <10 m. Section 5.5 presents more discussion of the shelfwide zonation patterns discerned by Lyons and Camp (1982).

Smith (1976) described the epibiota characteristic of patch reefs located in 12- to 18-m water depth near Sarasota, Florida. Exposed reef ledges typically were covered by encrusting sponges (Cliona), tunicates, serpulid and sabellid polychaete tubes, green algae (Caulerpa), and hydrozoan fire coral (Millepora alcicornis). However, the area immediately shoreward of the reefs was characterized by lush gorgonian growth typified by species such as Eunicea calyculata, Muricea elongata, M. laxa, and Pseudopterogorgia acerosa. Loggerhead sponges (Spheciospongia vesparium), green algae (Halimeda, Udotea, and Penicillus), and the ophiuroid Ophiothrix suensoni (seen associated with Muricea elongata), were also cited as typical of this fore reef zone. Smith also noted that patch reefs in water depths greater than about 20 m support more tropical and/or deep water hard corals (Scolymia lacera, Manicina areolata) and are depauperate in gorgonian species typical of the shallower reefs.

The Year 3 live-bottom stations we sampled in water depths of 13 to 19 m appear to be similar in species composition to the fore reef zone of patch reefs studied by Smith (1976). The lush gorgonian growth described by Smith was particularly evident at our Station 45.

We noted patches of seagrass/algae beds during Cruise I habitat mapping surveys (Chapter 4), and part of Station 51 was characterized by soft bottom with seagrass (Halophila decipiens) and several more algal species than were seen in the adjacent live-bottom area. Halophila decipiens is a fringing or pioneer species rather than a major seagrass bed former. The seagrass/algal "beds" seen in our study area probably represent the outer fringe of much more extensive seagrass beds known to occur in the Florida Bay region (Iverson and Bittaker, in press) and farther north in the Florida Big Bend area (Continental Shelf Associates and Martel Laboratories, Inc., 1985).

Our sediment trap results are comparable to those reported by Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc. (1985). They reported mean winter and spring deposition rates of 636 and 674 g dry wt m^{-2} d^{-1} respectively, for traps at 1 m above bottom at Station 52. We did not recover the 1-m traps at Station 52, but 2-m trap values were 691 g dry wt m^{-2} d^{-1} and values at either height at our other nearshore stations ranged from 461 to 912 g dry wt m^{-2} d^{-1}. No major differences by station or height above bottom were evident in our data, but there are too few data points for the results to be conclusive. In addition, by placing traps at 1-m and 2-m heights, we may have been missing most of the "action;" results reported by Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc. (1985) indicate that resuspension is the major source of deposited sediments and that major resuspension events may lift substantial quantities of sand particles to 0.5 m above bottom but generally not to 1 m above bottom. The Year 4 and 5 data also indicate that resuspension is episodic and related to major storm events (Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc., 1985).

5.4.4 Methodology Evaluation

Sampling Adequacy. Figure 5.23 shows representative species saturation curves for quadrat data. As progressively more replicates are included, progressively fewer new species are added. Although some leveling is evident in all of the curves, none appear to be approaching a slope of zero after 35 to 40 replicates. Additional sampling would have yielded significant numbers of additional, rare species.

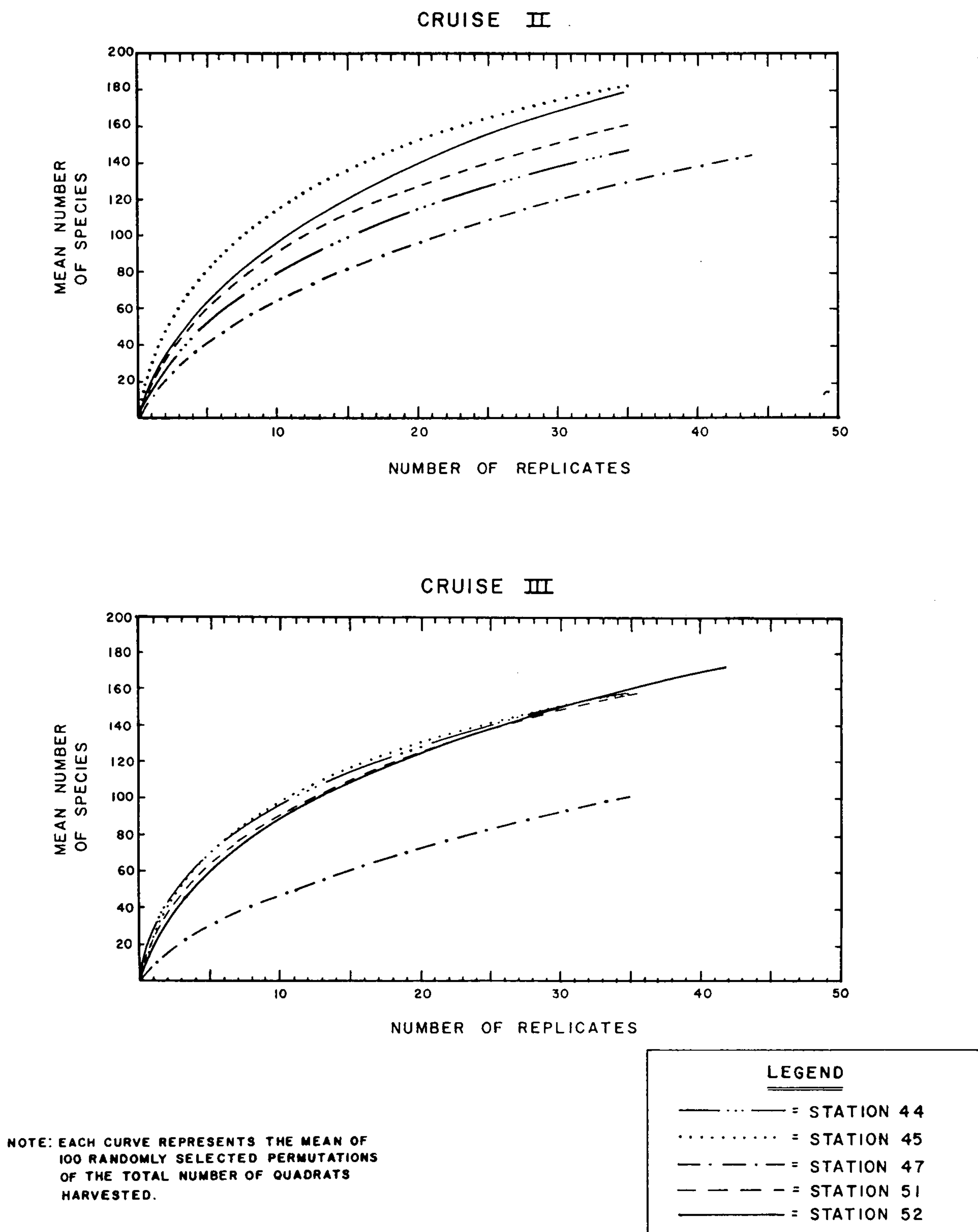


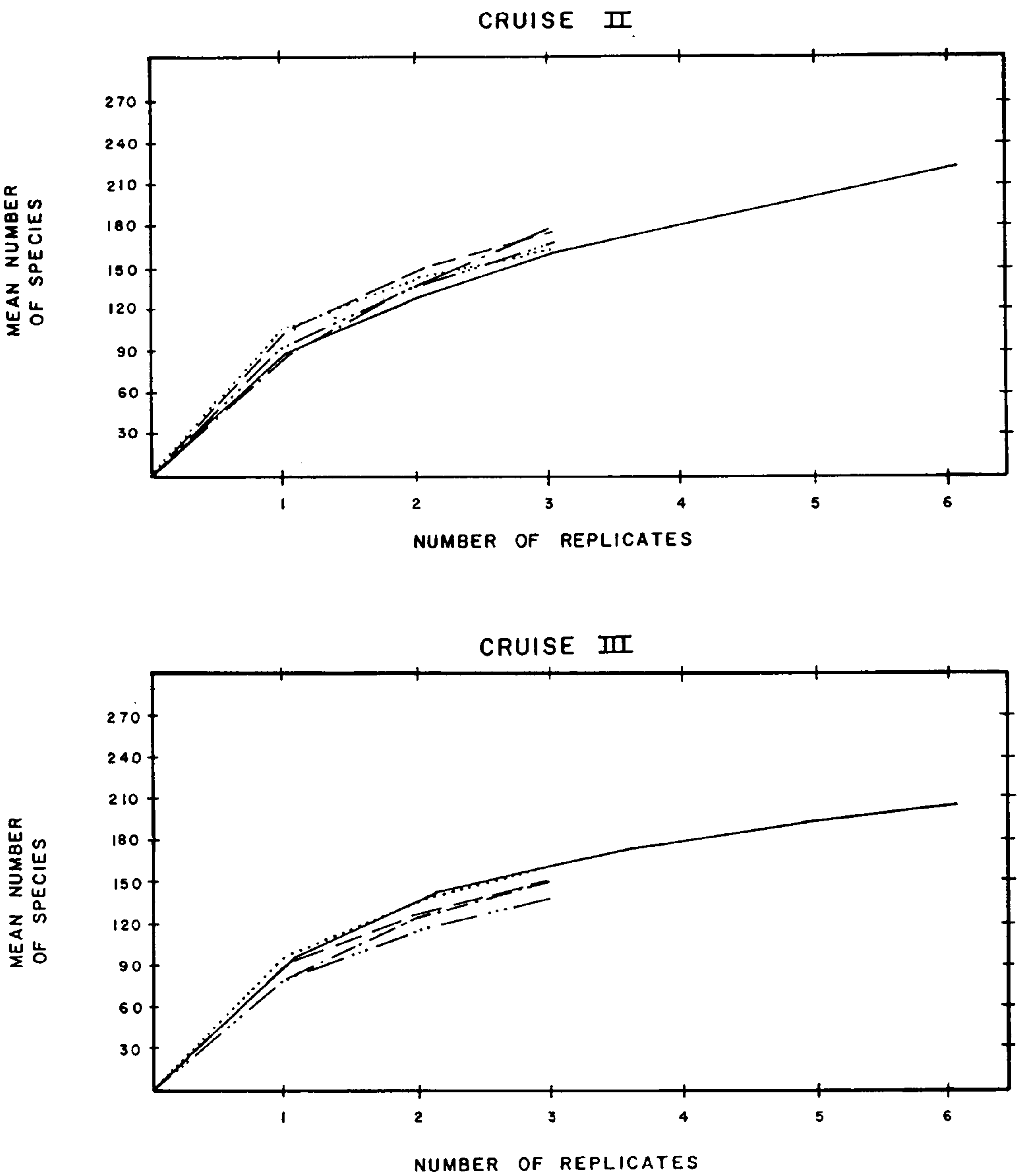
FIGURE 5.23. SPECIES SATURATION CURVES FOR QUADRATS HARVESTED AT LIVE-BOTTOM STATIONS DURING CRUISE II AND CRUISE III.

Triangle dredge species saturation curves also show some leveling with the standard three replicates (Figure 5.24). However, even at Station 52, where six replicates were obtained, the curves do not approach a slope of zero (Figure 5.24). Dredge sampling in other areas of the eastern Gulf of Mexico has shown that even 10 or 20 dredge samples may not be sufficient to bring the slope of the species saturation curve close to zero for a particular location (Continental Shelf Associates, Inc., unpublished data).

Comparison of the species composition of dredge catches from day and night sampling at Station 52 provides additional perspective on dredge sampling adequacy. Because few differences in catch could be attributed to real diel differences (e.g., nocturnal activity patterns), the two sets of dredge samples essentially constitute duplicate sampling of the same station. Species richness differed little between the two data sets. Cluster analysis showed that the day and night samples were more similar in species composition to each other than to other live-bottom stations (except Station 51, which was very similar to both sets of Station 52 dredge samples collected during Cruise II). Thus, a set of three dredge samples from a station appears to provide a representative sample of organisms sufficient to characterize the station and make comparisons with other stations.

Species saturation curves cannot be constructed for trawl data because there were no replicates. However, comparison of species lists from day and night trawls at Station 52 (for groups not expected to show any diel abundance patterns) indicates appreciable variability between duplicate trawls in numbers of species caught. The species composition of the day and night trawl catches from Station 52 differed more than did the day and night dredge catches; however, day and night trawl catches from Station 52 were more similar to each other than to catches from other live-bottom stations. Although additional trawl sampling at each station would have been desirable, a single trawl appears to provide sufficient data to characterize the epibiota of a station and allow comparison among stations.

In general, sufficient numbers of photographs (100) were analyzed to level the species saturation curves for photographic data. The main shortcoming of the photographic data was not sampling inadequacy but inability to identify the epibiota to species. In most cases, less than half of the biotic cover was identifiable to species in the remote benthic photographs (see Table 5.30), although about 60% to 90% was



NOTE: EACH CURVE REPRESENTS THE MEAN OF SIX PERMUTATIONS OF THE DREDGE SAMPLES.

LEGEND

- STATION 44
- STATION 45
- STATION 47
- STATION 51
- STATION 52

FIGURE 5.24. SPECIES SATURATION CURVES FOR DREDGE DATA.

identifiable to genus. The data provide useful estimates of relative abundance of epibiota but are not amenable to techniques such as cluster analysis due to the inconsistent level of identification.

In Situ vs. Remote Sampling. Because the Year 3 stations were in water depths accessible to divers, both remote and in situ sampling methods could be used and compared. The remote sampling methods and their in situ counterparts are as follows:

1) Dredge sampling and quadrat harvesting.
2) Trawl sampling and fish counts.
3) Remote and in situ benthic photography.

Table 5.40 shows that comparable numbers of species were captured by dredge and quadrat sampling at each station. As discussed above, both figures are underestimates of total species richness because there were too few samples to level the species saturation curve. Both data sets have other shortcomings. Dredge sampling typically misses many small, cryptic species that are more effectively sampled by quadrat harvesting. On the other hand, although quadrat harvesting yields representative data for the patch in which the quadrats were collected, the data may not be very representative of the station as a whole. This is illustrated by data from quadrats and dredges at Station 52, where the largest number of dredge samples was collected. Despite the lower degree of species saturation in the dredge data, the total number of species identified from the dredges was higher, both at Station 52 and over all stations (Table 5.40). This is due to the larger area encompassed by dredge sampling. The larger area sampled results in a higher probability of encountering rare species and also of sampling species from different habitats (e.g., different patches of live and soft bottom).

Quadrat harvesting provided valuable data, including counts for some organisms, relative frequency of occurrence values for others, and biomass values for major groups. However, this approach is limited in applicability to other live-bottom areas. One obvious restriction is that of water depth; the area must be shallow enough to be accessible to divers who can stay on the bottom long enough to harvest quadrats. Also, both the collection and laboratory processing of the samples are very labor intensive.

Trawl sampling and fish counts provided complementary data concerning fish populations associated with live bottom. Trawling could

TABLE 5.40. COMPARISON OF DREDGE AND QUADRAT SPECIES RICHNESS.

Station	Number of Species Collected	
	Dredge	Quadrat
44	215	212
45	224	234
47	250	182
51	224	211
52	234* (286†)	232
TOTAL	539	449

*Night dredges only
†Night and day dredges combined.

not be conducted effectively in areas of dense live bottom due to the resulting damage to the net; consequently, many of the species captured are associated primarily with soft bottom or are reef species that move away from dense live bottom to forage at night. Mid-water foragers also were not effectively trawled. The fish counts revealed a larger number of primary reef species. Many of the fishes seen by divers but not collected in trawls are either mid-water foraging species (e.g., jacks) or primary reef species that do not stray far from dense live bottom (e.g., butterflyfishes, damselfishes, wrasses).

Neither fish sampling technique allows quantitative assessment of fish populations. Partly, this is due to insufficient sampling effort to encompass the spatial and temporal variability of fish populations. Also, it is not possible to standardize the trawl sampling effort because we do not accurately know the distance trawled or at what point during a trawl the net became full.

Remote and in situ (quadrat) photography produced similar results. Differences in percent cover estimates were apparent at Station 44 where the patch of live bottom sampled by divers during Cruise II was more sparse than the station as a whole and the area sampled by divers during Cruise III was more dense than the station as a whole. A higher percentage of biotic cover was identified to species in the in situ photographs (Table 5.30). However, the breadth of coverage and the ease of obtaining a large number of photographs using the towed camera system outweigh the disadvantage of a lower percentage of identification to species.

Dodge et al. (1982) reported that several commonly used methods for estimating percent cover of reef species produce very similar results. Discrepancies between our line-intercept and quantitative slide analysis results probably are due more to spatial variability within stations than to methodology differences. Quantitative slide analysis was performed on photographs taken remotely over a large area or by divers at randomly scattered quadrats. In contrast, the line-intercept analysis was used on photographs from a single 10-m transect at each station. The transects were more likely to fall within (or outside of) a particular live-bottom patch and produce results atypical of the station area as a whole.

5.4.5 Conclusions

The following conclusions can be drawn from results of sampling at five live-bottom stations during fall 1982 and spring 1983:

1) The incidence of live bottom noted along television transects surveyed at each station ranged from 79% to 100%. Areas classified as live bottom ranged considerably in density of epibiota and typically were interspersed with patches of sand with few attached epibiota.

2) Percent cover within live-bottom patches, estimated from quantitative analysis of benthic still photographs ranged from 15% to 49%, with gorgonians, sponges, and algae being the major cover contributors.

3) The total numbers of species identified were 539 from dredges, 280 from trawls, and 449 from harvested quadrats. Molluscs, crustaceans, sponges, and algae together accounted for about two-thirds of the total in the dredge collections and over one-half in the trawl collections. Fishes accounted for about 20% of the species trawled.

4) Frequently collected sessile epibiota included sponges (Anthosigmella varians, Cinachyra alloclada, Geodia gibberosa), scleractinian corals (Phyllangia americana, Siderastrea radians, Solenastrea hyades), and algae (Dictyopteris jamaicensis, Udotea conglutinata). Frequently collected motile epifauna included hermit crabs (Paguristes tortugae, Petrolisthes galathinus) and brittle stars (Ophiothrix suensonii, O. angulata).

5) Most of the fishes collected in trawl samples are sand dwellers or secondary reef species (those that occur on hard bottom but are equally or more typical of sand bottom). Examples are planehead filefish (Monacanthus hispidus) and scrawled cowfish (Lactophrys quadricornis). Common primary reef dwellers in the trawls included white grunt (Haemulon plumieri) and jackknifefish (Equetus lanceolatus). In contrast, most of the fishes seen in visual counts by divers were primary reef dwellers, including several butterflyfishes, damselfishes, wrasses, and snappers. Fishes closely associated with dense hard-bottom areas are not effectively sampled by trawling.

6) Biomass of epibiota in harvested quadrats ranged from 624 to 4,324 g wet wt m^{-2}. Sponges were the major biomass contributors (average 58% of total). Gorgonians were also

significant biomass contributors (especially at Station 45), and algae were significant during fall at Stations 51 and 52.

7) Biomass and cover of sessile epifauna such as hard corals, gorgonians, and sponges were greater at stations where the sediment veneer was thin (1 to 2 cm) than at stations where the veneer was thick (4 to 5 cm or greater).

8) Species composition of epibiota varies apparently in relation to water depth and/or sediment thickness, which are positively correlated among the stations studied. Where the sand veneer overlying hard bottom is thicker than a few centimeters, the underlying substratum probably is infrequently exposed and sessile epibiota typical of hard-bottom areas have little chance to become established.

5.5 COMPARISON AND INTEGRATION WITH YEAR 1 AND 2 DATA

Year 3 data have been presented and discussed in the preceding sections. Here we summarize the combined data set from Year 1, 2, and 3 live-bottom stations.

Figure 5.25 shows locations of all live-bottom stations sampled during Year 1 and 2 or Year 3. Table 5.41 lists the respective water depths and sampling dates for the stations. During Year 1, 15 stations in water depths of 20 to 77 m were sampled during fall and spring. During Year 2, five Year 1 stations were replaced by new stations in water depths of 127 to 159 m; these new stations and the remaining Year 1 stations were sampled during summer and winter. During Year 3, five new stations in water depths of 10 to 19 m were sampled during fall and spring.

Most sampling at the live-bottom stations was comparable during the three study years: on each sampling date, three dredge samples and one trawl sample were collected and a television/still camera survey was conducted. Results can be used to characterize live-bottom epibiota of the southwest Florida shelf and to evaluate spatial patterns in species richness and composition of the epibiota. Data from quadrats, which were harvested at the Year 3 stations only, provide useful supplementary information.

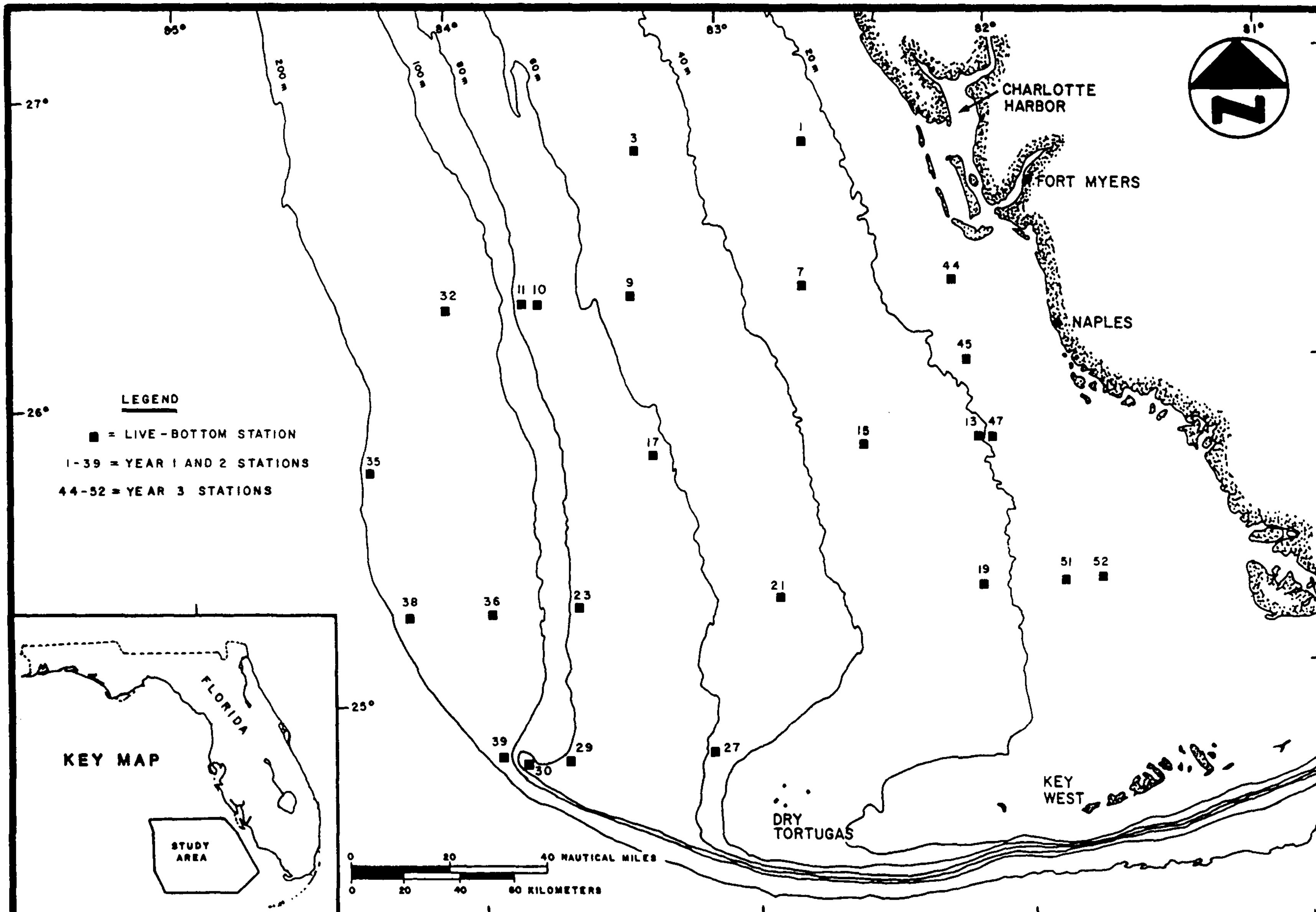


FIGURE 5.25. LOCATIONS OF LIVE-BOTTOM STATIONS SAMPLED DURING YEARS 1, 2, AND 3.

TABLE 5.41. WATER DEPTHS AND SAMPLING DATES FOR YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

Station	Water Depth (m)	Sampling Date*: Year 1 Cruises III	Year 1 Cruises IV	Year 2 Cruises II	Year 2 Cruises III	Year 3 Cruises II	Year 3 Cruises III
1	24	X	X	X	X		
3	50	X	X	X	X		
7	30	X	X	X	X		
9	56	X	X	X	X		
10	71	X	X				
11	77	X	X	X	X		
13	20	X	X	X	X		
15	32	X	X	X	X		
17	58	X	X				
19	22	X	X				
21	44	X†	X	X	X		
23	70	X	X	X	X		
27	54	X	X				
29	62	X	X	X	X		
30	76	X	X				
32	137			X	X		
35	159			X	X		
36	127			X	X		
38	159			X	X		
39	152			X§	X§		
44	13					X	X
45	17					X	X†
47	19					X	X
51	15.5					X	X
52	13.5					X	X

Except where noted otherwise, three dredge samples and one trawl sample were collected at each station each time it was sampled.

*Sampling dates:
Year 1, Cruise III = October-November 1980
Year 1, Cruise IV = April-May 1981
Year 2, Cruise II = July-August 1981
Year 2, Cruise III = January-February 1982
Year 3, Cruise II = December 1982
Year 3, Cruise III = May-June 1983.

†No trawl sample.

§Due to steep terrain at Station 39, samples were collected using rock dredge only (data not included here).

5.5.1 Television and Still Camera Observations

Television and still camera photography produce different types of information due to differences in photographic analysis methods and taxonomic resolution. Television videotapes were in black-and-white, and they were analyzed in approximately 15-m intervals along each transect surveyed. Taxonomic resolution on the videotapes is poor, and the main value of the television surveys is to provide an estimate of the overall percentage occurrence of live bottom at a station. Analysis of color still photographs by quantitative slide analysis (with exclusion of images containing few or no epibiota) provides estimates of percent cover and taxonomic composition of the epibiota within live-bottom patches.

Table 5.42 summarizes television and still camera photography results from the live-bottom stations; for details, see Chapters 5 and 6 of the Year 2 final report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985) and Section 5.3 of this report. The table also provides assemblage designations for each station based on visual observations during the broad scale habitat mapping surveys (Chapter 4). The assemblages, which are simply visual designations developed for broad-scale mapping purposes, provide a convenient framework for discussing and comparing station characteristics. The grouping of stations on the basis of the assemblages is shown in Figure 5.26.

The five Year 3 stations (44, 45, 47, 51, and 52) and two Year 1 and 2 stations (13 and 19) classified as Inner Shelf Live Bottom Assemblage I are located in water depths of 13 to 22 m (Figure 5.26). Large, conspicuous gorgonians are the distinguishing feature of the assemblage, and gorgonians contributed a significant proportion of total biotic cover at most stations except Station 19, which was the deepest of the stations in this group (22 m). The incidence of live bottom was high at the five Year 3 stations, but lower at the deeper Year 2 stations (Table 5.42). Percent cover typically was about 20% except at Station 45 (40%), and seasonal algal blooms accounted for higher cover percentages during summer or fall at Stations 13, 51, and 52. In general, these stations can be described as areas of widespread, thin to moderately dense, gorgonian-algal-sponge live bottom.

Eight of the Year 1 and 2 stations in water depths of 24 to 58 m are in areas designated as the Inner and Middle Shelf Live Bottom Assemblage II (Figure 5.26). The assemblage was recognized on the basis of a large diversity of sponges and the absence of the gorgonians

TABLE 5.42. SUMMARY OF TELEVISION AND STILL CAMERA DATA FROM YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

Station	Water Depth (m)	Assemblage*	Live-Bottom Incidence† (%)	Percent Biotic Cover§ Spring	Summer	Fall	Winter	Major Cover Contributors
1	24	Inner-Middle Shelf II	57	20	27	15	13	Algae, sponges
3	50	Inner-Middle Shelf II	34	17	19	8	13	Sponges, algae, ascidians
7	30	Inner-Middle Shelf II	29	16	18	15	14	Sponges, algae
9	56	Inner-Middle Shelf II	80	15	19	16	13	Algae (e.g., *Halimeda*), bryozoans
10	71	Middle Shelf Algal Nodule	55	22	--	11	--	Algae (e.g., *Peyssonnelia*), sponges
11	77	Middle Shelf Algal Nodule	57	7	31	13	15	Algae (e.g., *Peyssonnelia*), sponges
13	20	Inner Shelf I	42	22	60	19	22	Gorgonians, algae, sponges
15	32	Inner-Middle Shelf II	58	20	50	19	30	Sponges, algae
17	58	Inner-Middle Shelf II	24	8	--	16	--	Algae (e.g., *Halimeda*), sponges, bryozoans
19	22	Inner Shelf I	35	14	--	20	--	Sponges, algae (e.g., *Caulerpa*), gorgonians
21	44	Inner-Middle Shelf II	74	20	57	18	23	Sponges, algae
23	70	Middle Shelf Algal Nodule	97	37	68	34	26	Algae (e.g., *Peyssonnelia*, *Anadyomene*)
27	54	Inner-Middle Shelf II	14	12	--	8	--	Sponges, algae (e.g., *Caulerpa*, *Halimeda*)
29	62	*Agaricia* Coral Plate	100	80	90	64	75	Algae (e.g., *Anadyomene*, *Peyssonnelia*), hard coral (*Agaricia*)
30	76	Middle Shelf Algal Nodule	100	50	--	48	--	Algae (e.g., *Peyssonnelia*, *Anadyomene*), sponges
32	137	Outer Shelf Crinoid	49	--	9	--	8	Sponges, crinoids
35	159	Outer Shelf Low Relief	90	--	21	--	6	"Algae," sponges, antipatharians
36	127	Outer Shelf Crinoid	32	--	9	--	14	Crinoids, sponges, antipatharians
38	159	Outer Shelf Low Relief	100	--	16	--	11	"Algae," crinoids, sponges
44	13	Inner Shelf I	92	15	--	18	--	Sponges, gorgonians, algae
45	17	Inner Shelf I	100	39	--	41	--	Gorgonians, sponges
47	19	Inner Shelf I	88	21	--	17	--	Gorgonians, sponges
51	16	Inner Shelf I	84	21	--	49	--	Algae, seagrass, sponges, gorgonians
52	14	Inner Shelf I	79	22	--	39	--	Algae, sponges, gorgonians

*Each station was selected as representative of a visually distinct live-bottom type or "assemblage." See Section 4.0 for assemblage descriptions.

†Live-bottom incidence values are from television surveys within a 1 km^2 block around the station center. Incidence was estimated by categorizing the seafloor within 15-s intervals of videotape (approximately 15 m linear distance) over a total transect length of several kilometers per station. Values were averaged over all cruises.

§Percent cover values are from quantitative slide analysis of still photographs. Slides showing very low biotic cover (subjectively estimated as <5%) were excluded from analysis; thus, the values are representative of live-bottom patches within a station. See Table 5.41 for sampling dates.

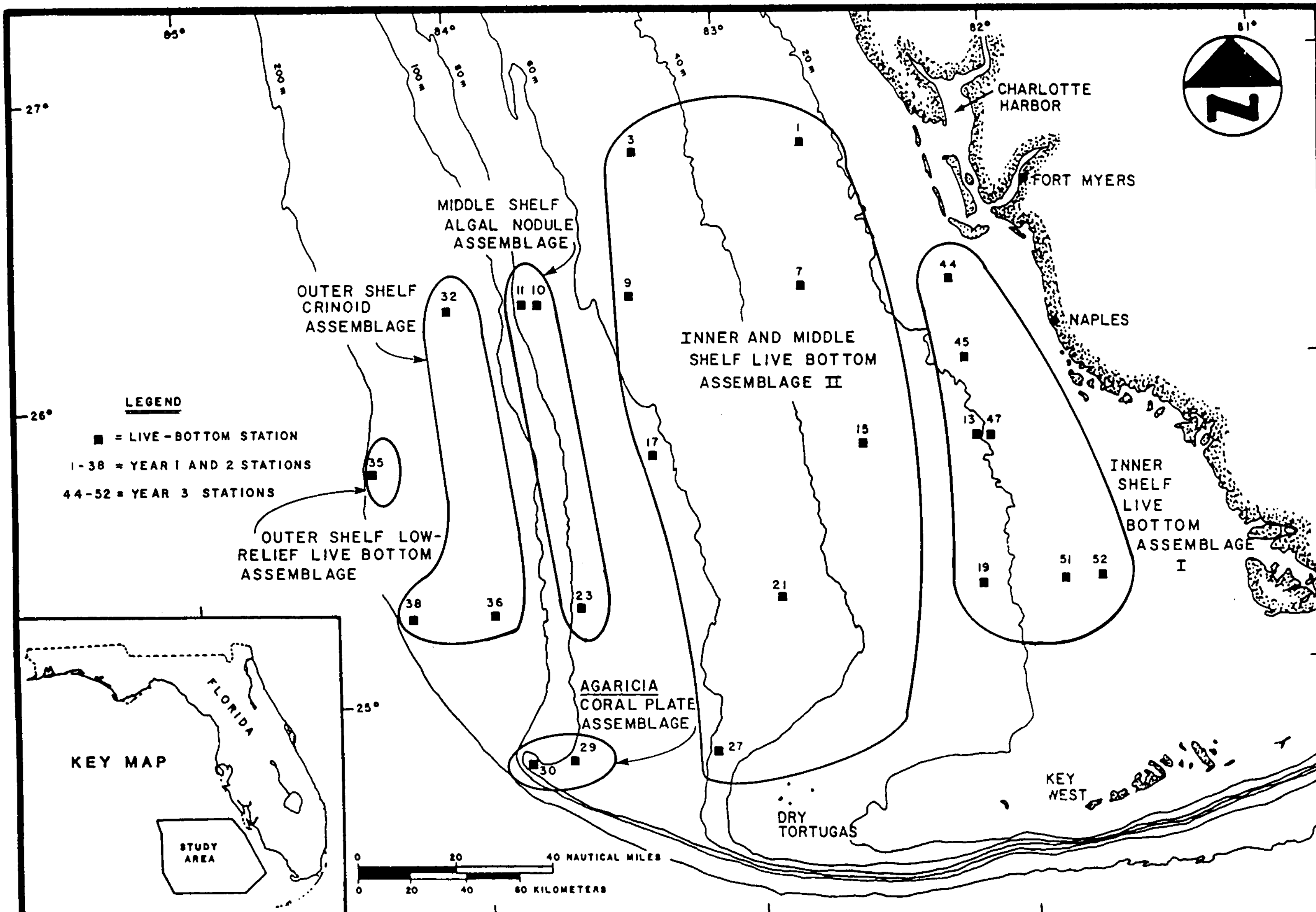


FIGURE 5.26. STATION GROUPINGS BASED ON VISUALLY DISTINCT ASSEMBLAGES RECOGNIZED DURING TELEVISION/STILL CAMERA SURVEYS.

characteristic of nearshore stations. The incidence of live bottom at these stations generally was lower than at those near shore, but the percent cover within live-bottom patches was about the same. Sponges were the primary cover at many of these stations (Table 5.42), and seasonal algal blooms were also important at some stations. The range of sponge vs. algal dominance is illustrated by Station 1, where various algae accounted for over 65% of the biotic cover during all seasons, and Stations 15 and 21, where algae contributed over 70% of the cover during summer and sponges contributed over 60% of the cover during all other seasons. At the deeper stations within this group (e.g., 3, 9, 17, and 27), algal cover was not as seasonal and the calcareous green alga Halimeda was very characteristic.

Stations 10, 11, and 23 are in areas designated as Middle Shelf Algal Nodule Assemblage (Figure 5.26). The stations are in the depth range of 70 to 77 m. The substrate at these stations consists of nodules formed by coralline algae (Lithothamnium, Lithophyllum). At Stations 10 and 11, the nodules were relatively sparse and live-bottom incidence was about 50 to 60%, whereas at Station 23 the nodules were dense and live-bottom incidence was 97%. Red algae in the order Cryptonemiales, including Peyssonnelia rubra and P. simulans, were major cover contributors. The leafy green alga Anadyomene menziesii also was a major cover contributor at Station 23. There was little seasonal variation in the percent cover of Anadyomene or Peyssonnelia.

Stations 29 and 30 are located in an area referred to as the Agaricia Coral Plate Assemblage. The substrate was formed by coralline algal nodules fused into a continuous crust, and the incidence of live bottom was 100% at both stations. Biotic cover was high and relatively consistent seasonally. The same algal species seen at Station 23, Anadyomene menziesii and Peyssonnelia spp., accounted for most of the total. In addition, plates of living hard coral (Agaricia spp.) covered a large area at Station 29, though percent cover values were only about 12% because the plates typically were obscured by leafy algae. Agaricia also occurred at Station 30, but was much less abundant than at Station 29. Station 30, at 77 m depth, was located near the maximum depth range of the algal pavement-Agaricia coral plate bottom type.

Stations 32, 36, and 38 are located in areas characterized as the Outer Shelf Crinoid Assemblage. Comatulid crinoids occurring on low relief outcrops or shell rubble were the conspicuous epibiota. (In the Marine Habitat Atlas [Woodward-Clyde Consultants and Continental Shelf

Associates, Inc., 1983b], Station 38 is shown within an area characterized as Outer Shelf Low-Relief Live Bottom Assemblage; however, when the station was surveyed during Year 2 sampling cruises, crinoids associated with shell rubble were the conspicuous feature of the seafloor.) The incidence of live bottom was moderate (30 to 50%), but percent cover within live-bottom patches was very low (about 10%).

Station 35, which at 159 m was the deepest live-bottom station, was in an area designated as Outer Shelf Low Relief Live Bottom Assemblage. These are areas of low-relief outcrops and shell rubble that support a sparse attached epibiota. Hexactinellid sponges and antipatharians are conspicuous components. Encrustations noted in some photographs from the Year 2 summer cruise were classified as "unidentified green algae" and also contributed a significant proportion of total biotic cover.

Another habitat type recognized on the outer shelf was the Outer Shelf Prominences Live Bottom Assemblage. Prominences are high-relief (several meters) features protruding through thick sand at certain locations on the outer shelf, particularly the seaward end of Transect C and the northern end of Transect L (see Chapter 4). Because of the rugged topography, no stations were sampled in the prominence areas.

5.5.2 Dredge and Trawl Collections

A total of 1,497 species was collected by dredge and trawl during the three years. Figure 5.27 shows the phyletic breakdown of species richness for combined dredge and trawl data. Molluscs contributed the largest number of species (306), followed by crustaceans (283) and fishes (220). The number of sponge species (94) is certainly an underestimate of the true total, as numerous specimens could not be identified to species.

Tables 5.43 and 5.44 show the taxonomic composition of dredge and trawl collections from the 24 live-bottom stations (Station 39, the 25th station, was sampled only by rock dredge and the results are not included here). The total number of dredge-collected species ranged from 97 to 341, and the number of trawl-collected species ranged from 59 to 259. Generally, dredge samples contained large numbers of crustacean, mollusc, and algal species, whereas fishes and crustaceans were the most speciose groups in the trawl collections. Most of the species collected in trawls were also collected in dredges, with the dredge species list accounting

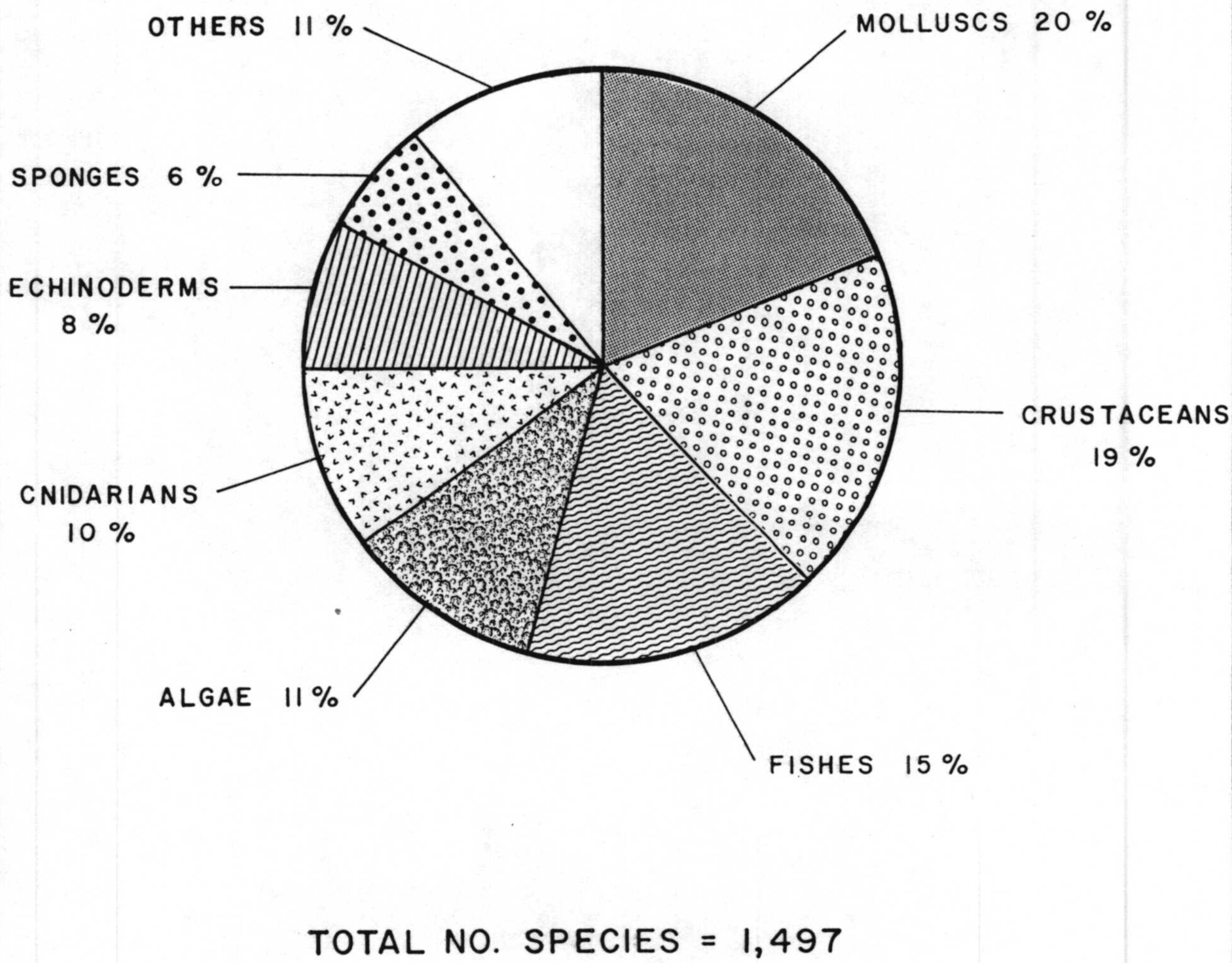


FIGURE 5.27. TAXONOMIC COMPOSITION OF THE COMBINED DREDGE AND TRAWL DATA SET FROM YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

TABLE 5.43. TAXONOMIC COMPOSITION OF DREDGE COLLECTIONS FROM YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

	No. of Species Identified								
Station	Algae	Sponges	Cnidarians	Crustaceans	Molluscs	Echinoderms	Fishes	Others	Total
1	69	14	13	61	60	22	29	42	310
3	29	31	29	70	82	24	26	50	341
7	47	24	30	64	78	14	22	37	316
9	30	4	13	78	64	26	25	40	280
10	14	20	15	49	20	22	17	22	179
11	20	19	19	63	37	24	12	32	226
13	39	26	27	68	75	28	27	35	325
15	25	42	23	70	67	16	23	26	292
17	16	21	12	58	60	22	24	35	248
19	19	18	12	51	42	22	18	15	197
21	35	45	15	73	62	17	22	31	300
23	22	15	13	37	31	28	11	14	171
27	8	19	12	44	39	18	18	28	186
29	17	26	31	15	27	33	15	31	195
30	8	21	20	23	8	17	14	18	129
32	2	6	12	33	18	20	11	15	117
35	1	3	26	15	14	21	5	12	97
36	2	4	30	33	22	23	8	10	132
38	1	3	22	20	13	23	3	12	97
44	8	53	23	47	38	16	9	21	215
45	26	55	24	35	43	12	5	24	224
47	22	31	20	60	52	17	22	26	250
51	25	52	23	41	36	10	5	32	224
52	25	48	21	43	42	9	3	43	234
All Stations	153	93	145	253	291	108	135	152	1,330

TABLE 5.44. TAXONOMIC COMPOSITION OF TRAWL COLLECTIONS FROM YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

Station	No. of Species Identified								
	Algae	Sponges	Cnidarians	Crustaceans	Molluscs	Echinoderms	Fishes	Others	Total
1	32	5	6	15	8	9	21	23	119
3	27	18	17	56	25	14	55	30	242
7	24	17	8	40	17	11	41	25	183
9	31	3	13	63	37	18	54	40	259
10	13	12	11	51	22	11	31	23	174
11	17	13	13	39	12	14	39	18	165
13	15	12	13	35	11	13	40	16	155
15	16	24	9	37	23	7	31	14	161
17	10	24	9	25	14	16	32	28	150
19	13	8	8	28	10	11	27	11	116
21	13	18	2	34	19	10	44	18	158
23	27	16	6	24	11	23	40	9	156
27	9	5	5	21	15	11	31	12	109
29	10	15	21	12	10	21	38	12	139
30	6	12	6	6	1	8	23	4	66
32	2	4	5	22	2	8	27	3	73
35	2	1	10	7	0	16	14	9	59
36	5	2	10	28	4	15	23	3	90
38	1	2	11	24	6	22	17	8	91
44	0	23	7	25	1	8	22	8	94
45	3	20	5	6	8	5	13	6	66
47	5	14	8	29	8	9	27	11	111
51	10	33	5	16	12	6	15	16	113
52	8	29	11	14	4	5	14	16	101
All Stations	106	69	87	189	120	89	192	105	957

for over 90% of the combined dredge + trawl list for all groups but fishes. For example, 93 of the total 94 sponge species were collected by dredge. About 40% of the fish species collected by trawl were not collected by dredge. Thus, the main value of the trawl samples is to characterize fish populations.

There are several notable features in the species richness tables. There was a large number of algal species at Station 1 (45% of the total number of algal species collected by dredge), and (as expected) very few algae were collected at the four outer shelf stations (32, 35, 36, and 38). Many sponge species were collected at the nearshore, Year 3 stations and also at Stations 15 and 21; the low totals at the outer shelf stations are due in part to taxonomic problems (many deepwater sponge specimens were not identifiable to species). Crustaceans and molluscs each typically accounted for 20 to 30% of the total number of species at each station.

The values in Tables 5.43 and 5.44 should not be used to examine broad scale patterns in species richness because some of the variation in the tabulated numbers is due to differences in sampling effort (number of dredges or trawls per station). To take these differences into account, we calculated the total number of species per set of six dredges (the minimum number available for any station). For the Year 3 stations and the outer shelf stations sampled only during Year 2, only six dredges were obtained overall, so the total was the same as listed in Table 5.43. For the 10 stations sampled during both Year 1 and Year 2, separate totals were calculated for each year (six dredges per year) and the values were averaged. As shown in Figure 5.28, species richness generally declined with increasing water depth.

Tables 5.45 and 5.46 list species that were frequently collected in dredge and trawl samples, respectively. Widely occurring species in the dredge samples included the angular brittle star Ophiothrix angulata, the arrow crab Stenorhynchus seticornis, and the ascidian Didemnum candidum. These species were also frequently collected in trawls. Common fish species included fringed filefish, Monacanthus ciliatus, and sand diver, Synodus intermedius. Most of the fishes collected in trawls (with important exceptions discussed below) are sand bottom species or secondary reef dwellers rather than primary reef species.

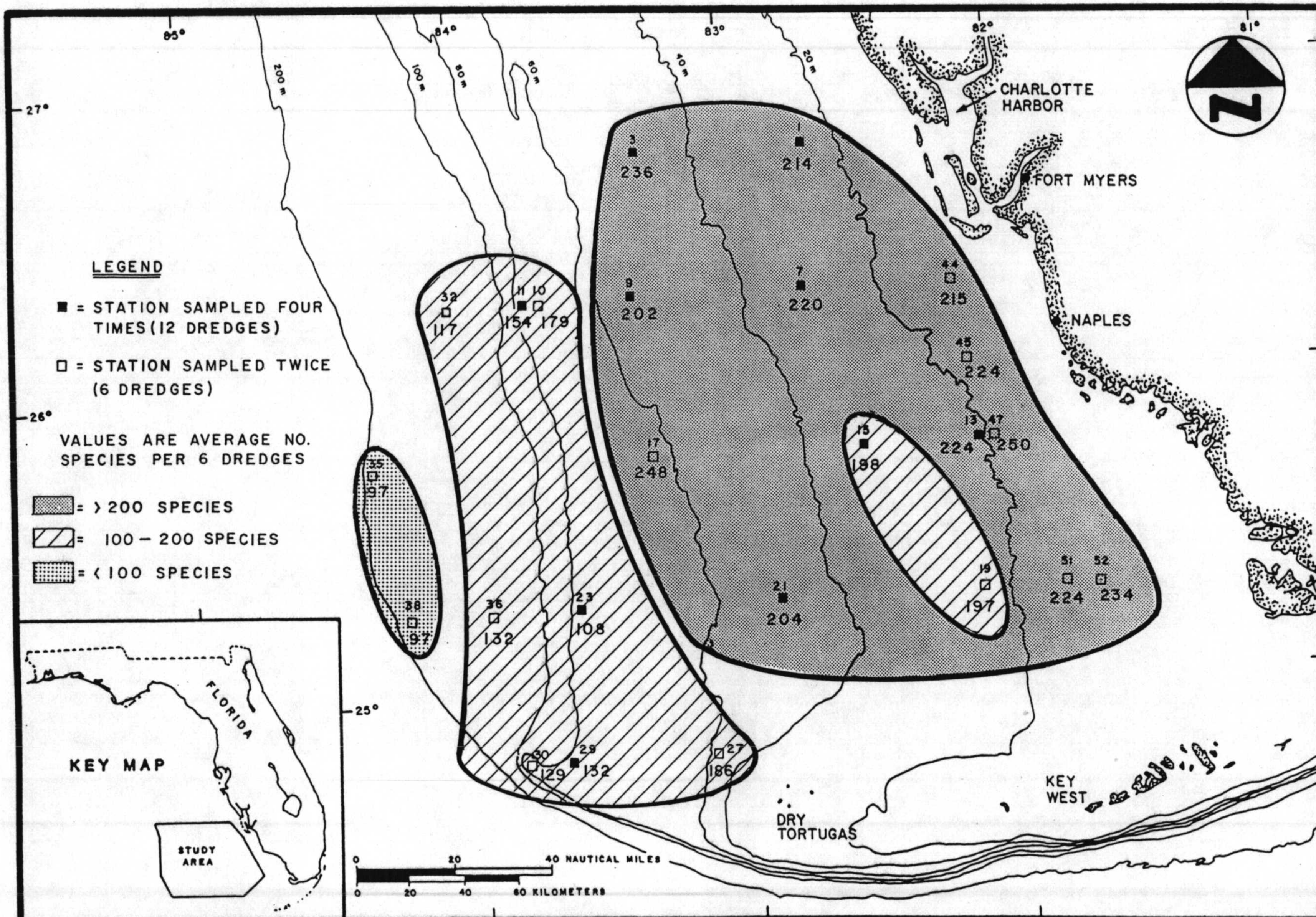


FIGURE 5.28. SPATIAL VARIATION IN SPECIES RICHNESS OF DREDGE COLLECTIONS.

TABLE 5.45. SPECIES COLLECTED BY TRIANGLE DREDGE AT 12 OR MORE OF 24 YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

ALGAE	
Lithothamnium calcareum	(16)
Halimeda gracilis	(14)
Lithothamnium ruptile	(12)
Udotea conglutinata	(12)
BRYOZOANS	
Celleporaria albirostris	(18)
Stylopoma spongites	(18)
Celleporaria magnifica	(17)
Nellia oculata	(13)
Amathia convoluta	(12)
Bugula neritina	(12)
Hippoporidra edax	(12)
Steganoporella magnilabris	(12)
CNIDARIANS	
Eudendrium carneum	(17)
Stephanoscyphus corniformis	(15)
Phyllangia americana	(13)
Thyroscyphus marginatus	(13)
CRUSTACEANS	
Stenorhynchus seticornis	(23)
Dromidia antillensis	(19)
Metapenaeopsis goodei	(16)
Phimochirus holthuisi	(16)
Synalpheus townsendi	(16)
Paguristes sericeus	(15)
Pagurus brevidactylus	(15)
Calappa angusta	(13)
Parthenope fraterculus	(13)
Mithrax (Mithrax) pleuracanthus	(13)
Gonodactylus bredini	(12)
Synalpheus pandionis	(12)
ECHINODERMS	
Ophiothrix angulata	(24)
Arbacia punctulata	(17)
Clypeaster subdepressus	(15)
Ophioderma brevispinum	(15)
Astropecten duplicatus	(14)
Ophiolepis elegans	(14)
Ophiostigma isocantha	(14)
Lytechinus variegatus carolinus	(13)
FISHES	
Monacanthus ciliatus	(16)
Scorpaena brasiliensis	(13)
Opsanus pardus	(12)
MOLLUSCS	
Vermicularia knorii	(17)
Laevicardium pictum	(15)
Chicoreus florifer	(14)
Oliva circinata	(14)
Murex rubidus	(13)
Turritella acropora	(12)
SPONGES	
Cinachyra alloclada	(19)
Ircinia strobilina	(19)
Placospongia melobesioides	(18)
Aiolochroia crassa	(15)
Anthosigmella varians	(15)
Aplysina fistularis v. fulva	(14)
Geodia gibberosa	(13)
Haliclona compressa	(13)
Niphates erecta	(13)
Homaxinella waltonsmithi	(12)
Ircinia felix	(12)
Pseudaxinella lunaecharta	(12)
UROCHORDATES	
Didemnum candidum	(21)
Eudistoma capsulatum	(14)

Values are in parentheses are number of stations at which the species was collected (out of 24 possible).

TABLE 5.46 SPECIES COLLECTED BY OTTER TRAWL AT 10 OR MORE OF 24 YEAR 1, 2, AND 3 LIVE-BOTTOM STATIONS.

BRYOZOANS	
Celleporaria albirostris	(12)
CRUSTACEANS	
Stenorhynchus seticornis	(19)
Dromidia antillensis	(12)
Mithrax (Mithrax) pleuracanthus	(12)
Metapenaeopsis goodei	(10)
Synalpheus townsendi	(10)
ECHINODERMS	
Ophiothrix angulata	(18)
Arbacia punctulata	(11)
FISHES	
Monacanthus ciliatus	(18)
Synodus intermedius	(15)
Serranus phoebe	(12)
Synodus poeyi	(12)
Serranus notospilus	(10)
Syacium papillosum	(10)
SPONGES	
Cinachyra alloclada	(14)
Placospongia melobesioides	(13)
Ircinia strobilina	(13)
UROCHORDATES	
Didemnum candidum	(17)

Values in parentheses are number of stations at which the species was collected (out of 24 possible).

5.5.3 Cluster Analyses

Separate cluster analyses were conducted for dredge and trawl data. For the dredge data, one analysis was conducted using the entire data set (all taxonomic groups) and one each was conducted using only algae, bivalves, cnidarians, crustaceans, echinoderms, or sponges. For the trawl data, there was one analysis using the entire data set and one using only fishes.

Presence/absence data from individual dredge or trawl samples at a station were converted to relative frequency-of-occurrence data (i.e., if a species occurred in 6 of 12 dredges its relative frequency-of-occurrence at that station was 0.5). With two exceptions, all available dredge and trawl samples from each station were included in the analysis. The exceptions were: (1) Station 52--dredge and trawl samples collected during the daytime for evaluation of diel differences were excluded and (2) Station 51--dredge and trawl data samples from a soft-bottom/algal area sampled during Cruise II were excluded. Because none of the stations were sampled on all six cruises and only ten Year 1 and 2 stations were sampled more or less synoptically during four cruises, we did not conduct separate "seasonal" analyses. Results of seasonal analyses of Year 1 and 2 dredge and trawl data are presented by Woodward-Clyde Consultants and Continental Shelf Associates, Inc. (1985).

Only organisms identified to species were included in the analyses. Due to computer program limitations, it was necessary to truncate the data base when the number of species exceeded 255. This was the case in both dredge and trawl "all biota" analyses. The data base was truncated in the following manner. Species were ranked in order of number of stations where they were collected. To ensure that each species had an equal chance of being represented in the list despite differences in sampling effort at the various stations, an "occurrence" was defined as presence of the species in at least 1/6 of the dredges or 1/2 of the trawls taken at that station (these being the minimum possible frequencies of occurrence at the stations sampled the fewest times). To be included in the dredge "all biota" analysis, a species had to occur at 6 or more of 24 stations. To be included in the trawl "all biota" analysis, a species had to occur at 4 or more of 24 stations. Of 1,330 species collected by dredge, 225 were included in the analysis; of 957 species collected by trawl, 176 were included in the analysis.

Cluster analyses were conducted using EAP procedure DENDRO (Smith, 1979) with the Bray-Curtis index as the similarity measure. Agglomerative, hierarchical clustering was performed using flexible sorting with $\beta = -0.25$. Both normal and inverse clustering were conducted. The outputs were station and species dendrograms and ordered two-way occurrence tables.

Results--Dredge Samples. The analyses for all taxonomic groups, algae, crustaceans, cnidarians, echinoderms, molluscs, and sponges are presented separately below. Two-way occurrence tables are too lengthy to be presented here but are provided in Appendix L. Summary tables listing representative species groupings are included in the text.

Two terms used below are "fidelity" and "constancy." Fidelity refers to the degree to which a species occur primarily at stations within the group rather than elsewhere. Constancy refers to the degree to which a species occurs at all stations in the group rather than one or two. In a formal nodal analysis, these terms are defined quantitatively (Boesch, 1977). Here, we use the terms qualitatively.

All Biota -- Overall species composition varied primarily in relation to water depth and/or distance from shore (Figure 5.29). Three major station groups emerged from the dredge cluster analysis of combined taxonomic groups (Figures 5.30). There is an inner shelf group that consists of stations in water depths of 44 m or less; this group can be further subdivided into those in water depths less than 19 m (Stations 44, 45, 51, and 52) and those in water depths of 19 to 44 m (Stations 1, 7, 13, 15, 19, 21, and 47). A middle shelf group consists of stations in water depths of 50 to 77 m; this group can be subdivided into those in 50 to 58 m water depth (Stations 3, 9, 17, and 27) and those in 62 to 77 m water depth (Stations 10, 11, 23, 29, and 30). Finally, there is an outer shelf station group that includes the four stations in water depths greater than 100 m (Stations 32, 35, 36, and 38). Subdivisions of the outer shelf group are not evident at the same level of dissimilarity as for the inner and middle shelf groups (Figure 5.30). This may be due in part to the exclusion of some outer shelf species from the analysis (there were only four outer shelf stations, but a species had to occur at six or more stations to be included).

Table 5.47 lists representatives of selected species groupings from the inverse cluster analysis along with their station/depth

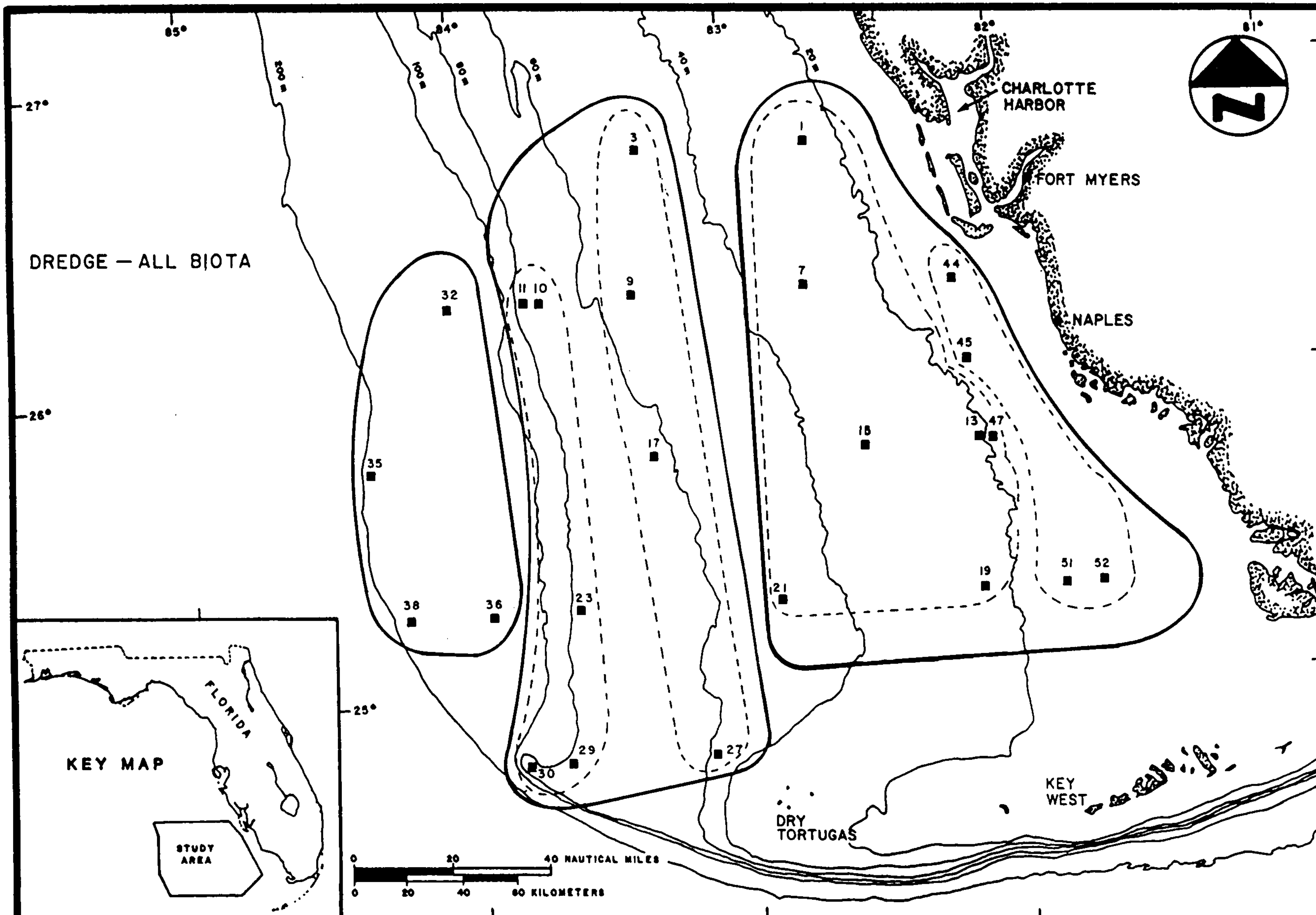


FIGURE 5.29. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, ALL BIOTA.

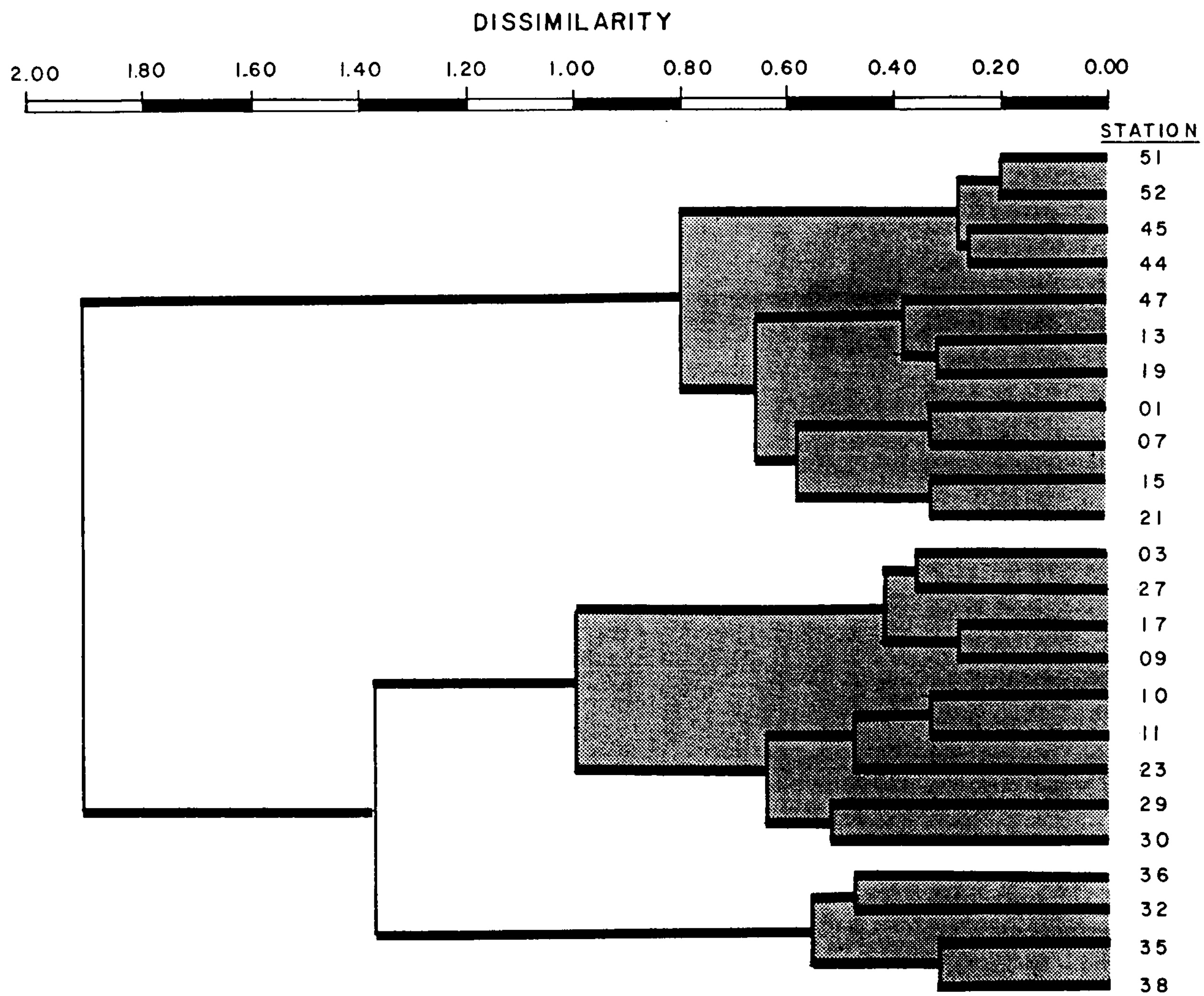


FIGURE 5.30. DENDROGRAM FROM CLUSTER ANALYSIS OF DREDGE DATA, ALL BIOTA.

TABLE 5.47. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, ALL PHYLETIC GROUPS.

Group	Representative Species	Station/Depth Affinities*
A	*Axinella bookhouti* (S) *Cinachyra kuekenthali* (S) *Igernella notabilis* (S) *Pterogorgia guadalupensis* (Cn)	Stations in depths < 19 m
B	*Iliacantha intermedia* (C) *Lobopilumnus agassizi* (C) *Scyllarus americanus* (C) *Sicyonia typica* (C)	Stations in depths of 19 to 44 m
C	*Arca zebra* (M) *Botryocladia occidentalis* (A) *Cladocora arbuscula* (Cn) *Gonodactylus bredini* (C) *Gracilaria debilis* (A) *Hypoconcha sabulosa* (C) *Laurencia intricata* (A) *Mithrax (Mithraculus) forceps* (C) *Paguristes punticeps* (C) *Pilumnus sayi* (C) *Podochela riisei* (C) *Serranus subligarius* (F) *Siderastrea radians* (Cn) *Solenastrea hyades* (Cn) *Spheciospongia vesparium* (S) *Udotea conglutinata* (A)	Stations in depths ≤ 44 m
D	*Aglaophenia elongata* (Cn) *Cypraea spurca acicularis* (M) *Eucidaris tribuloides tribuloides* (E) *Genocidaris maculata* (E) *Geodia neptuni* (S) *Mithrax (Mithrax) acuticornis* (C) *Peyssonnelia rubra* (A) *Peyssonnelia simulans* (A) *Steganoporella magnilabris* (B) *Stephanoscyphus corniformis* (Cn)	Stations in depths of 50 to 77 m
E	*Arbacia punctulata* (E) *Celleporaria albirostris* (B) *Cinachyra alloclada* (S) *Dromidia antillensis* (C) *Eudendrium carneum* (Cn) *Placospongia melobesioides* (S) *Stylopoma spongites* (B)	Stations in depths ≤ 77 m

TABLE 5.47. (CONTINUED).

Group	Representative Species	Station/Depth Affinities*
F	Echinolampas depressa (E) Micropanope sculptipes (C) Ophiomyxa flaccida (E) Parthenope fraterculus (C) Stylocidaris affinis (E) Tosia parva (E)	Stations in depths of 50 to 159 m
G	Comactinia meridionalis (E) Neocomatella pulchella (E) Ophioplax sp. B (E) Rhodochirus rosaceus (C)	Stations in depths of 127 to 159 m
H	Didemnum candidum (U) Ophiothrix angulata (E) Stenorhynchus seticornis (C)	Stations in all depths

A = alga
B = bryozoan
Cn = cnidarian
C = crustacean
E = echinoderm
F = fish
M = mollusc
S = sponge
U = urochordate (ascidian)

*Refer to Table 5.41 for a list of station depths.

affinities from the ordered two-way occurrence tables. The inner shelf stations were characterized by a large number of species with high fidelity and constancy for the station group. Among these inner shelf species are several hermit crabs (Paguristes punticeps, P. tortugae), seasonal algae (Gracilaria debilis, Laurencia intricata, Udotea conglutinata), scleractinian corals (Cladocora arbuscula, Phyllangia americana, Siderastrea radians, Solenastrea hyades), the bivalve mollusc Arca zebra, and the loggerhead sponge Spheciospongia vesparium. Both subgroups with the inner shelf group were distinguished by several additional characteristic species. The nearshore (<19 m) stations were characterized by suites of sponge and gorgonian species. Due to a limited number of station occurrences, most of the gorgonians were truncated from the species list for this analysis (see the separate discussion of Cnidaria below).

The normal cluster analysis showed distinct inner and middle shelf station groupings. However, several species collected at inner shelf stations also were found at stations in the middle shelf group (≤77 m) (Table 5.47). These widely distributed inner/middle shelf species included sponges such as Cinachyra alloclada and Placospongia melobesioides, bryozoans such as Celleporaria albirostris and Stylopoma spongites, the hydroid Eudendrium carneum, the purple-spined sea urchin Arbacia punctulata, and the lesser sponge crab Dromidia antillensis.

There was a large number of species with high fidelity and constancy for the middle shelf (50 to 77 m) station group (Table 5.47). Among the cnidarians, the representative middle shelf species were hydroids, such as Aglaophenia elongata, and the polyp stage of the scyphozoan Stephanoscyphus corniformis, rather than the hard corals or gorgonians typical of inner shelf stations. The red algal species, Peyssonnelia rubra and P. simulans, are crustose perennials that contribute significant cover at the algal nodule stations (10, 11, 23, 29, and 30) but also are present at other middle shelf stations. Two sea urchins, Eucidaris tribuloides tribuloides and Genocidaris maculata, also were typical of middle shelf stations.

No species included in the cluster analysis were present only at the outer shelf stations; due to the truncation criteria, species collected only at these four stations would have been deleted from the data base due to a low overall frequency of occurrence. However, some characteristic outer shelf species are listed in Table 5.47. Two crinoid species (Comactinia meridionalis and Neocomatella pulchella), an ophiuroid (Ophioplax sp. B), and a pagurid crab (Rhodochirus rosaceus) were very characteristic of outer shelf stations. Most other species collected at the outer shelf stations were either equally or more common at middle shelf stations. Examples of the former are the echinoids Echinolampas depressa and Stylocidaris affinis and the xanthid crab Micropanope sculptipes. Examples of the latter are the ophiuroid Ophiomxya flaccida, the hard coral Madracis asperula, and the parthenopid crab Parthenope fraterculus.

Algae -- Figure 5.31 summarizes normal cluster analysis results for algae collected by dredge. Distinct inner, middle, and outer shelf groups are evident. The main difference from the "all biota" analysis is that Stations 23, 29, and 30 did not cluster with the other stations (10 and 11) in their depth range (60 to 80 m), indicating a north-south gradient in algal species composition on the middle shelf. Also, in the algal analysis, Station 21 grouped with the middle shelf stations rather than the inner shelf stations. This suggests a break in species composition between 32 and 44 m depth rather than between 44 and 50 m depth.

Table 5.48 presents representative species from inverse cluster analysis results. Distinct algal zonation patterns are apparent. There is a strong inner shelf group; a group of inner-middle shelf species; and a group of middle shelf species. Most of the inner-middle and middle shelf species are calcareous algae (e.g., Halimeda, Lithothamnium, and Peyssonnelia). Among the middle shelf species, Peyssonnelia rubra and P. simulans are cryptonemialid red algae that account for a significant percentage of total biotic coverage at Stations 10, 11, 23, 29, and 30, although also occurring at stations farther inshore (to 44 m). In addition to Peyssonnelia, two species of leafy, green algae (Anadyomene menziesii and a new species of Palmellaceae) were very typical of Stations 23, 29, and 30. Anadyomene menziesii was a major cover contributor at these stations during all seasons (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985).

The major distinguishing feature of outer shelf stations is a lack of algal species due to low light levels. All of the outer shelf stations are located in water depths greater than 100 m, and the 1% (of surface incident) light level is at about 65 to 70 m in the study area (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983).

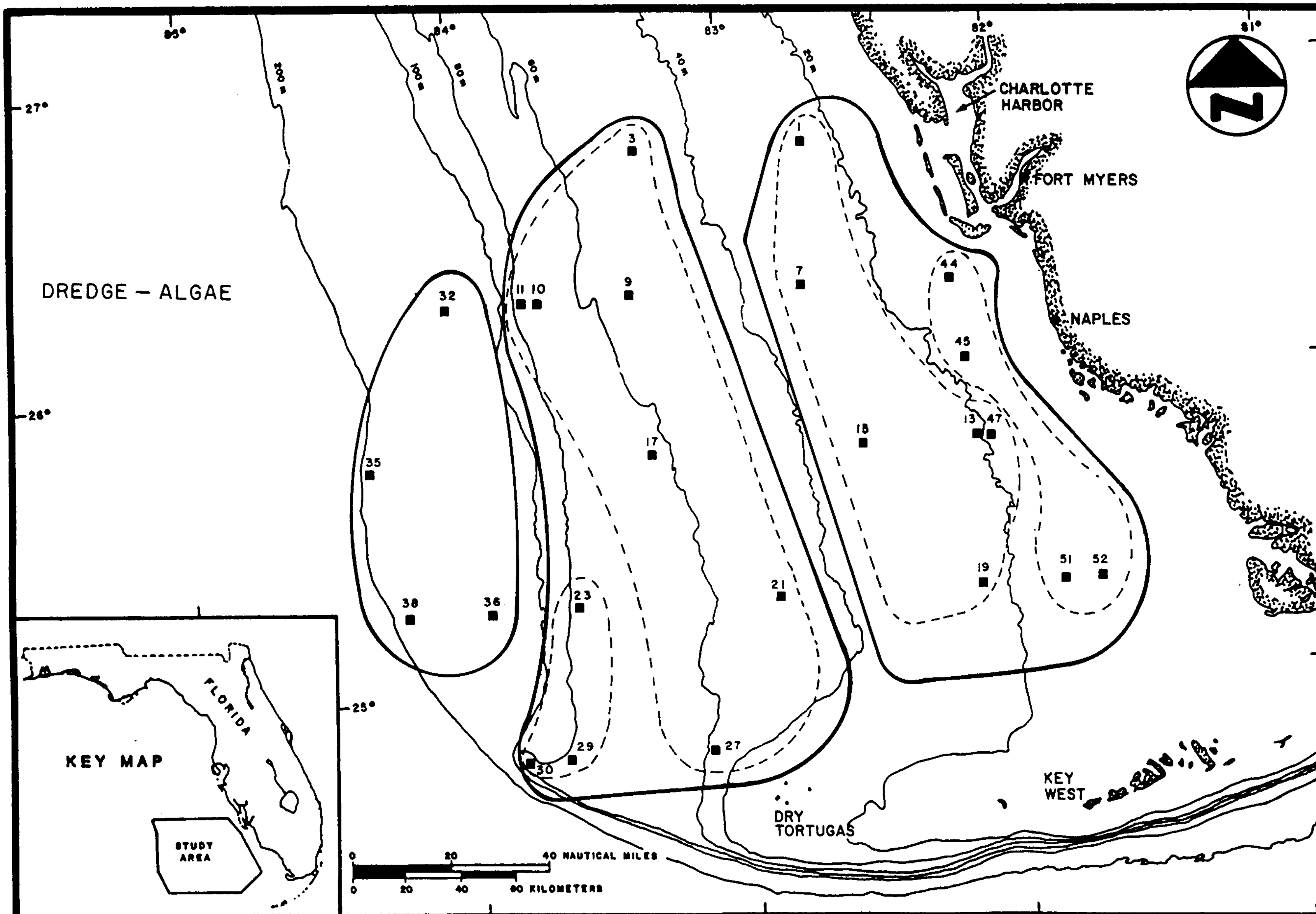


FIGURE 5.31. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, ALGAE ONLY.

TABLE 5.48. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, ALGAE ONLY.

Group	Representative Species	Station/Depth Affinities*
A	Agardhiella subulata Botryocladia occidentalis Gracilaria blodgetti Gracilaria debilis Halimeda scabra Laurencia intricata Udotea conglutinata	Stations in depths $\leq$ 32 m
B	Halimeda gracilis Lithothamnium calcareum	Stations in depths of 20 to 77 m
C	Peyssonnelia rubra Peyssonnelia simulans Struvea pulcherrima	Stations in depths of 44 to 77 m
D	Anadyomene menziesii Palmellaceae n. sp.	Stations 23, 29, & 30

*Refer to Table 5.41 for a list of station depths.

Bivalves -- Figure 5.32 shows normal cluster analysis results for dredge-collected bivalve molluscs. There is an inner-middle shelf group of stations in water depths of 13 to 58 m and a middle-outer shelf group of stations in water 62 to 159 m. Further clustering by depth is apparent within each major group. The main difference from the "all biota" analysis is that there is no distinct middle shelf group in the bivalve analysis; instead, middle shelf stations were grouped with inner or outer shelf stations. Also, some clustering across depth contours is evident within the middle-to-outer shelf group.

Table 5.49 lists representative species from inverse cluster analysis of bivalve data. Few species occurred across the entire inner and middle shelf; Chama macerophylla (leafy jewel box) is an example of a common, widely distributed hard-bottom species. Both the shallow, Year 3 stations (44, 45, 47, 51, and 52) and the Year 1 and 2 stations in depths of 20 to 58 m had suites of characteristic species. There were too few species that occurred at stations in depths of 50 to 77 m for a distinct middle shelf station group to emerge from the cluster analysis. Very few species were typical of the middle-outer shelf group as a whole or of either subgroup, and there were no ubiquitous species as for some other taxa. The difference between subgroups in the middle-to-outer shelf group was the presence of some inner-middle shelf species at Stations 10, 11, 23, 29, and 30.

Cnidarians -- Figure 5.33 shows the station map for the cluster analysis conducted using Cnidaria. The major inner, middle, and outer shelf station groups are the same as in the algal analysis and very similar to those in the "all biota" analysis. Results differ from those of the "all biota" analysis as follows: (1) within the inner shelf group, Stations 13, 19, and 47 form an intermediate cluster between shallower (<19 m water depth) stations and those in 20 to 32 m water depth; and (2) within the middle shelf group, Stations 23, 29, and 30 clustered apart from Stations 10 and 11, which are in the same depth range (60 to 80 m). The north-south gradient within this depth range is similar to that shown in the algal analysis.

Table 5.50 shows representatives of selected species groupings from inverse cluster analysis. Zonation was quite distinct, with most species showing strong fidelity for a particular station group and few species occurring in different station groups. The inner shelf group as a whole was typified by an assemblage of small scleractinian corals (tube coral, Cladocora arbuscula; the ahermatypic cup coral, Phyllangia

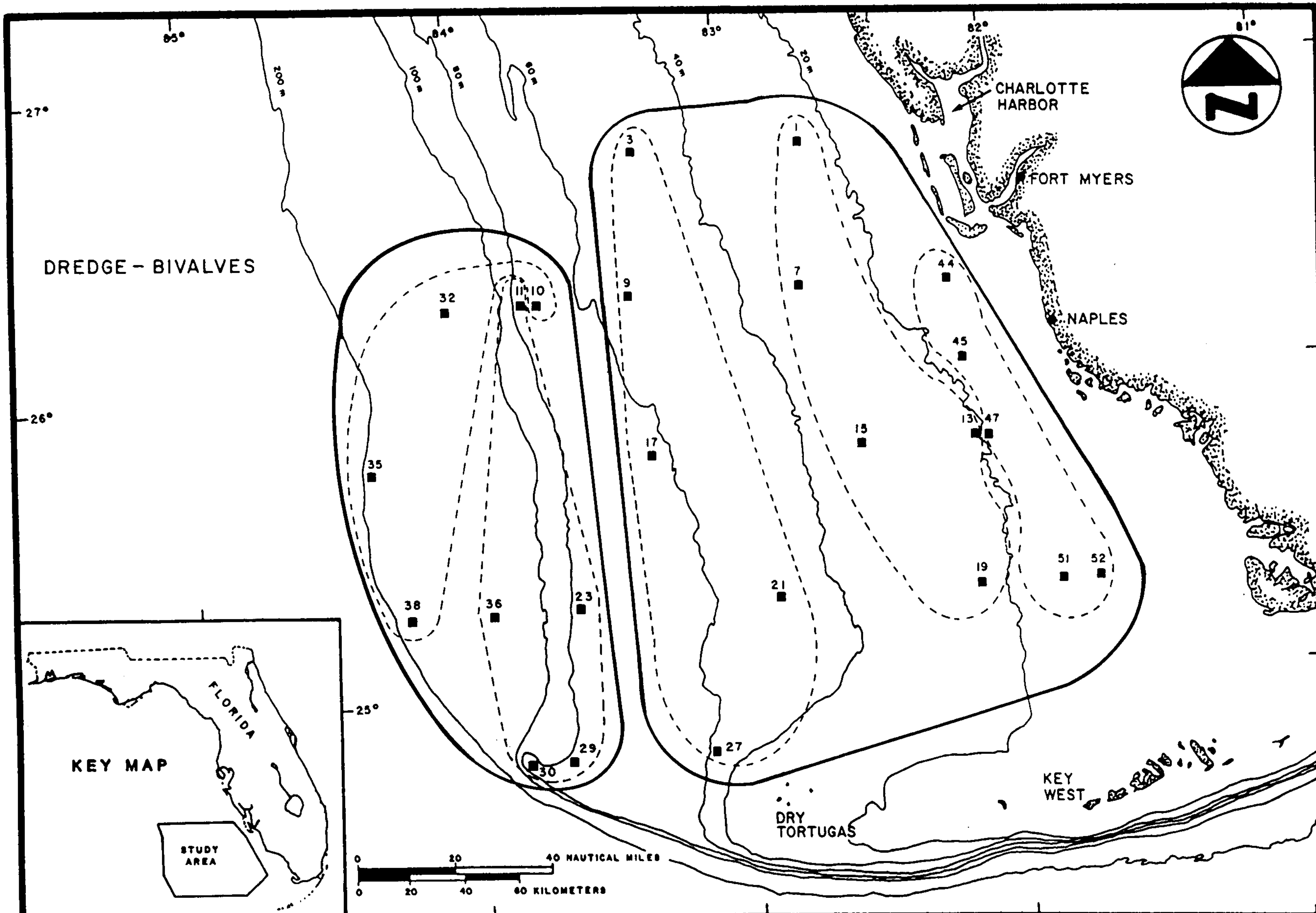


FIGURE 5.32. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, BIVALVES ONLY.

TABLE 5.49. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, BIVALVES ONLY.

Group	Representative Species	Station/Depth Affinities*
A	*Anadara notabilis* *Trachycardium muricatum* *Lithophaga nigra*	Stations in depths ≤ 19 m
B	*Argopecten gibbus* *Aequipecten muscosus* *Chione latilirata* *Eucrassatella speciosa* *Pecten raveneli*	Stations in depths of 20 to 58 m
C	*Chlamys benedicti* *Nemocardium tinctum*	Stations in depths of 44 to 58 m
D	*Chama macerophylla*	Stations in depths ≤ 58 m
E	*Barbatia candida* *Aequipecten phrygium*	Stations in depths of 127 to 159 m

*Refer to Table 5.41 for a list of station depths.

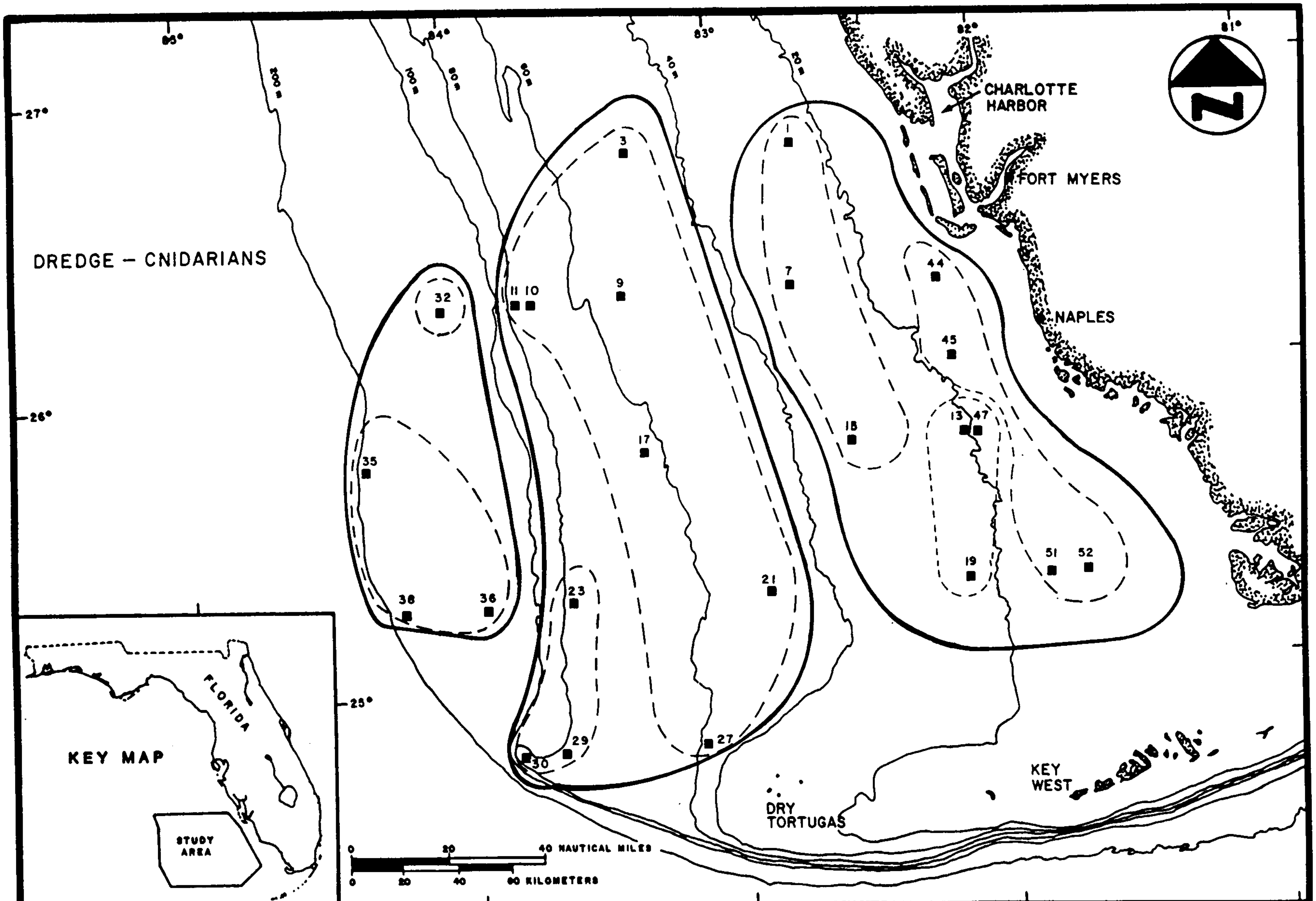


FIGURE 5.33. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, CNIDARIANS ONLY.

TABLE 5.50. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, CNIDARIANS ONLY.

Group	Representative Species	Station/Depth Affinities*
A	Eunicea calyculata Muricea elongata Plexaurella fusifera Plexaurella nutans Pseudoplexaura porosa Pseudoplexaura wagenaari Pseudopterogorgia acerosa Pseudopterogorgia rigida Pterogorgia guadalupensis	Stations in depths $\leq$ 20 m
B	Cladocora arbuscula Phyllangia americana Siderastrea radians Solenastrea hyades	Stations in depths $\leq$ 32 m
C	Eudendrium carneum	Stations in depths of $\leq$ 77 m
D	Madracis asperula Stephanoscyphus corniformis	Stations in depths of 44 to 159 m
E	Madracis brueggemanni Madracis formosa Madracis mirabilis	Stations 23, 29, & 30
F	Agaricia agaricites agaricites Agaricia agaricites purpurea Agaricia fragilis contracta Agaricia fragilis fragilis Antipathes gracilis Leptoseris (Helioseris) cucullata Madracis decactis Montastrea cavernosa Porites astreoides	Station 29
G	Antipathes pedata Caryophyllia horologium Ellisella barbadensis Javania cailleti Madrepora carolina Paracyathus pulchellus Placogorgia mirabilis Siphonogorgia agassizi Thesea grandiflora	Stations in depths of 127 to 159 m

*Refer to Table 5.41 for a list of station depths.

americana, starlet coral, Siderastrea radians, and mound coral, Solenastrea hyades). Other scleractinians occurring on the inner shelf, but not as widely, included the fleshy cactus coral Isophyllia sinuosa, small finger coral, Porites porites divaricata, mushroom coral, Scolymia lacera, and blushing star coral Stephanocoenia michelinii. Within the inner shelf group, stations at water depths of 20 m or less also were typified by a suite of gorgonian species (Pseudoplexaura spp., Pseudopterogorgia spp., Plexaurella spp., Muricea elongata, Eunicea calyculata, and Pterogorgia guadalupensis). A few gorgonian species also occurred at Station 19 (water depth: 22 m), but only Pseudopterogorgia acerosa was in common with the nearshore stations. Characteristic gorgonians at stations in water depths >20 m were Lophogorgia cardinalis and species of Leptogorgia and Ellisella.

Subgroupings within the inner shelf station group were generally according to water depth (Figure 5.33). Stations 13, 19, and 47 were different from the shallower stations in that occurrences of several characteristic nearshore gorgonian species were spotty. However, scleractinian species that occurred at stations both shallower and deeper than Stations 13, 19, and 47 also did not occur as consistently at these three stations.

Typical middle shelf cnidarian species included the hydroid Aglaophenia elongata, the scyphozoan Stephanoscyphus corniformis, and the scleractinian coral Madracis asperula. Two other hydroids, Eudendrium carneum and Thyroscyphus marginatus, were among the few occurring commonly at both inner and middle shelf stations.

Within the middle shelf group, Stations 23, 29, and 30 clustered separately due to the presence of several species of the hard coral Madracis. These stations all are characterized by a dense layer of coralline algal nodules (23) or a coralline algal crust (29 and 30), with biotic coverage consisting largely of leafy green algae (Anadyomene menziesii) and cryptonemialid red algae (Peyssonnelia spp.). Madracis is a characteristic member of this assemblage. Station 29 exhibited a distinct coral assemblage consisting of agariciid corals (Agaricia spp. and Helioseris cucullata) along with Madracis decactis, Montastrea cavernosa, and Porites astreoides--all common Caribbean reef corals. At Station 29, the low-relief hard substratum is formed primarily by coralline algae and plates of Agaricia.

The outer shelf group was typified by an assemblage of small, ahermatypic scleractinian corals (e.g., Caryophyllia horologium, Javania cailleti, and Paracyathus pulchellus), deepwater gorgonians (Ellisella barbadensis, Placogorgia mirabilis), and antipatharians (e.g., Antipathes spp., Aphanipathes spp.) (Table 5.50). Among outer shelf stations, relatively few of the characteristic species were collected from Station 32.

Crustaceans -- Figure 5.34 illustrates cluster analysis results for crustaceans collected by dredge. The inner shelf group and its subgroups are similar to those in the "all biota" analysis, consisting of stations in a water depth of <19 m and those in water depths of 19 to 32 m. However, the remaining stations clustered as a single middle-outer shelf group; that is, the outer shelf stations were not as distinct in species composition from middle shelf stations when only crustaceans were considered. Also, as noted previously in the analyses for algae and cnidarians, Stations 23, 29, and 30 did not cluster closely with Stations 10 and 11 in their depth range.

Table 5.51 lists representative species from inverse cluster analysis groupings. There is a large group of species with high constancy and fidelity for the inner shelf group, including several hermit crabs (Paguristes spp.), mithrax crabs (Mithrax spp.), a stomatopod (Gonodactylus bredini) and a scyllarid lobster (Scyllarus americanus). Both inner shelf subgroupings also were characterized by additional, smaller sets of characteristic species.

Although the dendrogram indicates a major break in species composition at about 40 m depth, several species could be characterized as inner-to-middle shelf in affinities. The pagurid crabs Manucomplanus corallinus and Phimochirus holthuisi, the diogenid crab Paguristes sericeus, and the swimming crab Portunus ordwayi occurred at most deep inner shelf stations (13 to 32 m) and middle shelf stations (44 to 77 m). In addition, Metapenaeopsis goodei, Pagurus brevidactylus, and Synalpheus townsendi occurred at most or all inner and middle shelf stations except Stations 23, 29, and 30. The lesser sponge crab, Dromidia antillensis, occurred at nearly all stations except those on the outer shelf (127 to 159 m). The arrow crab Stenorhynchus seticornis was one of the most widely distributed epifaunal species associated with hard bottom, occurring at stations in all depth ranges.

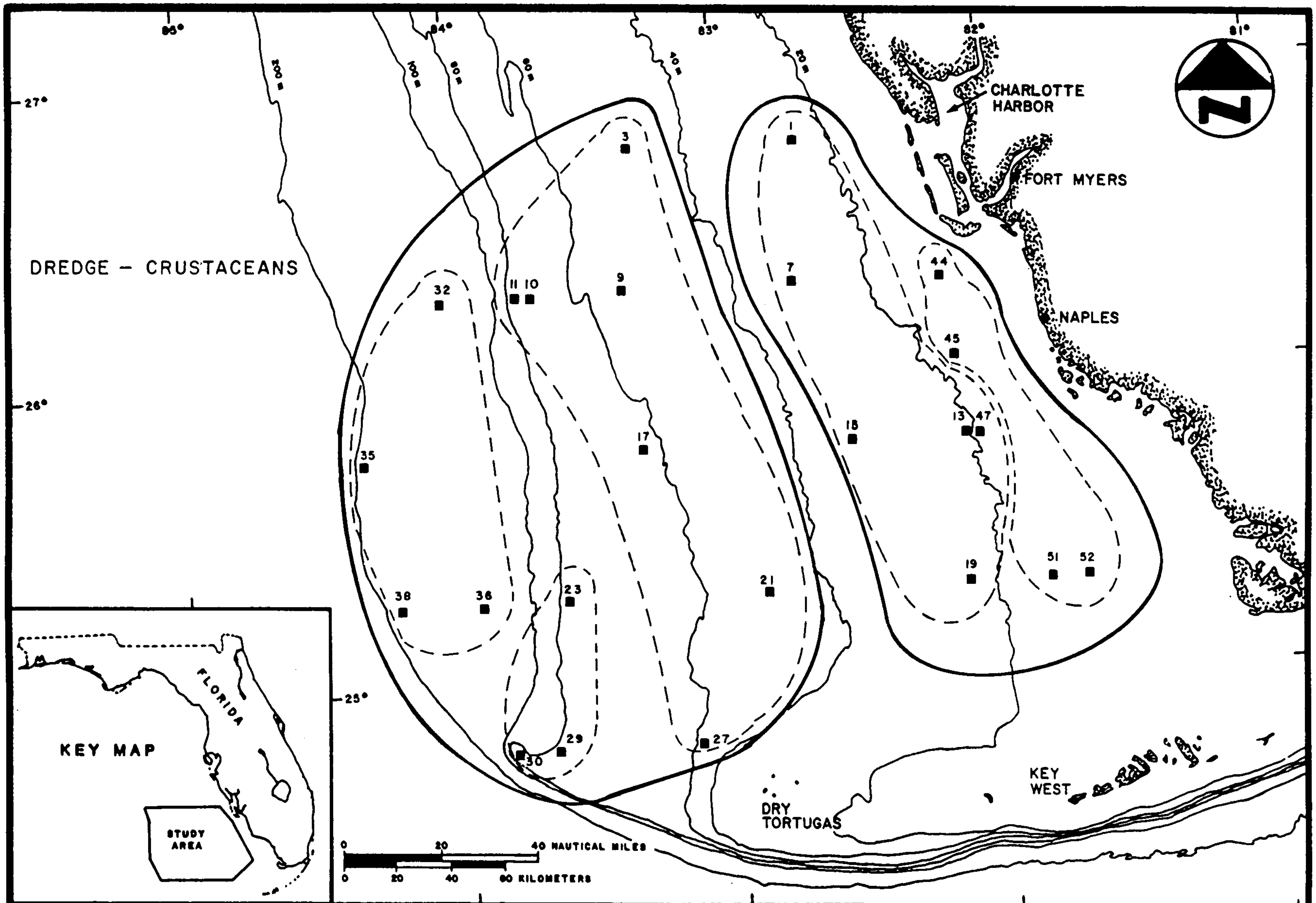


FIGURE 5.34. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, CRUSTACEANS ONLY.

TABLE 5.51. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, CRUSTACEANS ONLY.

Group	Representative Species	Station/Depth Affinities*
A	*Gonodactylus bredini*	Stations in depths ≤ 32 m
	Hypoconcha sabulosa	
	Macrocoeloma camptocerum	
	Mithrax (Mithraculus) forceps	
	Mithrax (Mithrax) pleuracanthus	
	Paguristes hummi	
	Paguristes punticeps	
	Paguristes tortugae	
	Pilumnus sayi	
	Podochela riisei	
	Scyllarus americanus	
B	*Iliacantha intermedia*	Stations in depths of 19 to 32 m
	Lobopilumnus agassizi	
C	*Callidactylus asper*	Stations in depths of 44 to 77 m
	Carpoporus papulosus	
	Dardanus insignis	
	Macrocoeloma septemspinosum	
	Paguristes triangulatus	
D	*Micropanope sculptipes*	Stations in depths of 44 to 159 m
	Parthenope fraterculus	
E	*Melybia thalamita*	Stations 23, 29, & 30
F	*Dromidia antillensis*	Stations in depths of ≤ 77 m
	Metapenaeopsis goodei	
	Phimochirus holthuisi	
	Synalpheus townsendi	
G	*Homola barbata*	Stations in depths of 127 to 159 m
	Nibilia antilocapra	
	Paguristes spinipes	
	Rhodochirus rosaceus	
H	*Stenorhynchus seticornis*	Stations in all depths

*Refer to Table 5.41 for a list of station depths.

The middle-outer shelf station group is a loose association in that few species are characteristic of the group as a whole (the xanthid crab Micropanope sculptipes and and the parthenopid crab Parthenope fraterculus are examples). Both the middle shelf subgroup (Stations 3, 9, 10, 11, 17, 21, and 27) and the outer shelf subgroup (Stations 32, 35, 36, and 38) appear to be well formed, each having a number of characteristic species (Table 5.51). The main distinguishing feature of Stations 23, 29 and 30 is the absence of many species found elsewhere; the crustacean catch at these stations was poor. This may be due in part to the substratum at these stations (dense algal nodules or algal nodule pavement), which are not conducive to dredging.

Echinoderms -- Figure 5.35 summarizes normal cluster analysis results for echinoderms. There is an inner-middle shelf group consisting of stations in water depths of 13 to 58 m, a narrow middle shelf group consisting of stations in water depths of 62 to 77 m, and an outer shelf group consisting of the four stations in water depths greater than 100 m. The results differ from those of the "all biota" analysis is that there is not as distinct a middle shelf group in the echinoderm analysis. Instead, the deep middle shelf stations (10, 11, 23, 29, and 30) clustered loosely with the outer shelf stations and the shallow middle shelf stations clustered with the inner shelf group. Also, some clustering across depth contours is apparent within the inner and middle shelf group (Stations 15 and 21 with Stations 44, 45, 51, and 52). As in the algal, cnidarian, and crustacean analyses, north-south zonation within the 60- to 80-m depth range is apparent, with Stations 29 and 30 grouping apart from Stations 10, 11 and 23.

Table 5.52 lists representative species groups from the inverse cluster analysis. The zonation pattern of the echinoderms showed more overlap between station groups than was the case for several other groups. Species typical of inner and middle shelf stations (out to 58 m depth) included Astropecten duplicatus (sea star) Clypeaster subdepressus (sea biscuit), and Lytechinus variegatus carolinus (green sea urchin). Although the dendrogram indicates a break in species composition at about 60 m depth, several species were distributed across the break--e.g., the sea urchins Eucidaris tribuloides tribuloides, Genocidaris maculata occurred at stations in the 50 to 77 m depth range. In addition, the purple-spined sea urchin Arbacia punctulata was common at all stations except those on the outer shelf.

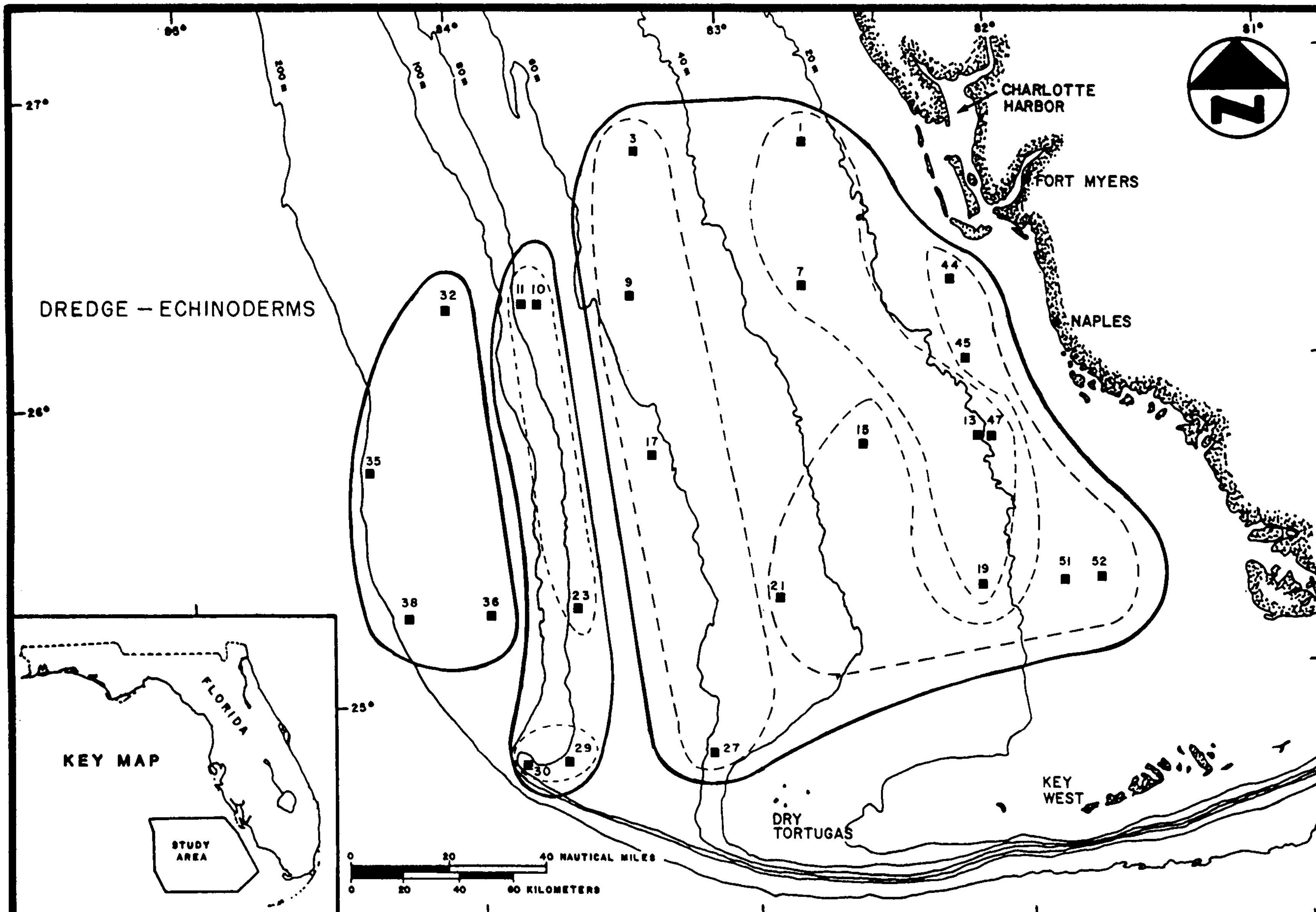


FIGURE 5.35. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, ECHINODERMS ONLY.

TABLE 5.52. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, ECHINODERMS ONLY.

Group	Representative Species	Station/Depth Affinities*
A	*Isostichopus badionotus* *Ophiothrix suensoni*	Stations in depths ≤ 44 m
B	*Clypeaster subdepressus* *Lytechinus variegatus carolinus* *Astropecten duplicatus*	Stations in depths ≤ 58 m
C	*Arbacia punctulata* *Ophiostigma isocantha*	Stations in depths ≤ 77 m
D	*Goniaster tesselatus* *Narcissia trigonaria*	Stations in depths of 50 to 58 m
E	*Eucidaris tribuloides tribuloides* *Genocidaris maculata*	Stations in depths of 50 to 77 m
F	*Ophioderma rubicundum* *Poraniella regularis*	Stations in depths of 62 to 77 m
G	*Analcidometra armata* *Nemaster discoidea* *Solaster caribbaeus*	Stations 29 and 30
H	*Echinolampas depressa* *Ophiomyxa flaccida* *Stylocidaris affinis* *Tosia parva*	Stations in depths of 56 to 159 m
I	*Comactinia meridionalis* *Leptonemaster venustus* *Neocomatella pulchella* *Ophiomusium* sp. A *Ophioplax* sp. A *Ophioplax* sp. B *Pectinaster mixtus*	Stations in depths of 127 to 159 m
J	*Ophiothrix angulata*	Stations in all depths

*Refer to Table 5.41 for a list of station depths.

On the outer shelf, a group of comatulid crinoids--Comactinia meridionalis, Neocomatella pulchella, and (to a lesser extent) Leptonemaster venustus and Crinometra brevipinna were very characteristic. Station 35 is located in an area that was chosen as representative of live bottom dominated by crinoids. However, the crinoids occurred at the other outer shelf live-bottom stations and in trawls at several outer shelf soft-bottom stations as well (Woodward- Clyde Consultants and Continental Shelf Associates, Inc., 1985). Echinoids such as Echinolampas depressa and Stylocidaris affinis occurred both on the outer shelf and at stations as shallow as 56 m.

Sponges -- Figure 5.36 summarizes normal cluster analysis results for sponges. There is a large group of inner shelf stations in water depths of 13 to 58 m and an outer shelf group consisting of all stations greater than 60 m in depth as well as the shallower Stations 1 (24 m), 7 (30 m), and 9 (56 m). Depth-related subclustering within each major group is apparent. The groupings are different from those in the "all biota" analysis in that distinct inner and middle shelf groups are not as apparent in the sponge analysis; in addition, Stations 1, 7, and 9 have crossed over a depth zone to cluster with the middle-to-outer shelf stations.

Table 5.53 lists representatives of species groupings from inverse cluster analysis. Typical inner-to-middle shelf species include the loggerhead sponge, Spheciospongia vesparium, the vase sponge Ircinia felix, the finger sponge Haliclona compressa, and Geodia gibberosa. Many species occurred primarily or exclusively at the shallowest stations (<19 m), including Axinella bookhouti, Cinachyra alloclada, Igernella notabilis, and Tethya seychellensis. The grouping of relatively shallow Stations 1 and 7 with the middle-to-outer shelf group apparently reflects the absence of several common inner-to-middle shelf species at those stations (e.g., Geodia gibberosa, Haliclona compressa, Ircinia campana, and I. felix).

Several sponge species were widely distributed. Examples are Cinachyra alloclada and Placospongia melobedioides (occurred at most or all stations except those on the outer shelf), as well as Ircinia strobilina (also occurred at some outer shelf stations).

Few species were typical of the outer shelf or middle-to-outer shelf stations (Table 5.53). One contributing factor is the large percentage of specimens from middle to outer shelf stations that could

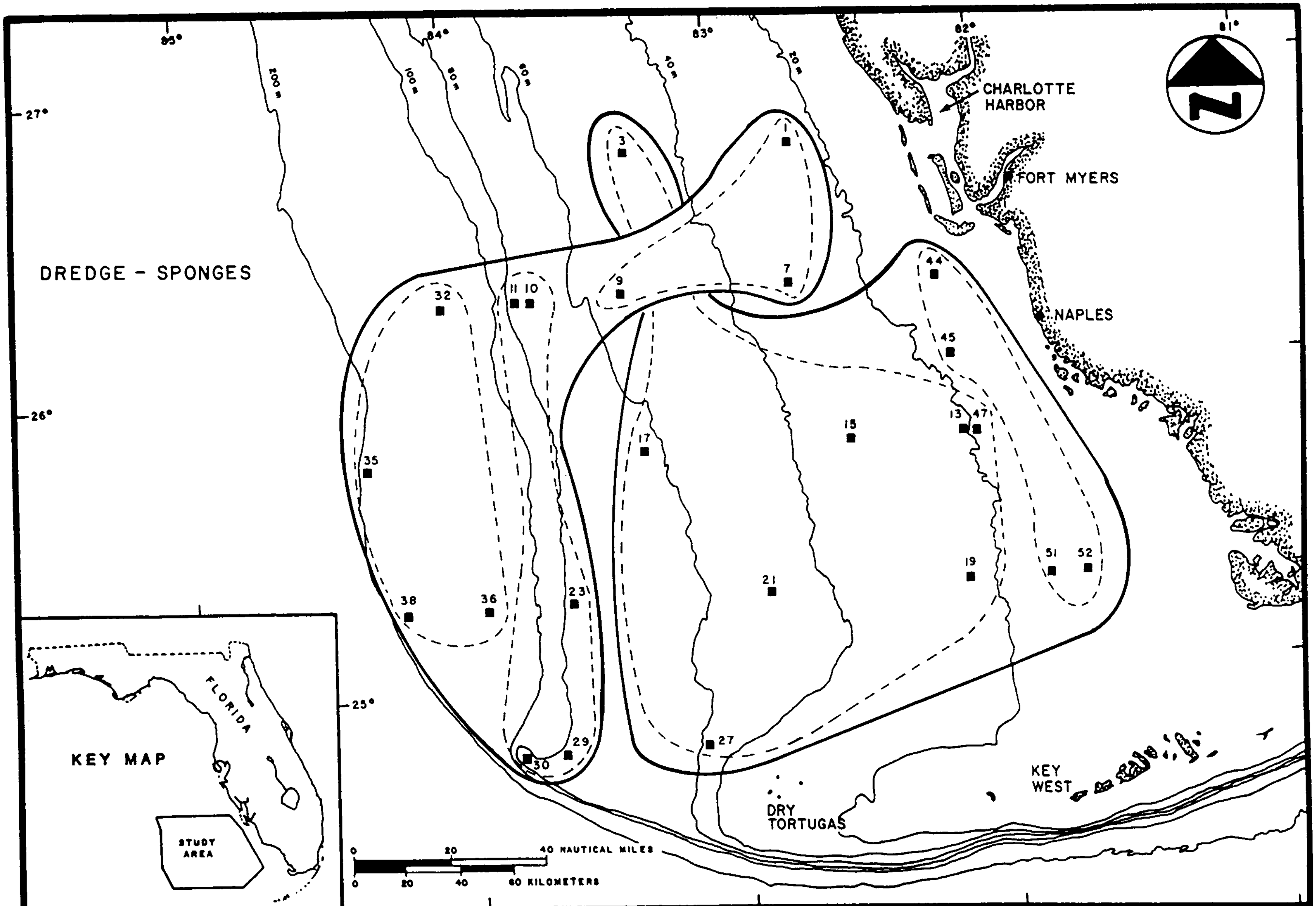


FIGURE 5.36. STATION GROUPINGS FROM CLUSTER ANALYSIS OF DREDGE DATA, SPONGES ONLY.

TABLE 5.53. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF DREDGE DATA, SPONGES ONLY.

Group	Representative Species	Station/Depth Affinities*
A	*Axinella bookhouti* *Cinachyra kuekenthali* *Euryspongea rosea* *Hemectyon pearsei* *Igernella notabilis* *Tethya seychellensis* *Thalysias juniperina*	Stations in depths < 19 m
B	*Aiolochroia crassa* *Anthosigmella varians* *Geodia gibberosa* *Haliclona compressa* *Ircinia felix* *Spheciospongia vesparium*	Stations in depths ≤ 58 m
C	*Cinachyra alloclada* *Ircinia strobilina* *Placospongia melobesioides*	Stations in depths ≤ 77 m
D	*Stylocordia ?longissima* *Pachastrella ?monilifera*	Stations in depths of 127 to 159 m

*Refer to Table 5.41 for a list of station depths.

not be identified to species (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). At Station 32, six species were identified; at Station 36, four species; and at Stations 35 and 38, three species (compared with up to 55 species at shallower stations). For these stations, there is little upon which to base similarity measures except absences of identifiable inner-to-middle shelf species.

Results--Trawl. Results of the cluster analysis conducted using all taxonomic groups collected in trawls were very similar to those described previously for the dredge samples and are not presented here. Results for fishes, the main group sampled more effectively by trawl than by dredge, are described below.

Figure 5.37 shows the station groupings from cluster analysis of trawl fish data, and Figure 5.38 presents the associated dendrogram. As in most of the other cluster analyses, the station groups are oriented primarily in relation to water depth and distance from shore. There is an inner shelf group consisting of stations in water depths less than 44 m and a middle-to-outer shelf group consisting of stations in water depths of 50 to 159 m. Within the latter group are three subgroups, one consisting of the outer shelf stations, a second consisting of Stations 23, 29, and 30, and a third consisting of the remaining middle shelf stations. The grouping of Stations 23, 29, and 30 apart from the other two stations in the same depth range (Stations 10 and 11) indicates a north-south gradient in species composition similar to that noted above for algae, cnidarians, and echinoderms.

Table 5.54 lists representative species from inverse cluster analysis. Both the inner shelf group and the subgroup consisting of Stations 45, 51, and 52 possess suites of characteristic species. Typical nearshore species included white grunt (Haemulon plumieri), hogfish (Lachnolaimus maximus), and orange filefish (Aluterus schoepfi). A few species such as fringed filefish (Monacanthus ciliatus) and sand diver (Synodus intermedius), occurred at most inner and middle shelf stations. Typical middle shelf species include blackedge moray (Gymnothorax nigromarginatus), bank sea bass (Centropristis ocyurus), and longfin scorpionfish (Scorpaena agassizi). Other primarily middle shelf species that also occurred at outer shelf stations (with lower constancy) included offshore lizardfish (Synodus poeyi), pancake batfish (Halieutichthys aculeatus), tattler (Serranus phoebe), and saddle bass (Serranus notospilus). The offshore stations were typified by other species such as roughtongue bass (Holanthias martinicensis--particularly common

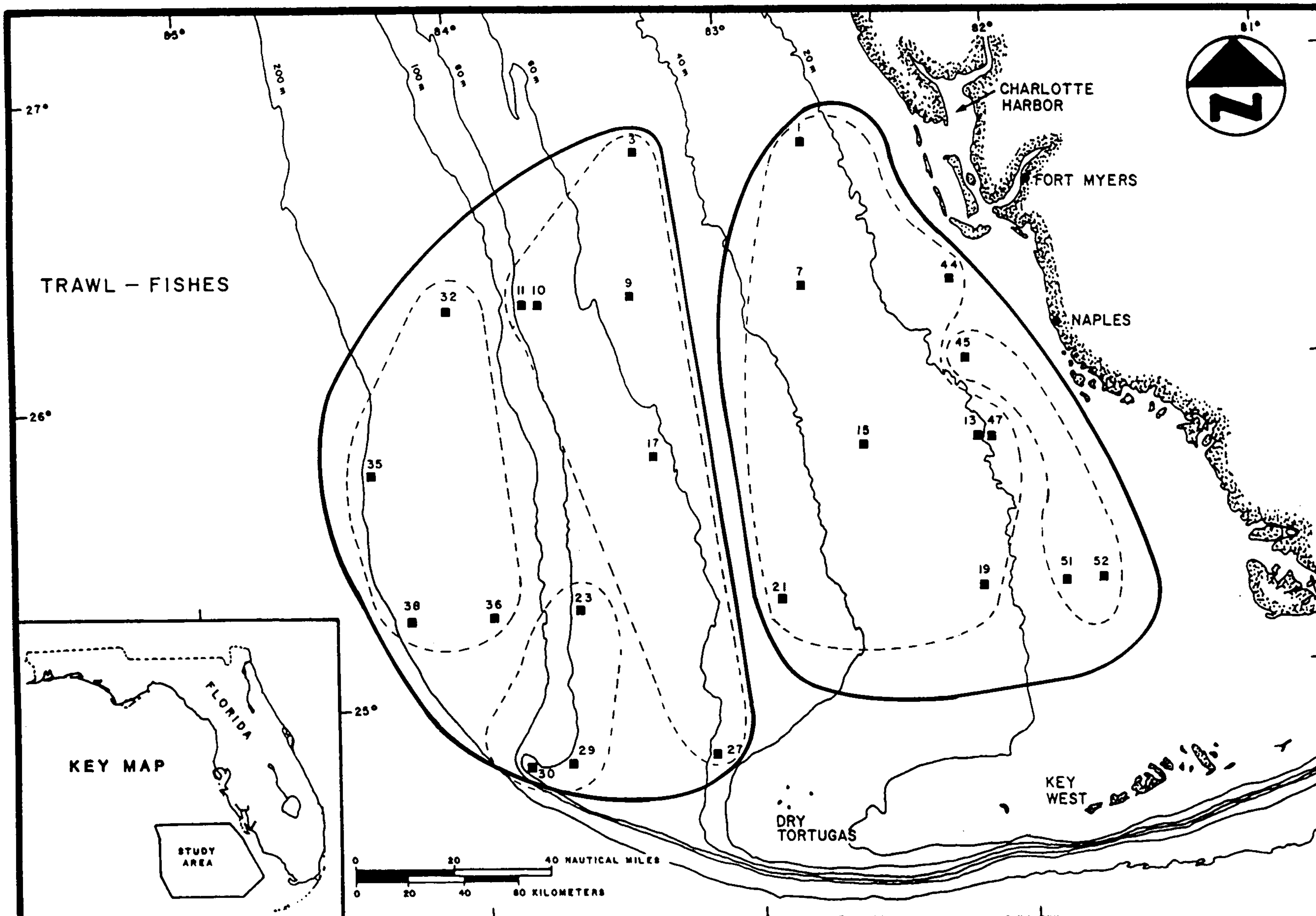


FIGURE 5.37. STATION GROUPINGS FROM CLUSTER ANALYSIS OF TRAWL DATA, FISHES ONLY.

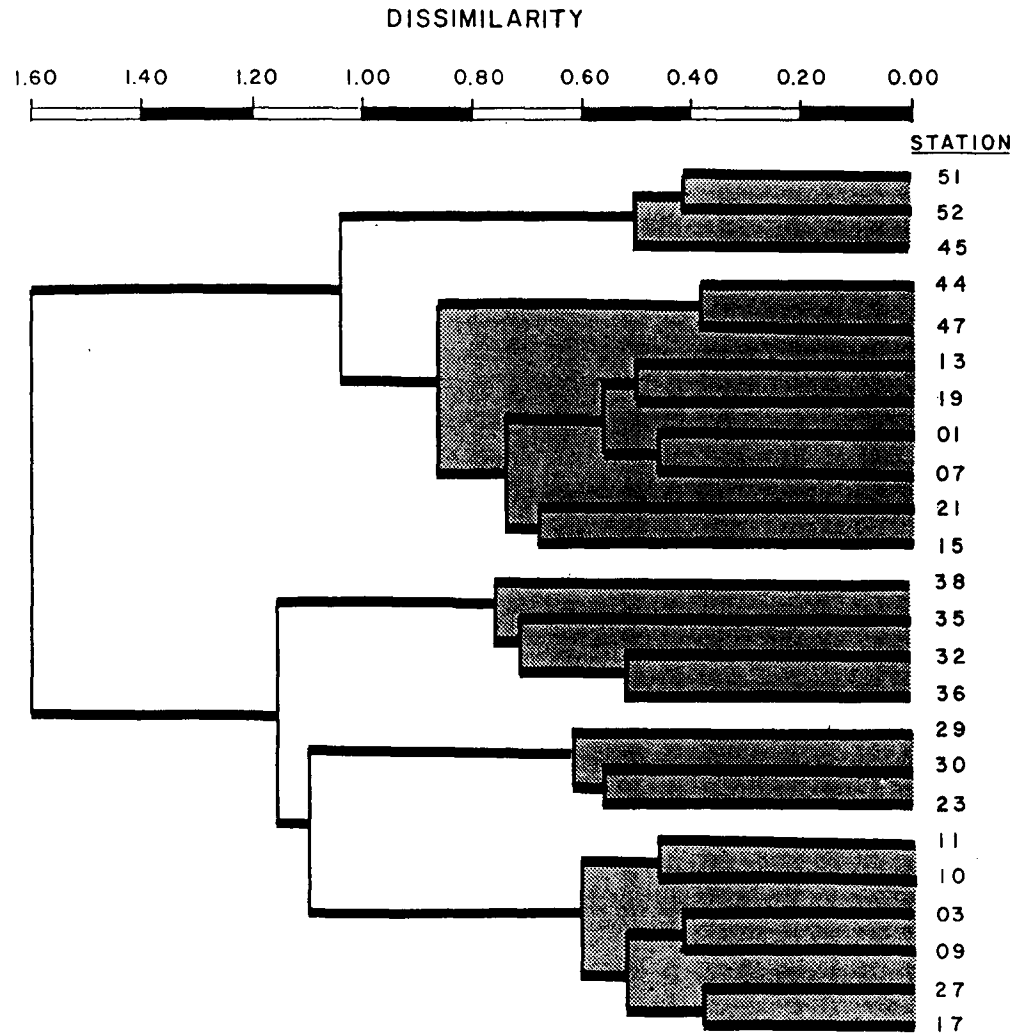


FIGURE 5.38. DENDROGRAM FROM CLUSTER ANALYSIS OF TRAWL DATA, FISHES ONLY.

TABLE 5.54. SELECTED SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF TRAWL DATA, FISHES ONLY.

Group	Representative Species	Station/Depth Affinities*
A	Aluterus schoepfi Haemulon plumieri Lachnolaimus maximus	Stations in depths < 20 m
B	Equetus lanceolatus Haemulon aurolineatum Lactophrys quadricornis	Stations in depths ≤ 44 m
C	Centropristis ocyurus Citharichthys gymnorhinus Gymnothorax nigromarginatus Scorpaena agassizi	Stations in depths of 50 to 77 m
D	Amblycirrhitus pinos Aulostomus maculatus Bodianus pulchellus Clepticus parrai Chromis cyaneus Diodon holocanthus Holacanthus tricolor Pomacentrus partitus	Station 29
E	Chromis scotti Serranus annularis Serranus tortugarum Sparisoma atomarium	Stations 23, 29 & 30
F	Antigonia capros Bellator egretta Holanthias martinicensis	Stations in depths of 127 to 159 m
G	Monacanthus ciliatus Synodus intermedius	Stations in all depths

*Refer to Table 5.41 for a list of station depths.

around rocky outcrops and probably not trawled effectively), deepbody boarfish (Antigonia capros), singlespot frogfish (Antennarius radiosus), and streamer searobin (Bellator egretta).

Station 29 exhibited a distinctive assemblage characterized by several tropical reef fishes, including damselfishes (Chromis cyaneus, Pomacentrus partitus), wrasses (Bodianus pulchellus, Clepticus parrai), angelfishes (Holacanthus tricolor). Other reef fishes associated with Stations 23 and 30 as well as Station 29 included parrotfishes (Sparisoma atomarium), damselfishes (Chromis scotti), and sea basses (Serranus annularis, S. tortugarum).

5.5.4 Discussion of Zonation Patterns

Cluster Analyses. Cluster analyses conducted using dredge and trawl data show primarily depth-related occurrence patterns of epibiota on the southwest Florida shelf. Species composition changes with depth due to correlated changes in environmental conditions that affect the establishment, survival, growth, and reproduction of epibiota. Examples of influential environmental factors are light penetration, temperature, substratum type, and frequency and intensity of sediment movement. Interactions among species (competition, predation, mutualism, etc.) also undoubtedly affect patterns of species occurrence and abundance.

The species composition of epibiota at a particular location on the shelf reflects the overlapping occurrence patterns of hundreds of species from various groups. Zones or station groupings are apparent in cluster analysis results because sets of species have similar occurrence patterns. In most of the analyses conducted, there were groups of species occurring primarily at inner shelf stations; others occurring at inner and middle shelf stations; species occurring at middle shelf stations; species occurring at middle and outer shelf stations; and species occurring primarily at outer shelf stations. In addition, there were many species that occurred at only a few stations and a few that were collected at most or all stations across the shelf.

The pattern of station groupings from cluster analysis varied somewhat depending on which taxa were included. Distinct inner, middle, and outer shelf station groups were apparent in the cluster analyses for algae, cnidarians, and echinoderms, whereas a distinct middle shelf group was not as apparent in the analyses of bivalve, crustacean, sponge, and fish data. In the case of the "all biota" analysis for the dredge data, the inner-middle-outer pattern was selected as best representing the results, but the dendrogram (Figure 5.30) indicates that outer and middle shelf stations were more similar to each other in species composition than were the inner and middle shelf groupings.

Most of the analyses indicated a major break in species composition between the depth of Station 15 (32 m) and Station 21 (44 m) or between Station 21 and Station 3 (50 m). For bivalves and echinoderms, the major break was at about 60 m. Also, in all analyses except the one for bivalves, the four outer shelf stations (32, 35, 36, and 38) were dissimilar in species composition to those on the middle shelf, indicating another break in species composition somewhere between the depth of Station 11 (77 m) and the shallowest of the the outer shelf stations (Station 36, 127 m).

Although species composition varied primarily in relation to water depth, strong latitudinal variation was evident in the 60- to 80-m depth range. In the analyses of algae, cnidarians, crustaceans, and fishes, Stations 23, 29, and 30 emerged as different in species composition from the other two stations (10 and 11) in the same depth range. In the echinoderm and sponge analyses, Stations 29 and 30 were distinct from Stations 10, 11, and 23. The three southern stations have similar substratum types--dense coralline algal nodules in the case of Station 23 and a fused coralline algal pavement in the case of Stations 29 and 30. Coralline algal nodules also occur at Stations 10 and 11, but at much lower densities. Algae are the main cover constituents at all five stations, but the predominant algal species at the three southern stations are either less abundant at the two northern stations (e.g., Peyssonnelia rubra, P. simulans) or not found there (Anadyomene menziesii).

Differences in temperature regime may help to explain the latitudinal gradient in species composition. During fall 1980 and spring 1981, near-bottom temperatures at Station 29 were 2 to 4°C higher than at Stations 10 and 11 (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). There is little seasonal variation in temperature at any of the stations in this depth range. Temperatures consistently in the range of 20 to 23°C, favorable for many tropical species, are maintained at the three southern stations in this depth range.

Another important consideration, particularly with regard to benthic algae, is the nutrient regime. Doming of nutrient isopleths along the outer shelf is a common feature attributable to upwelling along the shelf break (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983). Due to the steeper topography of the outer shelf on the southern transects, upwelled, nutrient-rich waters penetrate to shallower water depths than on the northern transects. Consequently, near-bottom nutrient (e.g., nitrate) concentrations are considerably higher at the three southern stations (23, 29, and 30) than at the northern stations (10 and 11). The difference in nutrient regimes could be important if nutrients are limiting to the macroalgal species that are conspicuous elements of the biota at stations in this depth range.

Cluster Analysis Groupings vs. Visually Designated Assemblages. Cluster analysis of dredge and trawl data and broad-scale mapping of biological community types from remote photographic surveys involve very different approaches to classifying benthic epibiota. It is useful to compare cluster analysis results with the broad zonation patterns recognized during the habitat mapping surveys (Chapter 4).

There was a strong indication of a distinct, nearshore biota in several cluster analyses, a grouping that corresponds more or less to the visually designated Inner Shelf Live Bottom Assemblage I (Figure 5.26). Classification of Stations 13 (20 m), 19 (22 m), and 47 (19 m) varied depending on which group was used for the cluster analysis, but in general, these three stations had a different species composition than the stations in shallower water depths. The results suggest a break in species composition at or near 20 m depth. Visually, the biota at Stations 13 and 47 (and to a lesser extent, Station 19) was considered similar to that seen at the shallower stations. However, in terms of species composition, these stations can best be characterized as transitional, with several of the gorgonian and sponge species found at shallower stations occurring less consistently with increasing water depth.

In contrast, the spatial pattern of stations where the epibiota would be classified as Inner and Middle Shelf Live Bottom Assemblage II (Figure 5.26) crosses major breaks in species composition in nearly all cluster analyses, including those for conspicuous sessile epibiota such as algae, cnidarians, and sponges. Some conspicuous sponges such as *Spheciospongia vesparium* (loggerhead) and *Ircinia* spp. occurred across a wide range of inner to middle shelf depths, contributing in part to visual similarity of the areas characterized as Inner and Middle Shelf Live Bottom Assemblage II. However, these sponges are equally characteristic of even shallower water depths (<20 m). In general, the Inner and Middle Shelf Live Bottom Assemblage II does not correspond to a coherent set of co-occurring species.

The Middle Shelf Algal Nodule Assemblage and the Agaricia Coral Plate Assemblage are two related groupings recognized in the 60- to 80-m depth range during visual surveys. Stations 10, 11, and 23 would be grouped under the first assemblage and Stations 29 and 30 under the second (the latter station having lesser growths of Agaricia). In several cluster analyses, the five stations in this depth range grouped together, but in general, the epibiota at Station 23 was more similar to that at Stations 29 and 30 than to that at Stations 10 and 11. Clearly there is a latitudinal gradient in species composition within this depth range, but selection of the break point between assemblages or community types depends on the criteria used (visual similarity vs. overall similarity of species composition). Visually, the epibiota at Station 29 is distinctive, particularly with regard to the abundance of the leafy green alga Anadyomene menziesii and the dense accumulations of agaricids. In addition, the area supports a variety of tropical reef fishes that do not occur elsewhere on the shelf. In these respects, the area at Station 29 should probably be considered a distinct community type in this depth range.

Most cluster analyses showed a break in species composition between the stations in 70 to 77 m depth and those in 127 to 159 m depth, but because there were no stations in between these depth ranges, it is difficult to determine exactly where the break occurs. To the extent that the Middle Shelf Algal Nodule Assemblage recognized during mapping surveys corresponds to a real set of co-occurring species, the photographic data can help to answer this question. The maximum depth at which this assemblage was 85 m on Transect B, 95 m on Transect D, 110 m on Transect E. Thus, the break in species composition probably is closer to 90 or 100 m rather than 77 m or 127 m.

Finally, cluster analyses indicated little dissimilarity in species composition among outer shelf locations within the depth range studied, suggesting that the assignment of separate assemblage designations probably is inappropriate. In fact, cluster analysis of trawl data from Years 1 and 2 showed that even the epibiota of outer shelf soft-bottom stations is very similar to that of the outer shelf live-bottom stations (see Section 8.3 in Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). High-relief rock outcrops ("prominences") seen along portions of Transects C and L were not sampled by dredge or trawl, but the conspicuous sessile epibiota (crinoids, antipatharians, alcyonarian corals, hexactinellid sponges, etc.) were similar to those seen elsewhere on the outer shelf.

Zonation Schemes. Faunal zonation schemes for the west Florida shelf have been proposed by Lyons and Collard (1974), Lyons (1980), and Lyons and Camp (1982). Their conclusions are based primarily on dredge and trawl data collected during the Hourglass cruises.

Lyons (1980) used Hourglass mollusc data to revise an earlier zonation scheme proposed by Lyons and Collard (1974). He recognized the following zones:

Zone	Depth Range
Shoreward	0 to 10 m
Shallow Shelf	10 to 40 m
Middle Shelf I	40 to 70 m
Middle Shelf II	70 to 140 m
Deep Shelf	140 to 200 m

The existence of a faunal break at about 70 m was cited as tentative, as the deepest Hourglass stations were at 73 m. Also, the existence of an additional zone near the shelf-edge was considered likely. Data from various invertebrate groups collected during the Hourglass cruises generally support the overall zonation scheme proposed by Lyons (1980), though the results depend somewhat on which faunal groups are included (Lyons and Camp, 1982).

The first three years of southwest Florida shelf studies involved a greater range of water depths and latitudes and a larger number of stations within depth ranges than the Hourglass cruises. Moreover, gross differences in habitat type (soft bottom vs. hard or live bottom) were minimized in the southwest Florida studies by designating separate sets of live- and soft-bottom stations (though, in reality, bottom types were often interspersed within stations). Not surprisingly, the zonation pattern evident from our studies is not identical to that recognized from the Hourglass studies. Based on the dredge cluster analysis for "all biota," with some additional information from photographic surveys, the zonation pattern would be approximately as follows:

Zone	Depth Range
Inner Shelf I	10 to 20 m
Inner Shelf II	20 to 45 m
Middle Shelf I	45 to 60 m
Middle Shelf II	60 to 100 m
Outer Shelf	100 to 200 m

A Shoreward (0 to 10 m) zone similar to that proposed by Lyons (1980) is not included in this scheme because our shallowest station was at 13 m depth. However, comparison of data from the Year 3 stations and the 6 m Hourglass stations (Section 5.4) confirms that benthos in water depths shallower than those sampled during the present studies may constitute another zone. The boundary is arbitrarily set at the 10-m isobath.

The Inner Shelf zones I and II together correspond approximately to the Shallow Shelf zone of Lyons (1980). The split into two subzones reflects a real difference in species composition that emerged in most cluster analyses and was visually evident during the television surveys.

The other major difference in the new zonation scheme is the delineation of a narrow Middle Shelf Zone II corresponding to the communities associated with algal nodule and algal pavement substrata in the 60 to 100 m depth range, primarily on the southern transects. During the mapping surveys, expanses of algal nodule live bottom were seen primarily on the southern Transects D and E (also on the corresponding portions of north-south Transects F and L). Smaller patches of algal nodule bottom were seen on Transect B, and none was seen on Transect A or C (Chapter 4). As the most southerly Hourglass stations were located between our Transects A and B (Figure 5.39), areas of dense algal nodule live bottom were not sampled (although substrates at Hourglass stations L and M contained some coralline algal rubble [Joyce and Williams, 1969]). Cluster analysis results for algae, cnidarians, crustaceans, and fishes, also show that the two 70 to 80-m stations on Transect B clustered with shallower middle shelf stations and did not form a distinct zone.

The delineation of "zones" or "assemblages" has several purposes: to characterize shelf epibiota on a broad scale (i.e., larger than that of individual stations), to provide foreknowledge of the type of benthic community that may be present at previously unstudied sites (e.g., potential drillsites for oil and gas), and to generate hypotheses about

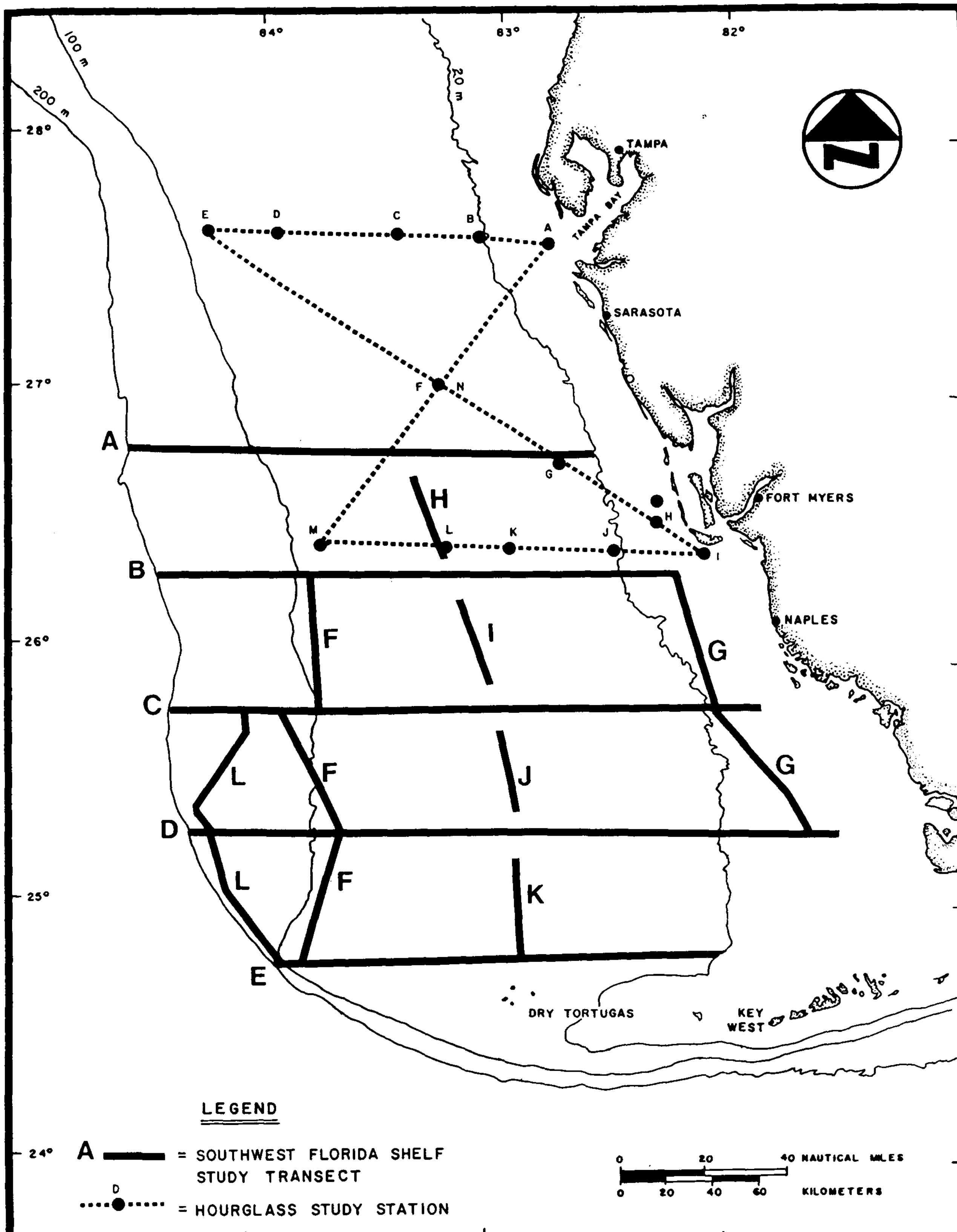


FIGURE 5.39. LOCATIONS OF SOUTHWEST FLORIDA SHELF YEAR 1, 2, AND 3 TRANSECTS IN RELATION TO HOURGLASS STUDY STATIONS.

environmental factors controlling the abundance and composition of the benthos. However, any broad scale characterization of the southwest Florida shelf must also include the recognition of patchiness in the distribution of the epibiota: patchiness within "zones," patchiness within stations, even patchiness within a single photograph or quadrat frame. For purposes of local characterization (e.g., in the vicinity of potential offshore drillsites), broad scale characterization is no substitute for a site-specific survey.

5.5.5 Summary

Sampling at 25 live-bottom stations on the southwest Florida shelf was conducted to provide a baseline description of the epibiota. Twenty stations in water depths of 20 to 159 m were sampled two or four times during 1980-1982. Five additional stations in depths less than 20 m were sampled twice during 1982-1983. Sampling at each station consisted of dredging, trawling, and a remote photographic survey with television and still camera. Additional sampling was conducted by divers at the shallow stations. The divers harvested epibiota in quadrats and conducted visual fish counts.

In all, 1,497 species were identified from the dredge and trawl collections. Crustaceans and molluscs each accounted for about 20% of the total, with fishes, algae, and cnidarians also contributing significant percentages. In general, the number of species collected per unit of sampling effort declined with increasing water depth.

Widely distributed sessile epibiota included sponges (*Cinachyra alloclada*, *Ircinia strobilina*, *Placospongia melobesioides*), algae (*Lithothamnium calcareum*, *Halimeda gracilis*), ascidians (*Didemnum candidum*), bryozoans (*Celleporaria albirostris*, *C. magnifica*, *Stylopoma spongites*), and hydroids (*Eudendrium carneum*). Frequently collected motile epibiota included arrow crabs (*Stenorhynchus seticornis*), brittle stars (*Ophiothrix angulata*), and sea urchins (*Arbacia punctulata*).

Most of the fishes collected in the trawls are sand dwellers or secondary reef dwellers, with primary reef dwellers being well represented at only a few stations. Frequently collected fishes included fringed filefish (*Monacanthus ciliatus*), sand diver (*Synodus intermedius*), and offshore lizardfish (*S. poeyi*). Comparison of visual censusing results with the trawl catches at the shallow stations indicates that other primary reef species are present in dense live bottom areas, but these areas are not trawled effectively.

Cluster analysis of dredge and trawl data from all stations indicates a pattern of depth-related station groupings. Species composition of the epibiota varies primarily in relation to factors correlated with water depth and/or distance from shore. The major exception is in the 60- to 80-m depth range, where a strong north-south gradient in species composition is evident. The southern stations in this depth range are characterized by a distinctive epibiota associated with a substratum of coralline algal nodules or a fused coralline algal pavement. A dense growth of plate corals (Agaricia) occurs in association with the coralline algal pavement, and many tropical reef fishes are associated with this unique area.

Sampling conducted by divers at the shallow, nearshore stations indicates there is a relationship between the thickness of the sand veneer overlying hard bottom and the density and species composition of the epibiota. The presence of sessile epibiota in areas of sand-covered hard bottom suggests that the underlying rock must periodically be exposed, as many sessile species must initially attach to hard bottom. Where the sediment veneer is thicker than a few centimeters, the underlying rock presumably is infrequently exposed and there is little opportunity for development of a sessile epifauna. The major exception to this generalization would be in areas characterized by surface rubble layers or biogenic hard substratum (e.g., coralline algal nodules or algal nodule pavement).

5.6 CHARLOTTE HARBOR AREA BLOCK 887 SURVEY

In December 1982, Continental Shelf Associates, Inc. conducted a survey of Charlotte Harbor Area Block 887 for Shell Offshore Inc. (Shell). The block is located in a water depth of 65 to 70 m on the southwest Florida shelf (Figure 5.40). A television/still camera survey and dredge and trawl sampling were conducted within the block. Results were summarized in a report to Shell (Continental Shelf Associates, Inc., 1983).

Survey results were unusual in that a single species of green algae, Codium isthmocladum, accounted for most of the biotic cover. Although the block is located within the area encompassed by Years 1 and 2 of Southwest Florida Shelf Studies (Figure 5.40), these results were unlike any noted previously. During Cruise III of the present study

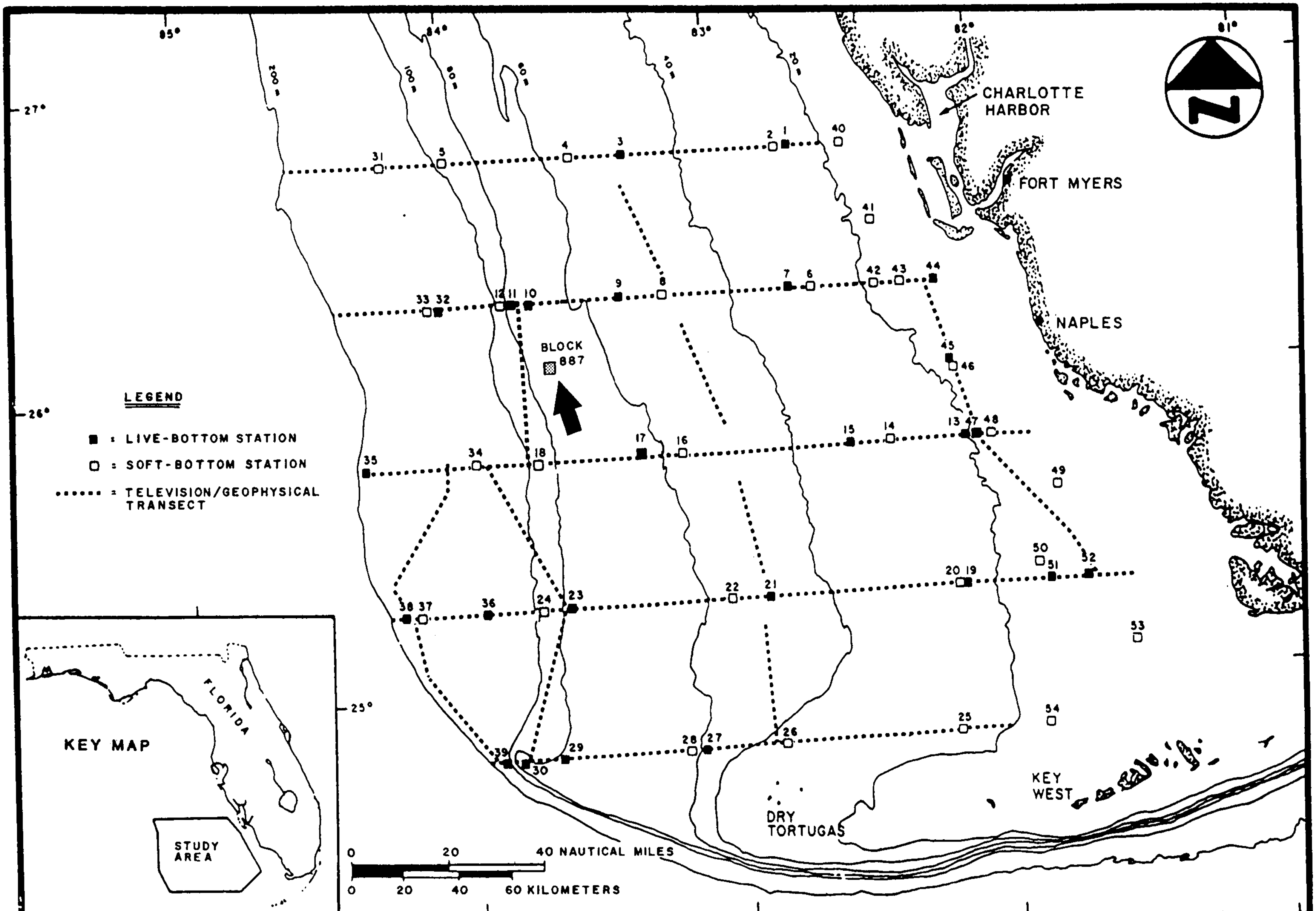


FIGURE 5.40. LOCATION OF CHARLOTTE HARBOR AREA BLOCK 887 IN RELATION TO YEAR 1, 2, AND 3 TRANSECTS AND STATIONS.

(June 1983), we obtained additional television and still camera data in Block 887 while the survey vessel was enroute to St. Petersburg from Transect L. This section presents photographic data from the two surveys and selected dredge data from the first survey for comparison with data from nearby Year 1 and 2 stations.

5.6.1 Methods

The original survey for Shell was conducted during 15 to 17 December 1982. Twelve transects radiating from a central point (an area of potential drillsites) (Figure 5.41) were surveyed using the television/still camera system described previously. Five dredge samples and one trawl sample were collected at locations identified during the television/still camera survey (Figure 5.41).

The second survey was conducted on 7 to 8 June 1983. Four of the previously surveyed television/still camera transects were resurveyed (Figure 5.41). No dredge or trawl sampling was conducted.

Videotapes, photographs, and dredge and trawl samples were analyzed as described in Section 5.2.2.

5.6.2 Results

Table 5.55 summarizes quantitative slide analysis results from the two surveys. Total biotic cover was substantially higher during the first survey due to the presence of the green alga *Codium isthmocladum*, which accounted for 71% of total biotic cover. Very little *C. isthmocladum* was seen during the second survey. Red algae in the order Cryptonemiales accounted for about 10% cover during the first survey and 15% during the second survey. Included were two widespread species of crustose algae, *Peyssonnelia rubra* and *P. simulans*; the coralline alga *Lithothamnium occidentale*; and unidentified red algae identified only to order (Cryptonemiales) or family (Corallinaceae). Sponges were the most abundant identifiable epifauna but accounted for only 0.26% to 0.27% cover.

Dredge and trawl sampling during the first survey resulted in the collection of 137 distinct taxa, of which 114 were identified to species. Species occurring in at least four of the five dredge samples included the algae *Codium isthmocladum*, *Lithothamnium occidentale*, and *Peyssonnelia rubra*; the sponges *Microciona* spp.; the crustaceans

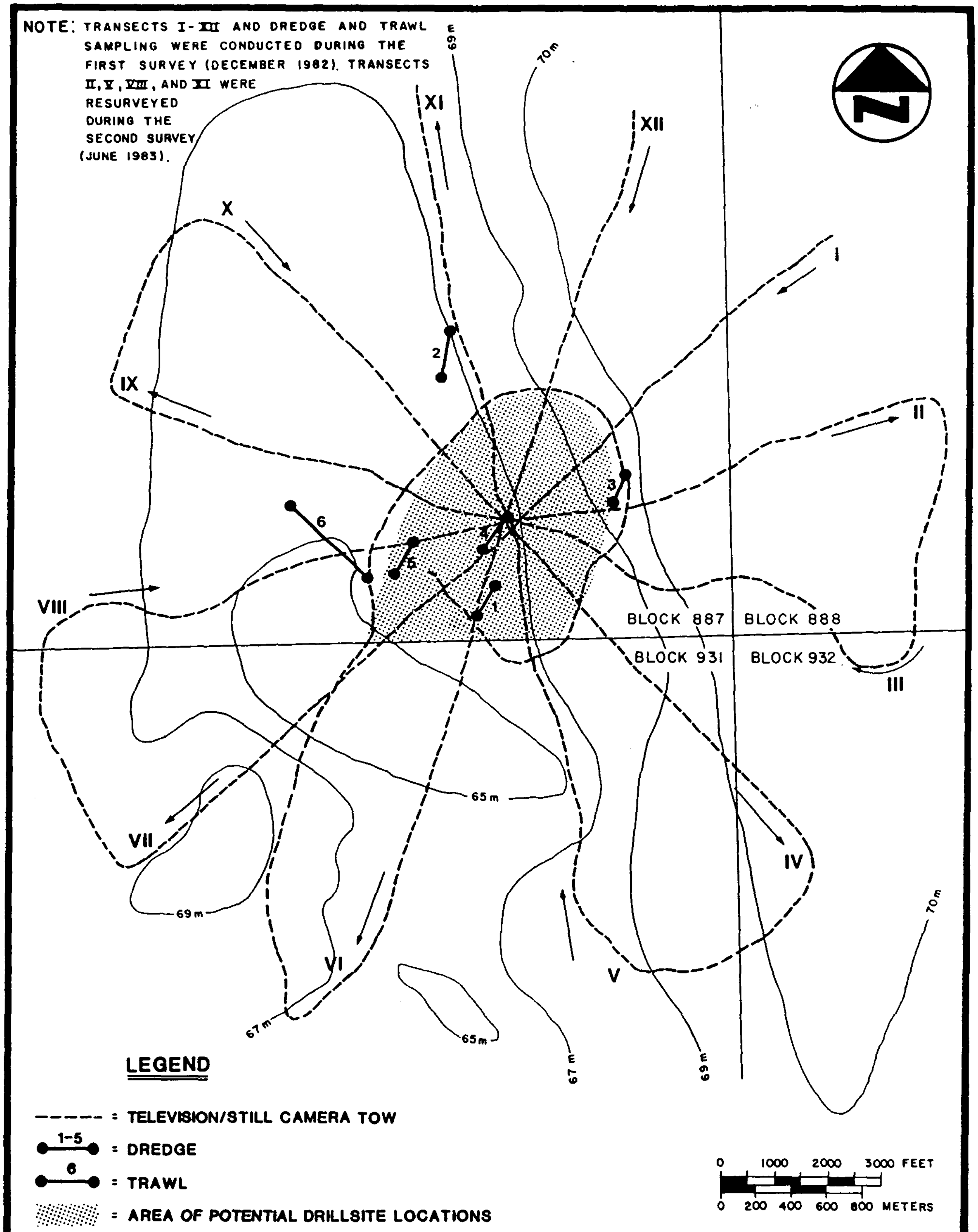


FIGURE 5.41. LOCATIONS OF TELEVISION/STILL CAMERA TRANSECTS AND DREDGE AND TRAWL SAMPLING IN CHARLOTTE HARBOR AREA BLOCK 887.

TABLE 5.55. COMPARISON OF QUANTITATIVE SLIDE ANALYSIS DATA FROM TWO SURVEYS OF CHARLOTTE HARBOR AREA BLOCK 887.

Biota/Substrate Type	Average Percent Cover	
	First Survey (December 1982)	Second Survey (June 1983)
BIOTA		
Green Algae		
Codium isthmocladum	24.62	0.35
Halimeda sp.	0.56	0.10
Unidentified green algae	0.00	0.57
Red Algae		
Peyssonnelia rubra	5.05	4.65
Peyssonnelia simulans	0.00	0.43
Lithothamnium occidentale	0.57	
Gracilaria sp.	0.00	0.01
Rhodymenia sp.	0.03	
Cryptonemiales	3.51	
Unidentified Corallinaceae	0.00	11.22
Unidentified red algae	0.00	0.21
Porifera	0.26	0.27
Other identifiable biota	0.24	0.35
Unidentified biota	0.00	0.86
TOTAL BIOTA	34.84	19.02
SUBSTRATE		
Sand	57.47	80.93
Rubble	7.70	0.02
Rock		0.03
TOTAL SUBSTRATE	65.17	80.98

Micropanope sculptipes, Osachila tuberosa, Parthenope fraterculus, and Phimochirus holthuisi; the bryozoan Stylopoma spongites; and the ophiuroid Ophiolepis elegans.

5.6.3 Discussion

Block 887 is located near several live-bottom stations sampled during the Southwest Florida Shelf Ecosystems Study (Years 1 and 2) (Figure 5.40). Stations 9, 10, 11, 17, and 23 are the most comparable in terms of location and water depth:

Location	Water Depth (m)
Station 9	56
Station 10	71
Station 11	77
Station 17	58
Station 23	70
Block 887	65-70

Table 5.56 compares photographic data from the Block 887 surveys with data from these nearby Year 1 and 2 stations. Algae constituted most of the biotic cover at all of the locations indicated. The level of green algal cover seen in Block 887 during the first survey was much higher than at any of the other locations--reflecting the bloom of Codium isthmocladum. During the second survey in Block 887, green algal cover was similar to that seen at Stations 10, 11, and 17 during spring. Red algal cover percentages at Block 887 during both seasons were intermediate between those seen at Stations 11 and 23. Red algae in the order Cryptonemiales, including Peyssonnelia spp., were the most abundant algae at these three locations.

The photographic data suggest a greater affinity of Block 887 with stations in a slightly greater water depth (Stations 10, 11, and 23) than with those in lesser water depths (Stations 9 and 17). The latter, although also algal-dominated, are typified by more brown and green algae (particularly Halimeda spp. among the latter), whereas Block 887 and the deeper stations are more typified by cryptonemialid red algae. The cryptonemialids are present at fairly constant levels throughout the year at the stations in 70 to 80 m depth (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). At Block 887, the Codium bloom is superimposed on the "background" of

TABLE 5.56. COMPARISON OF PHOTOGRAPHIC SURVEY DATA FROM CHARLOTTE HARBOR AREA BLOCK 887 WITH DATA FROM NEARBY SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY STATIONS.

	Season and Location											
	Fall*						Spring†					
	Southwest Florida Shelf Ecosystems Study Station					Block	Southwest Florida Shelf Ecosystems Study Station					Block
Group	9	10	11	17	23	887	9	10	11	17	23	887
Green Algae	12.1	2.8	2.8	8.8	11.6	25.2	4.3	0.9	0.2	1.6	12.4	1.0
Red Algae	1.1	5.9	7.9	1.5	18.4	9.2	1.1	6.0	4.2	0.2	20.3	16.5
Brown Algae	1.8	0.1	0.3	0.0	0.0	0.0	5.7	7.2	0.0	1.7	0.1	0.0
Sponges	0.1	2.1	1.6	1.8	4.4	0.3	1.9	7.4	1.8	3.0	3.7	0.3
Bryozoans	0.8	0.0	0.0	3.6	0.0	0.0	0.9	0.0	0.0	1.0	0.0	0.1
Other Biota	0.4	0.4	0.6	0.4	0.3	0.2	0.7	0.7	1.0	1.0	0.6	1.2
TOTAL BIOTA	16.3	11.3	13.2	16.1	34.7	34.8	14.6	22.2	7.2	8.5	37.1	19.0

*Fall = Fall Cruise (October-November 1980) for the Southwest Florida Shelf Ecosystems Study Stations and first survey (December 1982) for Charlotte Harbor Area Block 887.

†Spring = Spring Cruise (April-May 1981) for the Southwest Florida Shelf Ecosystems Study Stations and second survey (June 1983) for Charlotte Harbor Area Block 887.

perennial red algae. The relatively low bryozoan cover at Block 887 is also more similar to bryozoan cover values at Stations 10, 11, and 23 than to those at Stations 9 and 17.

In species composition, dredge samples from Block 887 are similar to Year 1 and 2 middle shelf stations (40 to 80 m depth range). Informal comparison of lists of frequently collected species (Table 5.57) suggests that species composition in Block 887 is more similar to that at stations in 70 to 80 m depth (10, 11, and 23) than to that at stations in 50 to 60 m depth (9 and 17). The degree of similarity depends on the group, however. Among the algae, *Codium isthmocladum* was collected in Block 887 and at Stations 9 and 17, but not at Station 10, 11, or 23 (*C. isthmocladum* was collected in dredge samples from stations in water depths of 15 to 58 m during Year 1, 2, and 3 sampling). Sponge species identified in Block 887 were the same as those at Station 9 (however, most sponges collected at all of these locations were not identifiable to species, making comparisons tenuous). Within the other groups listed in Table 5.57, the Block 887 species list is more similar to lists from Stations 10, 11, and 23 than to those from Stations 9 and 17.

Data from the Charlotte Harbor Area Block 887 surveys provide important perspective on the previous years of Southwest Florida Shelf Studies. Photographs and dredge data indicate general similarities of the Block 887 biota to those seen at both greater and lesser water depths. However, the striking abundance of *Codium* seen during the first survey and the large difference between surveys show that one can still go to a new location within the study area (or visit a previously sampled location another time) and find something unexpected.

TABLE 5.57. SPECIES FREQUENTLY COLLECTED IN DREDGE SAMPLES FROM CHARLOTTE HARBOR AREA BLOCK 887 AND SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY STATIONS.

Species	Southwest Florida Shelf Ecosystems Study Station					Charlotte Harbor Area Block 887
	9	10	11	17	23	
ALGAE						
Anadyomene menziesii					**	
Caulerpa sertularioides	*	*		**		
Codium isthmocladum	*			*		**
Halimeda gracilis	**	*	*	**	*	
Lithothamnium occidentale	*					**
Peyssonnelia rubra	*	**	*	*	**	**
BRYOZOANS						
Amathia convoluta	**			*		
Bracebridgia subsulcata	*			**	*	
Bugula neritina	*	*	*	**	*	
Cellaria irregularis	**	*	*	**		
Celleporaria albirostris	*	*		**	*	*
Celleporaria magnifica	*	*	*	**		*
Steganoporella magnilabris	**	*	*	**	*	*
Stylopoma spongites	**	*	*	**	*	**
CNIDARIANS						
Madracis asperula	**	*	*	*	*	*
Oculina tenella	*			**		
Stephanoscyphus corniformis	*	**	*	*	*	
CRUSTACEANS						
Callidactylus asper	*	*		**		
Dardanus insignis	*	**	*	*	*	*
Galathea rostrata	*	*	*	**	*	*
Micropanope sculptipes	*	*	**	*	*	**
Munida pusilla	*	**	*	**	*	*
Osachila tuberosa	*	*	**	*		**
Paguristes sericeus	**	*		*	*	
Parthenope agona	*	*	*	**		
Parthenope fraterculus	*	*	**	*	*	**
Phimochirus holthuisi	*	**	*	*	*	**
Stenocionops furcata furcata	*	*	*	**		

TABLE 5.57. (CONTINUED).

Species	Southwest Florida Shelf Ecosystems Study Station 9	10	11	17	23	Charlotte Harbor Area Block 887
ECHINODERMS						
Astropecten duplicatus	**			**		
Echinolampas depressa	**	*	*	**	*	
Eucidaris tribuloides tribuloides	**	*	*	**	*	*
Genocidaris maculata	**	*	*		*	*
Ophiolepis elegans	**	*		**	*	**
Ophiomyxa flaccida	**	*	**	**	*	*
Ophiothrix angulata	**	**	**	**	*	*
Stylocidaris affinis	*	**	**		*	*
SPONGES						
Cinachyra alloclada	*	*	*	**		*
Geodia neptuni		**	**	**	*	
Ircinia strobilina		**	**	**	*	
Microciona spp.	*	*	*			**
Placospongia melobesioides		**	**	*	*	
UROCHORDATES						
Didemnum candidum	**	**	**	**	*	*
Polycarpa obtecta	**		*	**		

*Indicates species occurred in one or more dredge samples (but <75% of total number).
**Indicates species occurred in ≥75% of dredge samples.

6.0 SOFT-BOTTOM STATIONS

6.1 INTRODUCTION

Eleven soft-bottom stations were chosen following Cruise I to be sampled on Cruises II and III (Figure 6.1). Water depths and Loran-C and latitude/longitude coordinates for the soft-bottom stations are provided in Table 6.1.

At each soft-bottom station, divers collected infaunal and sediment samples for grain size and hydrocarbon analyses. Station 52, which was also a live-bottom station, was designated for additional sampling. At this "intensive" station, divers collected infaunal samples along a transect extending from a soft-bottom area to a live-bottom area to evaluate effects of the proximity of live bottom on macroinfaunal abundance and community composition.

6.2 METHODS

6.2.1 Field Methods and Equipment

Infauna. Divers collected 10 infaunal samples at each station on each cruise. At Station 52, where there was a distinct boundary between live- and soft-bottom areas, additional samples were collected along a transect extending from live bottom to soft bottom. Samples were collected within the live-bottom area and at distances of 5, 8, 30, and 75 m from live bottom. During Cruise II, the 75-m sampling location was not aligned with the others due to an initial error in positioning of the transect relative to the live-bottom area (Figure 6.2). During Cruise III, all sampling locations were along a single transect. The exact locations of the transects were not the same on the two cruises.

Divers sampled infauna using 12.5 cm x 12.5 cm x 23 cm deep stainless steel corers (Figure 6.3). The top of each corer was covered by 0.5-mm screen to prevent loss of organisms. To collect samples, divers pushed each corer into the sediment to a depth of 10 cm, excavated the surrounding sediment, and placed one hand beneath the excavated corer to remove it. Each sample was placed in a cotton bag, which was tied shut and carried to the surface for shipboard processing.

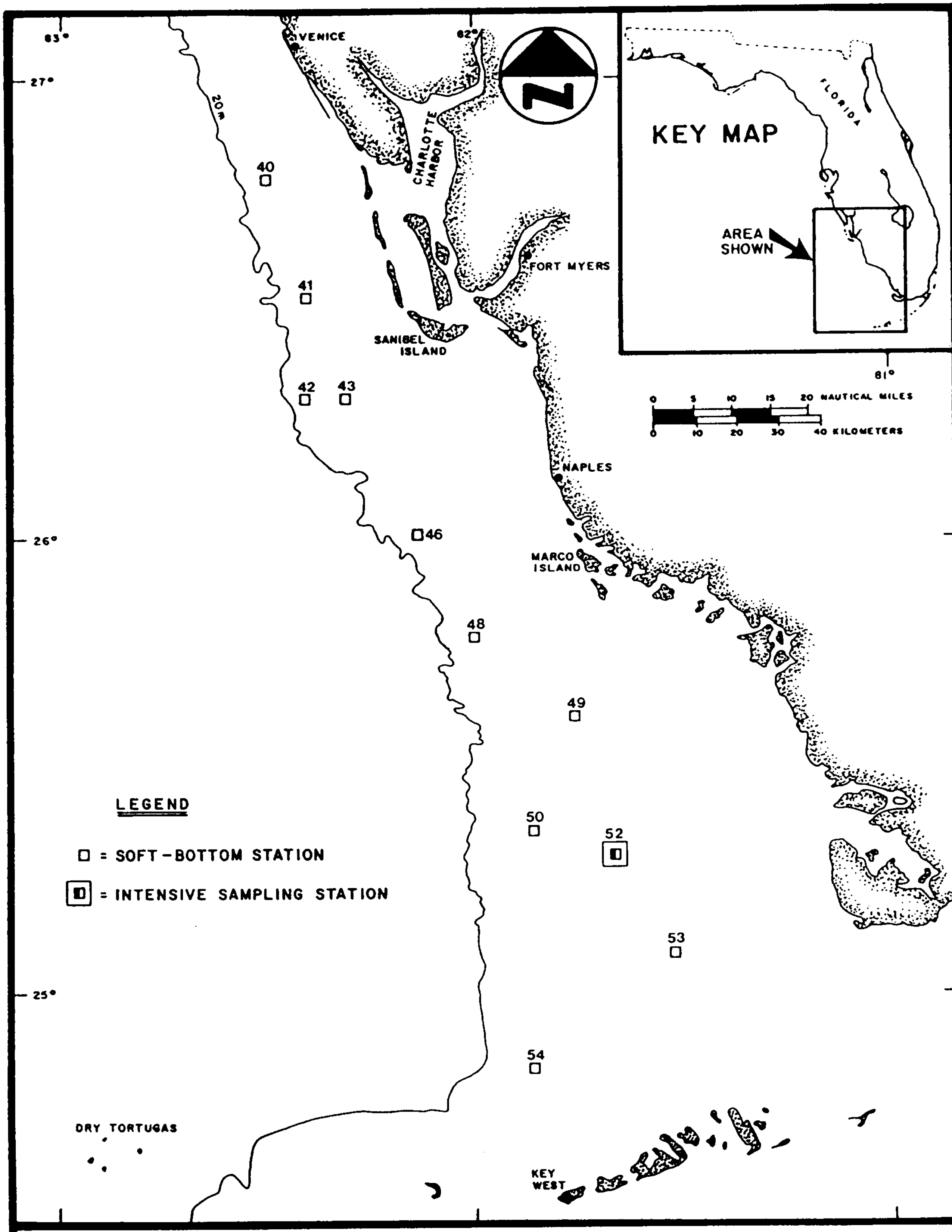


FIGURE 6.1. LOCATIONS OF SOFT-BOTTOM STATIONS SAMPLED DURING CRUISES II AND III.

TABLE 6.1. WATER DEPTHS AND LOCATIONS OF SOFT-BOTTOM STATIONS SAMPLED DURING CRUISES II AND III.

Station	Water Depth (m)	Latitude (N)	Longitude (W)	Loran-C Coordinates	
40	18	26°46.75'	82°30.42'	14105.1	44216.5
41	16	26°32.22'	82°24.50'	14084.7	44106.3
42	17	26°17.01'	82°25.42'	14049.2	44058.0
43	16	26°17.40'	82°18.89'	14064.1	44008.8
46	18	26°01.02'	82°07.88'	14052.6	43878.9
48	18	25°46.15'	82°01.10'	14036.4	43798.8
49	12	25°35.46'	81°46.23'	14045.1	43681.5
50	16	25°20.50'	81°51.50'	14006.3	43700.1
52	14	25°17.80'	81°39.80'	14024.3	43625.4
53	10	25°05.31'	81°31.68'	14017.1	43572.0
54	17	24°49.92'	81°50.55'	13952.6	43672.0

Cruise II: December 1982
Cruise III: May-June 1983.

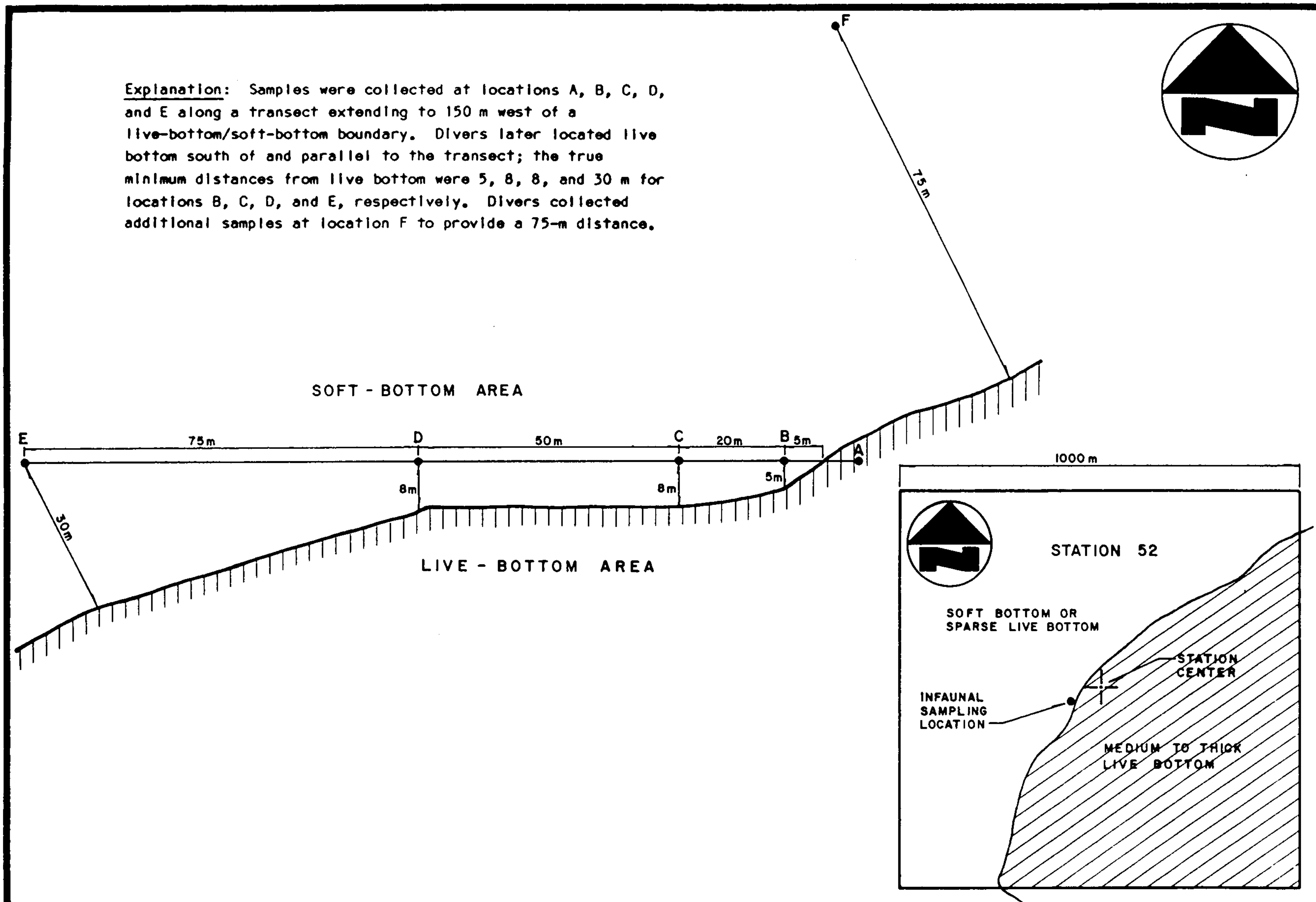


FIGURE 6.2. DIAGRAM SHOWING CRUISE II INFAUNAL SAMPLING LOCATIONS IN RELATION TO A LIVE-BOTTOM AREA AT STATION 52.

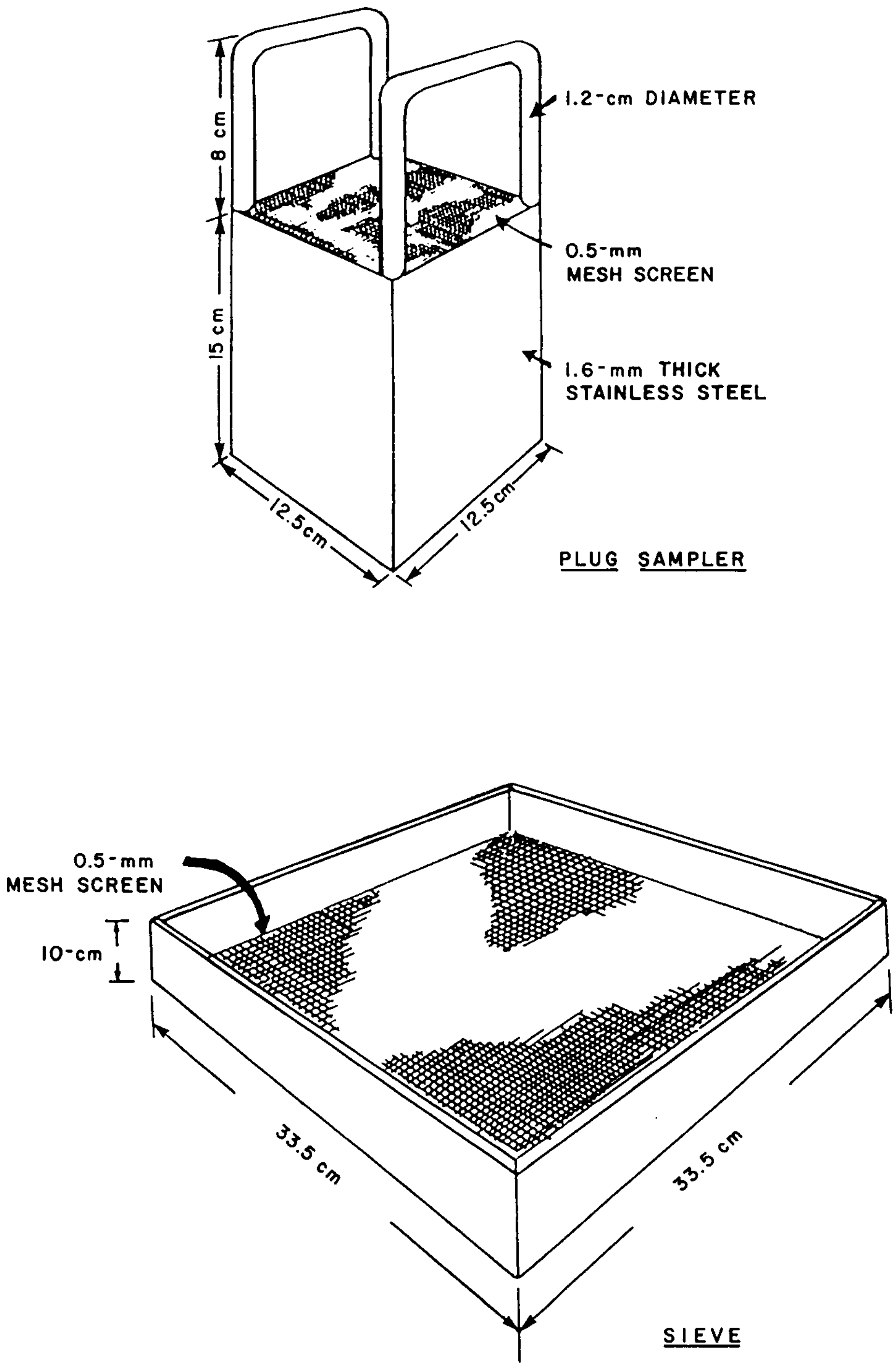


FIGURE 6.3. SIEVE AND PLUG SAMPLER USED FOR QUANTITATIVE INFAUNAL SAMPLING (FIGURE COURTESY OF MOTE MARINE LABORATORY).

On board ship, the samples were immersed in a narcotizing solution of 10% magnesium chloride for approximately 1 h and then transferred to a 0.5-mm mesh box sieve. The sieve was gently rinsed to wash out fine sediments, and the material remaining on the sieve was rinsed into 1-l plastic jars bearing internal and external labels. The samples were fixed and stained using 10% buffered formalin with rose bengal and stored for onshore laboratory processing.

Sediment Samples. Divers collected sediment samples for grain size, carbonate, and hydrocarbon analyses from the same area where infaunal samples were obtained. Methods and results for the hydrocarbon sampling are presented in Chapter 7.

Three replicate grain size/carbonate cores were obtained at each soft-bottom station during Cruise II, and two replicates were obtained at each station during Cruise III. The samples were collected using an 8-cm diameter core tube inserted to a depth of 5 cm. Both ends of the core tube were capped underwater, and the samples were returned to the ship. The samples were then transferred to acid-washed nalgene bottles and stored frozen.

6.2.2 Laboratory Methods

Infaunal Sample Processing and Identification. Of the ten infaunal samples collected at each station, eight were processed and the remaining two were archived.

In the laboratory, samples were decanted, split into heavy (coarse sediments and molluscs) and light (detritus and most of the infauna) fractions, and preserved in 70% isopropyl alcohol. The heavy fraction was sorted by eye in white enamel pans. The light fraction was sorted using a binocular dissecting microscope. Specimens were examined using a high-power stereo microscope or a compound microscope and identified by reference to available descriptive literature and in-house museum collections. Specimens were sent to taxonomic consultants for identification or confirmation of identification as needed.

Sediment Grain Size and Carbonate Analyses. Sediment samples were analyzed for grain size and carbonate content as illustrated in Figure 6.4. Sand size fractions were determined by sieving through a nested series of sieves (phi interval=0.5) using standard soils analysis techniques. Silt and clay fractions were determined using the standard

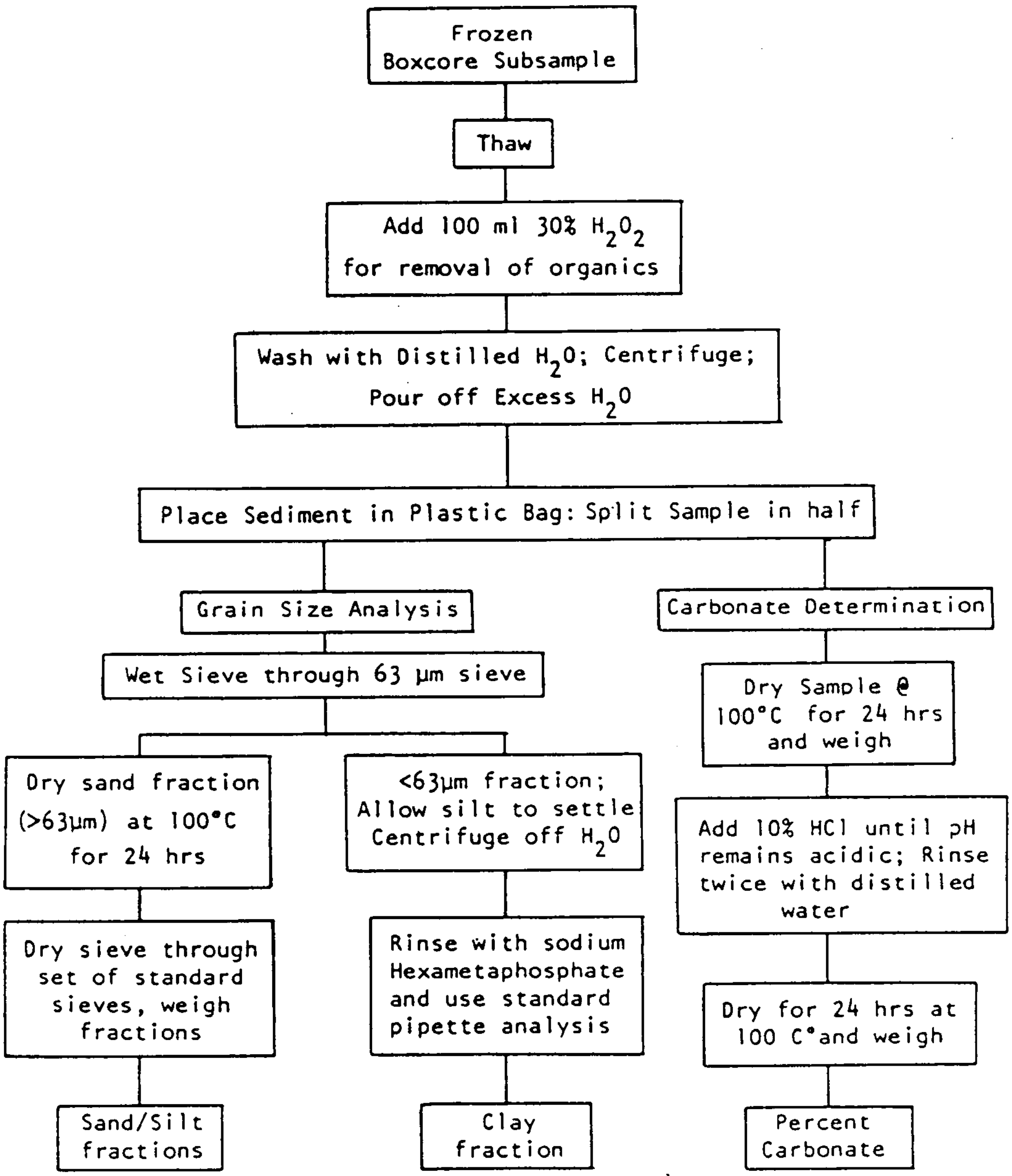


FIGURE 6.4. SEDIMENT GRAIN SIZE AND CARBONATE ANALYSIS METHODOLOGY.

pipette method. Carbonate content was estimated by measuring weight loss upon acidification with 10% HCl.

6.2.3 Data Analysis

Infaunal and sediment data were entered on computer for tabulation and analysis (see Section 2.3). Descriptive statistics and analyses were conducted using SAS (SAS Institute, 1982) and the Ecological Analysis Package (EAP) (Smith, 1979).

For sediment data, statistics calculated were mean and median grain size, phi sorting, skewness, and kurtosis, calculated following Folk (1974). Appendix J, which contains the sediment data, also summarizes methods for calculation of each statistic. Textural diagrams were prepared following Shepard (1954). Mean percent carbonate was calculated for each sample.

For infauna, summary statistics calculated were mean density (total infauna and broken down by phyletic groups), diversity, equitability, and expected species richness. Diversity was calculated using the Shannon-Wiener index:

$$H' = -\sum p_i \ln(p_i)$$

where p_i is the abundance of species (i) as a proportion of the total. Equitability was calculated following Pielou (1975):

$$J' = H/\ln(S)$$

where H is the Shannon-Wiener index and S is the total number of species. The expected species richness for a fixed number of individuals was calculated by the rarefaction technique as described by Simberloff (1978). The number of individuals was arbitrarily set at 15. Only organisms identified to species level were included in these calculations. The number of species identified from each sample was also tabulated, and ranked species abundance tables were prepared for each station (by cruise and pooled over cruises) and for all stations combined.

Higher level analyses were also conducted using infaunal data. Agglomerative, hierarchical cluster analysis with flexible sorting (β = -0.25) was conducted using the Bray-Curtis index as the similarity measure. The clustering program (Procedure DENDRO in the Ecological Analysis Package; Smith, 1979) recalculates large dissimilarity values by a "step across" method, and therefore some dendrograms include values greater than 1.0. Because of computer program limitations, a maximum of 255 species could be included in each analysis; data sets were truncated by specifying a minimum frequency of occurrence for inclusion in the analysis (Table 6.2). For additional information on cluster (classification) analyses, see Boesch (1977) and Pielou (1984).

6.3 RESULTS--SEDIMENTS

Table 6.3 summarizes sediment composition data from the soft-bottom stations, and Table 6.4 lists descriptive classifications of the sediments in terms of grain size moments. Figures 6.5 and 6.6 are textural diagrams for sediments from Cruises II and III, respectively.

Mean grain size ranged from 125 m (fine sand) to 733 m (coarse sand) (Table 6.3). Coarse mean grain sizes were noted at Station 52 (especially in and near the live-bottom area) and Station 41. The finest mean grain sizes were at Stations 40 and 54. There is no apparent geographic pattern to the mean grain size values. Although mean and median grain sizes from the two cruises were generally comparable, pronounced between-cruise variations were evident at Stations 52 (live-bottom area) and 54.

Sediment texture diagrams indicate that sediments at all stations except 54 can be classified as sand (Figures 6.5 and 6.6). Station 54 sediments can be characterized as silty sand. Stations 40, 52, and 53 also exhibited slightly higher than average silt and clay content (Table 6.3).

Sediment carbonate values reflect the location of the stations in an area of transition between carbonate and quartz sediments. Most stations had values >75%, but sediments at Stations 40 and 49 were predominantly quartz sands (carbonate values of 25% or less), and those at Stations 41 and 42 were intermediate in carbonate content.

The following paragraphs provide briefly summarize sediment composition and diver substrate observations at individual soft-bottom stations.

Station 40. Sediments at Station 40 were poorly to moderately sorted fine quartz sand. The grain size distribution was very leptokurtic (sharply peaked), with 60 to 70% of total weight in the 88 to

TABLE 6.2. NUMBERS OF SPECIES INCLUDED IN INFAUNAL CLUSTER ANALYSES.

Analysis	Total No. Species	Inclusion Criterion (No. individuals)*	No. Species Included in Analysis
CRUISE II:			
Including all distances from live bottom at Station 52	453	5	232
Including only 75 m from live bottom at Station 52	383	3	242
CRUISE III:			
Including all distances from live bottom at Station 52	353	3	239
Including only 75 m from live bottom at Station 52	311	2	233
CRUISES II AND III:			
Including only 75 m from live bottom at Station 52	497	6	238

*Because of computer program limitations, a maximum of 255 species could be included in each analysis. The data sets were truncated by specifying a minimum frequency of occurrence for inclusion in the analysis. A species was included in the analysis only if at least the given number of individuals was collected (sum of all cores, all stations involved).

TABLE 6.3. SEDIMENT COMPOSITION DATA FROM YEAR 3 SOFT-BOTTOM STATIONS.

		Sediment Composition														
		Cruise II							Cruise III							
				Size Fraction*							Size Fraction*					
Station	Water Depth (m)	Mean Grain Size (μm)	Median Grain Size (μm)	Shell Hash (%)	Sand (%)	Silt (%)	Clay (%)	Carbonate (%)	Mean Grain Size (μm)	Median Grain Size (μm)	Shell Hash (%)	Sand (%)	Silt (%)	Clay (%)	Carbonate (%)
40	18	125	142	0.1	84.6	11.8	3.4	24	142	147	0.1	90.9	7.8	1.2	21
41	16	476	414	2.1	97.2	0.3	0.4	36	547	507	2.4	97.0	0.4	0.2	49
42	17	364	325	0.9	98.4	0.2	0.4	29	285	288	0.5	99.0	0.5	0.1	38
43	16	343	324	0.7	98.2	0.5	0.7	88	338	318	0.8	97.8	0.7	0.7	88
46	18	343	323	0.2	98.9	0.4	0.5	97	227	232	0.2	98.1	1.2	0.5	95
48	16	219	221	0.3	97.3	1.4	1.0	91	175	166	0.2	96.6	2.4	0.8	88
49	11.5	271	210	4.9	93.6	0.5	1.0	25	190	186	1.7	97.4	0.4	0.4	18
50	16	215	189	2.1	94.8	1.7	1.4	82	212	195	1.0	97.5	1.1	0.4	90
52-LB†	13.5	484	473	14.2	79.0	4.8	2.0	97	733	657	32.3	61.9	4.4	1.5	98
52-5m		704	617	40.4	49.7	6.9	3.0	98	347	234	19.5	64.7	11.7	4.1	98
52-8m		574	422	32.9	55.4	8.2	3.5	98	431	262	23.9	64.8	8.5	2.9	97
52-30m		364	194	19.0	67.1	9.8	4.2	98	516	309	24.8	66.2	6.6	2.4	98
52-75m		313	193	14.0	75.2	7.5	3.3	98	381	227	18.4	70.9	8.1	2.5	98
53	10	319	256	10.2	80.9	5.9	3.0	99	382	307	11.4	83.8	3.2	1.6	98
54	17	214	245	11.4	58.9	25.9	3.9	99	137	92	8.1	50.8	33.4	7.7	97

* Size fractions: shell hash (≥ 2 mm), sand (62 μm to 2 μm), silt (4 μm to 62 μm), and clay (< 4 μm).
† Suffixes for Station 52 refer to distance from live bottom (LB).

TABLE 6.4. DESCRIPTIVE CLASSIFICATION OF SOFT-BOTTOM STATION SEDIMENTS ON THE BASIS OF GRAIN SIZE, SORTING, SKEWNESS, AND KURTOSIS.

Cruise-Station	Descriptive Classification of Sediments*			
	Mean Grain Size	Sorting	Skewness	Kurtosis
II - 40	Fine sand	Poorly sorted	Strongly fine skewed	Very leptokurtic
III- 40	Fine sand	Moderately sorted	Fine skewed	Very leptokurtic
II - 41	Medium sand	Moderately sorted	Strongly coarse skewed	Mesokurtic
III- 41	Coarse sand	Moderately sorted	Coarse skewed	Platykurtic
II - 42	Medium sand	Moderately well sorted	Strongly coarse skewed	Leptokurtic
III- 42	Medium sand	Moderately well sorted	Coarse skewed	Very leptokurtic
II - 43	Medium sand	Moderately well sorted	Coarse skewed	Leptokurtic
III- 43	Medium sand	Moderately well sorted	Coarse skewed	Leptokurtic
II - 46	Medium sand	Moderately sorted	Coarse skewed	Leptokurtic
III- 46	Fine sand	Moderately sorted	Near symmetrical	Mesokurtic
II - 48	Fine sand	Moderately well sorted	Near symmetrical	Mesokurtic
III- 48	Fine sand	Moderately well sorted	Coarse skewed	Leptokurtic
II - 49	Medium sand	Poorly sorted	Strongly coarse skewed	Very leptokurtic
III- 49	Fine sand	Moderately well sorted	Strongly coarse skewed	Very leptokurtic

TABLE 6.4. (CONTINUED).

Cruise-Station	Descriptive Classification of Sediments*			
	Mean Grain Size	Sorting	Skewness	Kurtosis
II - 50	Fine sand	Moderately sorted	Strongly coarse skewed	Leptokurtic
III- 50	Fine sand	Moderately sorted	Coarse skewed	Leptokurtic
II - 52-LB	Medium sand	Very poorly sorted	Near symmetrical	Leptokurtic
-5m	Coarse sand	Very poorly sorted	Near symmetrical	Platykurtic
-8m	Coarse sand	Very poorly sorted	Near symmetrical	Platykurtic
-30m	Medium sand	Very poorly sorted	Coarse skewed	Leptokurtic
-75m	Medium sand	Very poorly sorted	Coarse skewed	Leptokurtic
III- 52-LB	Coarse sand	Very poorly sorted	Near symmetrical	Platykurtic
-5m	Medium sand	Very poorly sorted	Coarse skewed	Leptokurtic
-8m	Medium sand	Very poorly sorted	Coarse skewed	Mesokurtic
-30m	Coarse sand	Very poorly sorted	Coarse skewed	Platykurtic
-75m	Medium sand	Very poorly sorted	Strongly coarse skewed	Mesokurtic
II - 53	Medium sand	Poorly sorted	Coarse skewed	Very leptokurtic
III- 53	Medium sand	Poorly sorted	Coarse skewed	Leptokurtic
II - 54	Fine sand	Very poorly sorted	Fine skewed	Mesokurtic
III- 54	Fine sand	Very poorly sorted	Coarse skewed	Mesokurtic

*Classification based on Folk (1974). See Appendix J.

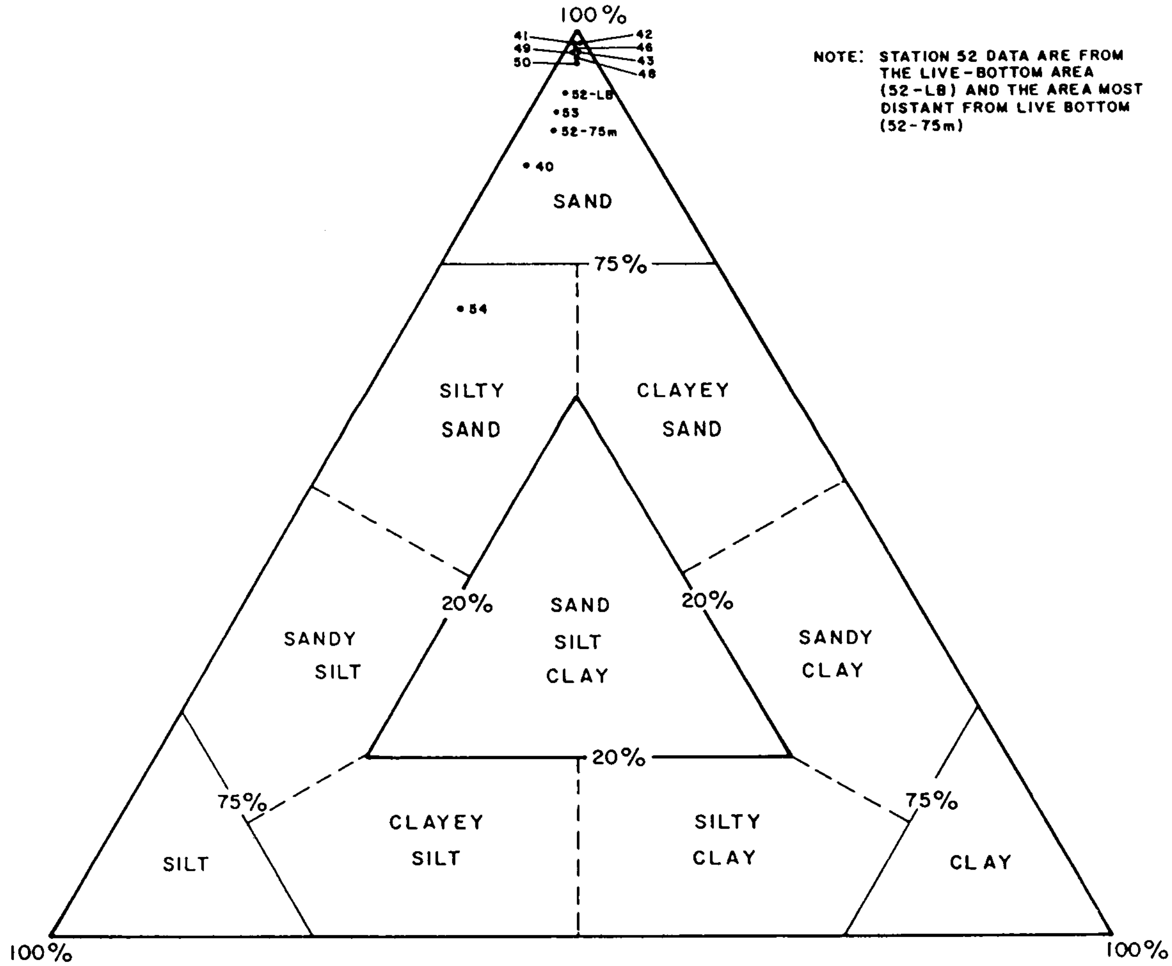


FIGURE 6.5. SEDIMENT TEXTURE FOR SOFT-BOTTOM STATIONS, CRUISE II.

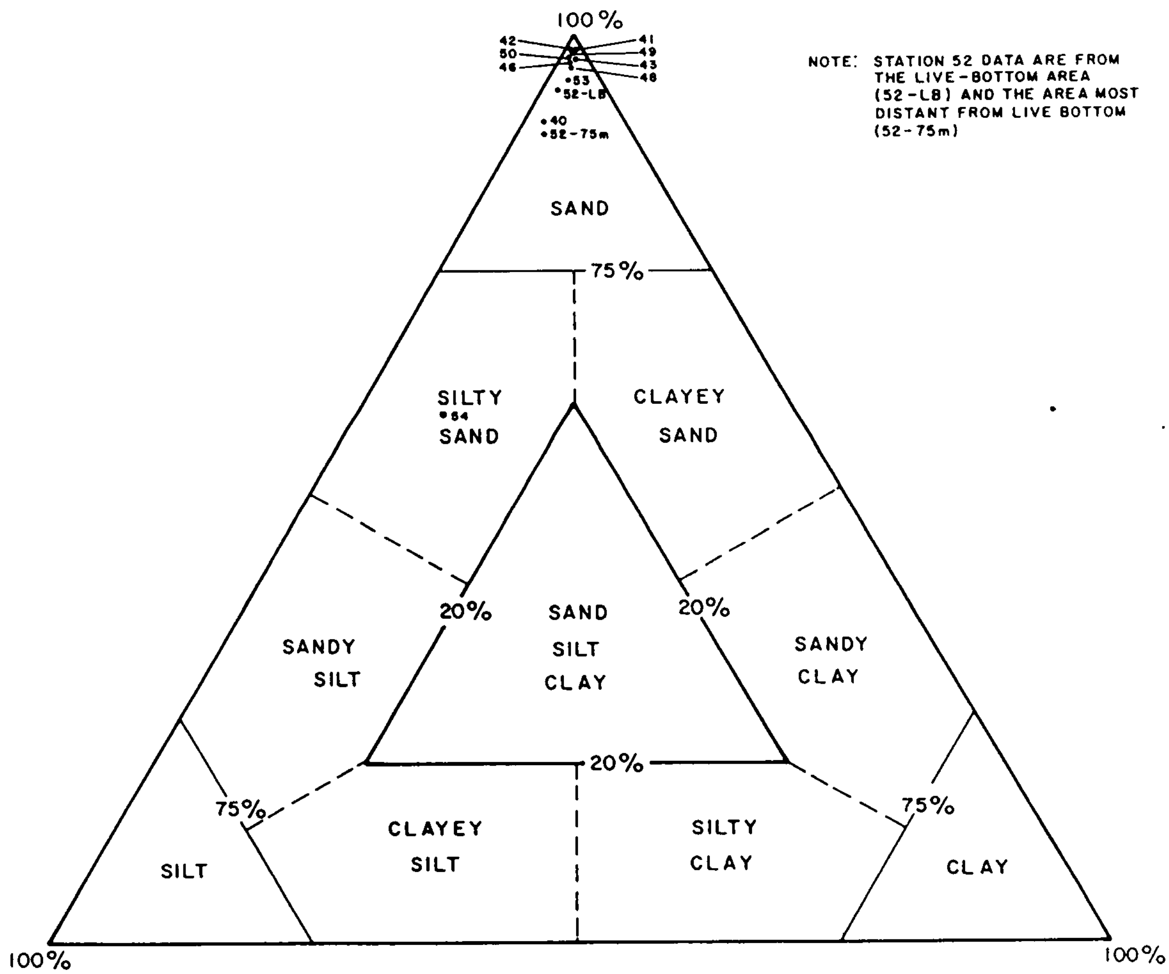


FIGURE 6.6. SEDIMENT TEXTURE FOR SOFT-BOTTOM STATIONS, CRUISE III.

250 m size range, but skewed toward fine particles. Silt and clay content was higher here than at any other station except 54. Divers noted patches of yellow/brown algal film on the substrate during both cruises.

Station 41. Sediments at Station 41 were medium to coarse, moderately sorted quartz/carbonate sand. There was very little silt or clay, and the size distribution was skewed toward coarse sand. Shell hash (particles >2 mm in diameter) was more abundant here than at the other northern stations. Sand ripples were seen during both cruises. The Cruise II ripples were aligned in an east/west orientation and were about 6 cm in height, with a wavelength of about 35 cm. Ripples seen during Cruise III were somewhat larger, with a height of 8 to 16 cm.

Station 42. Sediments at Station 42 were also medium quartz/carbonate sand, though better sorted than at Station 41. The size distribution was skewed toward coarse particles and leptokurtic, with most of the weight in the 177 to 500 μm size range. Irregular, bioturbated sand ripples (approximately 6 cm in height and 40 cm in wavelength) were seen during Cruise II; during Cruise III, the bottom appeared heavily bioturbated and no sand ripples were evident. Divers saw a brown algal film on the bottom during Cruise II.

Station 43. Sediments at Station 43 were moderately well sorted medium sands similar in size distribution to those at Station 42, though predominantly carbonate rather than quartz. The grain size distribution was skewed toward coarse sand and very peaked, with about 70% of the weight in the 250 to 500 μm size range. No diver observations were recorded during Cruise II; during Cruise III, the bottom was smooth and covered by a patchy algal film. The layer of unconsolidated sediments was thin, with a rock layer present at about 12 cm depth. Many detached or fragmented sponges were seen on the bottom during Cruise III.

Station 46. Sediment composition at Station 46 differed somewhat between cruises. Cruise II sediments were moderately sorted medium sand with a size distribution skewed toward coarse sand and most of the weight in the 250 to 500 μm size range. Cruise III sediments were fine sand with little skewness or kurtosis. Sediments were predominantly carbonate. Patches of algal film were seen on the seafloor during both cruises. Heavily bioturbated remnants of sand ripples were seen during Cruise II but none were evident during Cruise III.

Station 48. Sediments at Station 48 were moderately well sorted fine carbonate sands. The size distribution was skewed toward coarse sand during Cruise III. Divers noted patchy brown algal film and some bioturbation during Cruise II; the bottom was more heavily bioturbated during Cruise III. No sand ripples were noted.

Station 49. Sediments at Station 49 were fine to medium quartz sand, with the size distribution skewed toward coarse sand. The 125 to 250 μm size (fine sand) fraction accounted for about 80% of dry weight in Cruise III samples and 65% of dry weight in Cruise II samples; Cruise II samples contained a slightly higher proportion of particles in the 250 to 354 μm (medium sand) size range and consequently had a higher mean grain size. No sand ripples were noted at this station.

Station 50. Sediments at Station 50 were moderately sorted fine carbonate sands with a size distribution skewed toward coarse sand. About 65 to 70% of sediment dry weight was in the 125 to 354 μm (fine to medium sand) size range. No sand ripples were noted at this station, but large mounds due to bioturbation were evident during Cruise II. A thin algal film was seen on the substrate during Cruise III.

Station 52. Sediments at Station 52 differed from those seen at other soft-bottom stations, reflecting in part the influence of nearby live bottom. Mean and median grain sizes were generally higher than at most other stations; carbonate content was consistently near 100%. Sediments within the live-bottom area and out to at least 75 m from it were very poorly sorted, containing significant proportions of various grain sizes ranging from "gravel" (actually shell hash) to silt and clay. The sediments were generally coarse-skewed; shell hash particles >2 mm in diameter contributed up to 40% of total sediment weight in some samples. In general, mean and median grain sizes and proportions in the >2 mm size class were highest either within the live-bottom area or at 5-m or 8-m distance from it, and were lowest at the greatest distance from it (75 m). However, the trends were not consistently related to distance from live bottom (Figure 6.7). No sand ripples were noted during Cruise II; poor visibility prevented diver observations during Cruise III.

Station 53. Sediments at Station 53 were poorly sorted medium sands, with the size distribution skewed toward coarse sand. As at Stations 52 and 54, carbonate content was nearly 100%. Shell hash

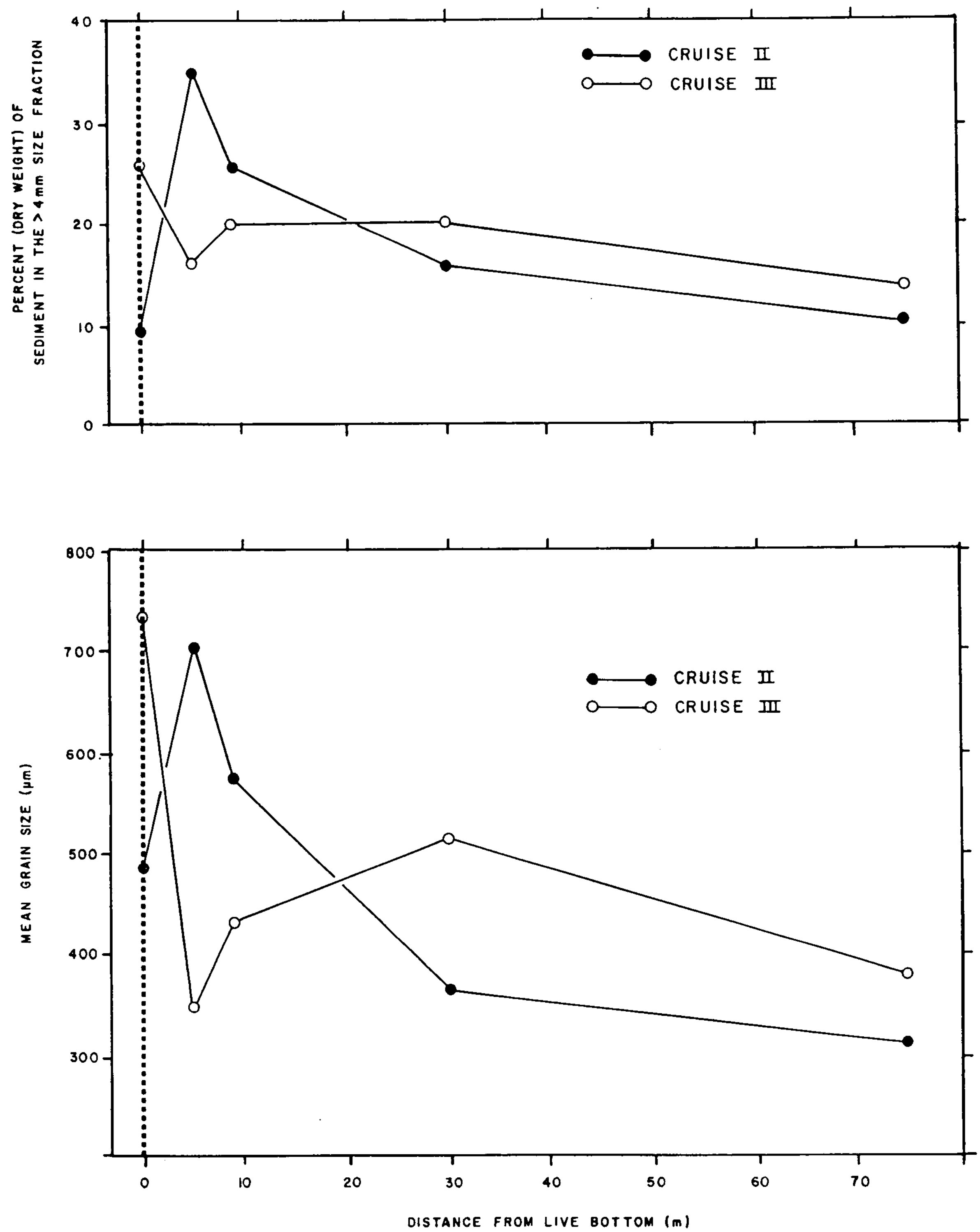


FIGURE 6.7. RELATIONSHIPS OF SEDIMENT GRAIN SIZE VARIABLES TO DISTANCE FROM LIVE BOTTOM AT STATION 52.

particles (>2 mm in diameter) contributed about 10% of total weight, and silt and clay accounted for another 5 to 10%. The size distribution was leptokurtic, with sediments in the size range 125 to 354 µm (fine to medium sand) accounting for about 50% of the total. No sand ripples were seen at this station.

Station 54. Sediments at Station 54 consisted of a wide range of sand particle sizes from very fine to very coarse (no modal sand size fraction), mixed with a significant proportion (25 to 35%) of medium to coarse silt. Shell hash accounted for about 10% of sediment by weight. Carbonate content was nearly 100%. Divers noted bioturbated substrate and a patchy brown algal film during Cruise II. No sand ripples were seen during either cruise.

6.4 RESULTS--INFAUNA

6.4.1 Taxonomy

A total of 579 species was identified from the infaunal collections. Of the total, 42% were polychaetes, 32% were crustaceans 11% were bivalves, and 9% were gastropods. Among the polychaetes, well-represented families included Syllidae (38 species), Spionidae (20 species), Paraonidae (19 species), Capitellidae (13 species), and Nereidae (10 species). Most of the crustaceans were amphipods (85 species) or cumaceans (16 species).

Table 6.5 lists the most abundant species collected on each cruise. Of the species listed, some were extremely abundant at only one or a few stations (e.g., *Paraprionospio pinnata* and *Mediomastus californiensis* on Cruise II and *Ceratonereis irritabilis* on Cruise III), whereas others were more evenly abundant (e.g., *Armandia maculata*, *Myriochele oculata*). Most species were rare--that is, they occurred at only one or a few stations (Figure 6.8).

6.4.2 Abundance, Species Richness, Diversity, and Equitability

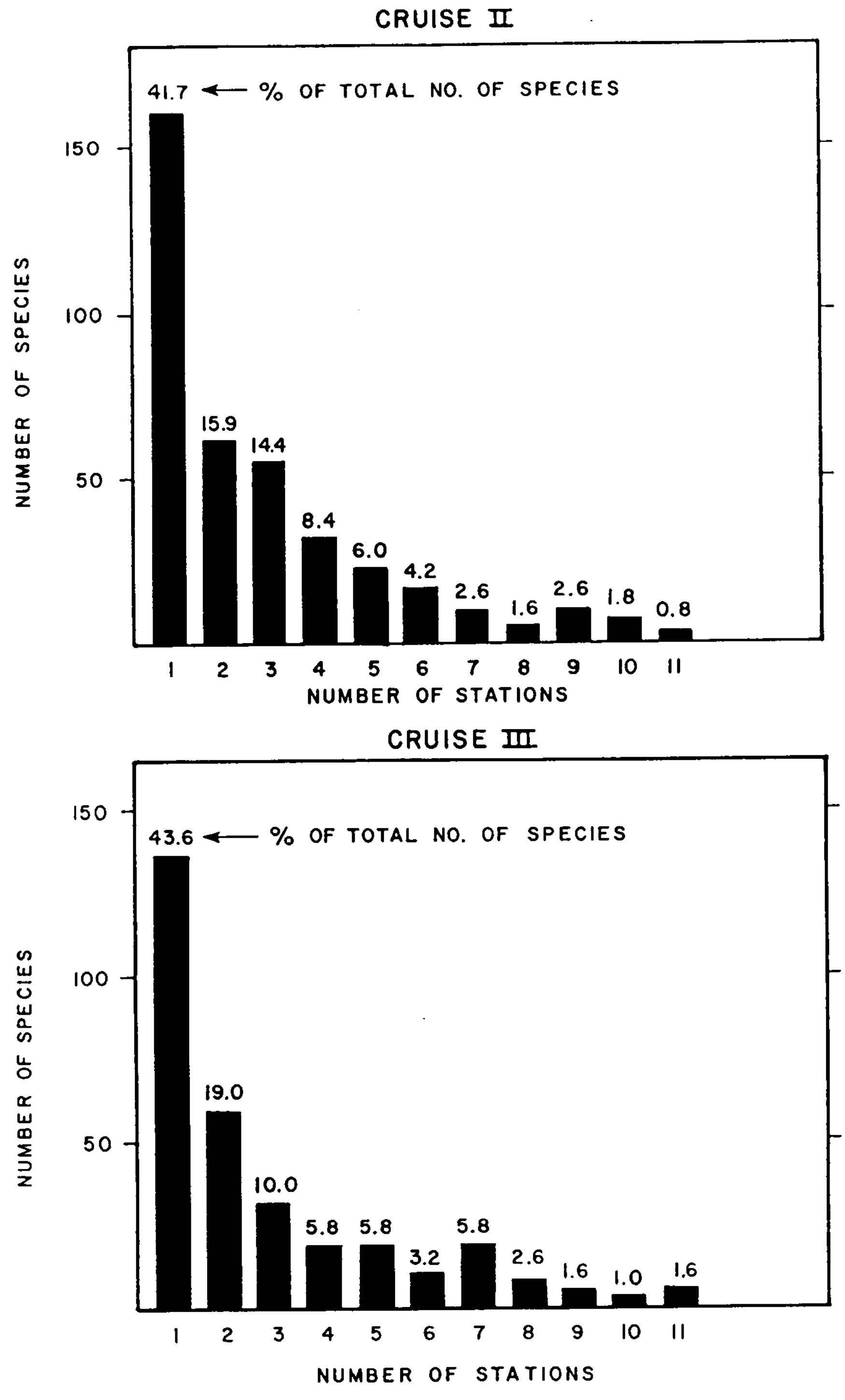
Table 6.6 summarizes infaunal abundance, species richness, diversity, and equitability. Abundance values do not include nematodes, oligochaetes, or copepods, which are considered meiofauna rather than macroinfauna; however, counts for these taxa are included in Appendix I. Total density ranged from 3,000 m^{-2} (Station 40, Cruise III) to 13,272 m^{-2} (Station 53, Cruise II) with no consistent spatial pattern among stations. There was considerable between-cruise variation in

TABLE 6.5. THE MOST ABUNDANT INFAUNA ON EACH CRUISE.

Species	Grand Mean Abundance* (No. m^{-2})	Cumulative Percentage of Total Individuals Collected
CRUISE II:		
Paraprionospio pinnata (P)	536	6
Mediomastus californiensis (P)	385	10
Cirrophorus americanus (P)	236	13
Myriochele oculata (P)	190	15
Leptochelia sp. A (T)	180	17
Cyclaspis sp. A (C)	173	19
Axiothella sp. A (P)	171	21
Goniadides carolinae (P)	145	23
Prionospio cristata (P)	141	24
Ampelisca sp. B (A)	135	26
CRUISE III:		
Prionospio cristata (P)	225	3
Myriochele oculata (P)	224	7
Armandia maculata (P)	190	9
Goniadides carolinae (P)	152	12
Diplodonta punctata (B)	132	14
Lucina nassula (B)	117	15
Tellina versicolor (B)	116	17
Crenella divaricata (B)	110	19
Cirrophorus americanus (P)	108	20
Ceratonereis irritabilis (P)	94	22

A = amphipod
B = bivalve
C = cumacean
P = polychaete
T = tanaid.

*Unweighted average of mean abundances from each station.



NOTE: MAXIMUM NO. OF STATION OCCURRENCES = 11 (AT STATION 52, ONLY THE 75-m LOCATION IS INCLUDED).

FIGURE 6.8. FREQUENCY DISTRIBUTION OF STATION OCCURRENCES FOR INFAUNAL SPECIES.

TABLE 6.6. INFAUNAL ABUNDANCE, SPECIES RICHNESS, AND COMMUNITY STRUCTURE INDICES.

	Density (No. m^{-2})		Diversity (Shannon-Wiener H')		Equitability (Pielou's J')		No. Species			Expected Species No.*	
Station	Cruise II	Cruise III	Cruise II	Cruise III	Cruise II	Cruise III	Cruise II	Cruise III	Total	Cruise II	Cruise III
40	8,800	3,000	1.66	3.36	0.41	0.86	58	50	88	4.8	11.3
41	6,088	10,160	3.09	3.28	0.71	0.73	79	89	130	9.4	10.0
42	6,112	3,456	3.80	3.35	0.84	0.82	92	60	128	12.2	10.8
43	4,984	8,024	3.77	3.55	0.83	0.77	92	100	153	12.0	11.0
46	8,520	3,696	3.99	3.73	0.83	0.84	122	84	161	12.3	11.9
48	6,176	4,656	3.77	3.65	0.83	0.83	96	80	136	12.0	11.6
49	4,136	5,536	3.91	3.20	0.86	0.77	92	63	126	12.5	10.3
50	9,624	4,200	3.88	3.80	0.82	0.85	115	88	166	12.2	12.0
52-LB	4,896	9,656	4.20	3.43	0.89	0.73	110	108	172	13.2	10.5
52-5m	10,008	9,104	4.13	3.41	0.85	0.73	129	104	197	12.8	10.4
52-8m	9,944	9,840	4.12	3.36	0.83	0.72	143	106	201	12.6	10.3
52-30m	9,984	10,928	4.01	3.41	0.82	0.71	137	122	190	12.0	10.1
52-75m	10,776	9,280	4.02	3.72	0.81	0.80	147	106	200	12.0	11.7
53	13,272	5,840	3.85	3.60	0.79	0.81	135	87	175	11.8	11.4
54	6,512	8,040	3.48	3.48	0.81	0.79	75	84	116	11.3	11.0
Mean†	7,727	5,990	3.57	3.52	0.78	0.81	100	81	144	11.1	11.2

*Expected number of species for n=15 individuals drawn at random from all individuals collected.
†Of the Station 52 locations, only 52-75 m is included in the mean values.

abundance at most stations. There was no spatial pattern in the differences--that is, there was no indication that stations toward the north or those in shallow water were more variable than the others. There was also no indication that Cruise II values were consistently higher or lower than Cruise III values.

The number of species identified ranged from 88 (Station 40) to about 200 (several different distances from live bottom at Station 52) (Table 6.6). Except for the relatively large number of species collected at Station 52, there was no consistent spatial pattern to the species richness values. Between-cruise variations in species richness were much less pronounced than were the density variations.

Shannon-Wiener diversity values ranged from 1.66 (Station 40, Cruise II) to 4.20 (Station 52, live-bottom area, Cruise II) (Table 6.6). The very low value at Station 40 on Cruise II was due to the abundance of two polychaete species--Paraprionospio pinnata and Mediomastus californiensis--which accounted for 53% and 22%, respectively, of all macroinfaunal individuals at that station. At most stations, Cruise II diversity values were higher than the Cruise III values, with the major exception being Station 40.

Equitability is a measure of the apportionment of individuals among species. Equitability values ranged from 0.41 to 0.89 during Cruise II and from 0.71 to 0.86 during Cruise III (Table 6.6). The Cruise II values for Stations 40 and 41 were considerably lower than those for the other stations, whereas all of the Cruise III values fell within a narrow range. At Station 52, all of the Cruise III values were lower than their Cruise II counterparts, due to the abundance of a nereid polychaete, Ceratonereis irritabilis, in all of the Cruise III samples. Among the other stations, there was no consistent evidence for a decrease (or increase) between cruises.

The "expected species number," like the equitability index, is a measure of the the evenness of distribution of individuals among species. The values in Table 6.6 indicate the number of species that one would expect to find in a random sample of 15 individuals from all individuals collected at a station during a particular cruise. Expected species numbers were less variable among stations than were the actual numbers of species collected (Table 6.6). Patterns in the expected species numbers are similar to those noted for the equitability index. During Cruise II, the values at Stations 40 and 41 were considerably lower than those at the remaining stations, which had values in the range of 11 to 13; the highest value was noted at the live-bottom area within Station 52. During Cruise III, the values were in a much narrower range. Cruise III values were slightly lower than Cruise II values at all stations except 40 and 41.

Table 6.7 lists the percentage composition of the infauna at each station. During both cruises, polychaetes accounted for the largest percentage of total individuals. However, Cruise II samples contained a higher percentage of polychaetes than Cruise III samples (58% vs. 49%). Molluscs accounted for an average of 7% of individuals collected during Cruise II and 20% of individuals collected during Cruise III; bivalves contributed 53% of the mollusc total during Cruise II and 78% during Cruise III. Stations 42, 43, and 53, in particular, were characterized by large numbers of bivalves during Cruise III. Crustaceans accounted for about 20% of the total during both cruises.

6.4.3 Abundance and Species Composition at Individual Stations

The following paragraphs summarize infaunal data for each station. Additional in-depth discussion of data from Station 52 (different distances from live bottom) is presented in Section 6.4.6.

Station 40: Mean abundance ranged from 3,000 m^{-2} (Cruise III) to 8,800 m^{-2} (Cruise II) (Table 6.6). During Cruise II, the population was dominated numerically by the polychaetes *Paraprionospio pinnata* (Spionidae) and *Mediomastus californiensis* (Capitellidae), which accounted for 75% of all individuals (Table 6.8). *Paraprionospio pinnata* is a tubicolous, surface deposit feeder that occurs in a wide range of sediment types in the northern and eastern Gulf of Mexico; *M. californiensis* is a burrowing, subsurface deposit feeder that occurs primarily in medium to very fine sand or silt/clay (Uebelacker and Johnson, 1984). Most polychaete families at this station were represented by only one or two species. Exceptions were Capitellidae (three species during Cruise II), Paraonidae (four species during Cruise III), Syllidae (three species during Cruise III), Spionidae (three species during Cruise III), and Nephtyidae (three species during Cruise III).

Station 41: Mean abundance ranged from 6,088 m^{-2} (Cruise II) to 10,160 m^{-2} (Cruise III) (Table 6.6). The polychaete *Goniadides carolinae* (Goniadidae) was the most abundant species on both cruises

TABLE 6.7. TAXONOMIC COMPOSITION OF THE INFAUNA BY STATION AND CRUISE.

Station	Percentage of Total Individuals			
	Polychaetes	Crustaceans*	Molluscs	Others†
CRUISE II:				
40	86	9	3	2
41	58	26	6	10
42	54	30	8	8
43	44	28	20	8
46	55	24	6	15
48	55	28	4	13
49	47	29	7	17
50	61	20	9	10
52-LB	56	22	6	16
52-5m	59	17	3	21
52-8m	62	19	2	17
52-30m	56	20	5	19
52-75m	63	19	7	11
53	58	29	4	9
54	58	10	19	13
CRUISE III:				
40	44	21	26	9
41	56	10	15	19
42	35	24	35	6
43	28	26	39	7
46	49	27	14	10
48	50	30	11	9
49	51	25	16	8
50	46	26	18	10
52-LB	53	19	18	10
52-5m	59	17	14	10
52-8m	57	19	14	10
52-30m	65	17	8	10
52-75m	58	15	15	12
53	37	18	34	11
54	50	14	29	7

*Excluding copepods.
†Excluding nematodes and oligochaetes.

TABLE 6.8. ABUNDANT INFAUNAL SPECIES AT STATION 40.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Paraprionospio pinnata (P)	4,656	53
Mediomastus californiensis (P)	1,944	75
Cyclaspis sp. A (C)	216	78
Sigambra tentaculata (P)	200	80
Aglaophamus verrilli (P)	144	81
Aricidea taylori (P)	128	83
Acuminodeutopus naglei (A)	88	84
Magelona pettiboneae (P)	80	85
Listriella barnardi (A)	72	86
Notomastus hemipodus (P)	48	86
CRUISE III:		
Goniada maculata (P)	176	6
Aglaophamus verrilli (P)	160	11
Armandia maculata (P)	144	16
Tellina versicolor (B)	136	20
Volvulella persimilis (G)	104	24
Turbonilla conradi (G)	96	27
Magelona pettiboneae (P)	80	30
Cyclaspis sp. A (C)	80	32
Natica pusilla (G)	72	35
Myriochele oculata (P)	64	37

A = amphipod
B = bivalve
C = cumacean
G = gastropod
P = polychaete.

(Table 6.9). Syllid polychaetes were particularly well represented (nine species on Cruise II, eight on Cruise III); most other polychaete families were represented by only a few species. Both the syllid and goniadid polychaetes are considered carnivore/scavengers (Fauchald and Jumars, 1979).

Station 42: Mean abundance ranged from 3,456 m^{-2} (Cruise III) to 6,112 m^{-2} (Cruise II) (Table 6.6). There were no strikingly abundant species on either cruise (Table 6.10). Well-represented polychaete families were Paraonidae (eight species on Cruise II, four on Cruise III) and Syllidae (six species on Cruise II, one on Cruise III).

Station 43: Mean abundance ranged from 4,984 m^{-2} (Cruise II) to 8,024 m^{-2} (Cruise III) (Table 6.6). Bivalve molluscs were particularly well represented in the list of most abundant species for Cruise III (Table 6.11). Well-represented polychaete families included Paraonidae (five species on Cruise II, two on Cruise III) and Syllidae (five species on Cruise II, three on Cruise III).

Station 46: Mean abundance ranged from 3,696 m^{-2} (Cruise III) to 8,520 m^{-2} (Cruise II) (Table 6.6). No species accounted for more than 10% of total abundance on either cruise (Table 6.12). Well-represented polychaete families included Paraonidae and Spionidae (both with seven species on each cruise) and Pilargidae (five species on Cruise II, three on Cruise III).

Station 48: Mean abundance ranged from 4,656 m^{-2} (Cruise III) to 6,176 m^{-2} (Cruise II) (Table 6.6). The most abundant species during each cruise were spionid polychaetes (Table 6.13). Well-represented polychaete families included Paraonidae (seven species on Cruise II, five on Cruise III) and Spionidae (six species on Cruise II, five on Cruise III).

Station 49: Mean abundance ranged from 4,136 m^{-2} (Cruise II) to 5,536 m^{-2} (Cruise III) (Table 6.6). The spionid polychaete Prionospio cristata was first or second in abundance on both cruises, and three spionids together accounted for 39% of individuals identified to species during Cruise III (Table 6.14). The amphipod Eudevenopus honduranus was among the most abundant species on both cruises. Syllids and paraonids were well represented in the Cruise II samples (there were seven syllid species and five paraonids); spionids were the most speciose polychaete family in the Cruise III samples (six species).

TABLE 6.9. ABUNDANT INFAUNAL SPECIES AT STATION 41.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Goniadides carolinae (P)	1,368	22
Protodorvillea kefersteini (P)	576	32
Cyclaspis sp. A (C)	496	40
Parapionosyllis longicirrata (P)	328	46
Cirrophorus americanus (P)	192	49
Branchiostoma caribaeum (Ce)	160	51
Ancistrosyllis hartmanae (P)	104	53
Magelona sp. A (P)	104	55
Leptochelia sp. A (T)	88	56
Acuminodeutopus naglei (A)	88	58
CRUISE III:		
Goniadides carolinae (P)	1,352	13
Myriochele oculata (P)	1,104	24
Armandia maculata (P)	520	29
Branchiostoma caribaeum (Ce)	440	34
Semele nuculoides (B)	296	36
Nephtys simoni (P)	272	39
Acteocina canaliculata (G)	200	41
Prionospio cristata (P)	136	42
Protodorvillea kefersteini (P)	128	44
Crassinella cf. *lunulata* (B)	128	45

A = amphipod
B = bivalve
C = cumacean
Ce = cephalochordate
G = gastropod
P = polychaete
T = tanaid.

TABLE 6.10. ABUNDANT INFAUNAL SPECIES AT STATION 42.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Cyclaspis sp. A (C)	464	8
Hesionura elongata (P)	368	14
Pettiboneia sp. A (P)	352	19
Protodorvillea kefersteini (P)	296	24
Synelmis albini (P)	288	29
Cirrophorus americanus (P)	248	33
Prionospio cristata (P)	168	36
Paraprionospio pinnata (P)	168	38
Heteropodarke sp. A (P)	152	41
Magelona pettiboneae (P)	136	43
CRUISE III:		
Armandia maculata (P)	392	11
Synelmis albini (P)	232	18
Olivella dealbata (G)	128	22
Diplodonta punctata (B)	96	24
Myriochele oculata (P)	88	27
Metharpinia floridana (A)	88	30
Haminoea succinea (G)	72	32
Pitar fulminatus (B)	64	34
Anchialina typica (M)	64	35
Protodorvillea kefersteini (P)	48	37

A = amphipod
B = bivalve
C = cumacean
G = gastropod
M = mysid
P = polychaete.

TABLE 6.11. ABUNDANT INFAUNAL SPECIES AT STATION 43.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Cirrophorus americanus (P)	480	10
Paraprionospio pinnata (P)	288	15
Cyclaspis sp. A (C)	256	20
Diplodonta punctata (B)	240	25
Strombiformis hemphilli (G)	224	30
Synelmis albini (P)	184	34
Leptochelia sp. A (T)	184	37
Ampelisca sp. C (A)	128	40
Mediomastus californiensis (P)	120	42
Tellina listeri (B)	120	45
CRUISE III:		
Tellina versicolor (B)	840	10
Myriochele oculata (P)	672	19
Crassinella lunulata (B)	568	26
Diplodonta punctata (B)	344	30
Gouldia cerina (B)	216	33
Chevalia mexicana (A)	200	35
Goniadides carolinae (P)	200	38
Metharpinia floridana (A)	184	40
Varicorbula operculata (B)	160	42
Nephtys simoni (P)	120	44

A = amphipod
B = bivalve
C = cumacean
G = gastropod
P = polychaete
T = tanaid.

TABLE 6.12. ABUNDANT INFAUNAL SPECIES AT STATION 46.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Myriochele oculata (P)	696	8
Axiothella sp. A (P)	512	14
Cirrophorus americanus (P)	424	19
Protodorvillea kefersteini (P)	328	23
Prionospio cristata (P)	288	26
Hesionura elongata (P)	232	29
Tubiluchus corallicola (Pr)	224	32
Pionosyllis gesae (P)	192	34
Synelmis albini (P)	184	36
Cyclaspis sp. A (C)	152	38
CRUISE III:		
Prionospio cristata (P)	272	7
Apoprionospio pygmaea (P)	232	14
Armandia maculata (P)	200	19
Tellina versicolor (B)	192	24
Paraprionospio pinnata (P)	168	29
Cirrophorus americanus (P)	152	33
Myriochele oculata (P)	112	36
Crassinella lunulata (B)	80	38
Aricidea taylori (P)	64	40
Leptochela serratorbita (D)	56	41

B = bivalve
C = cumacean
D = decapod
P = polychaete
Pr = priapulid.

TABLE 6.13. ABUNDANT INFAUNAL SPECIES AT STATION 48.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Paraprionospio pinnata (P)	424	7
Cirrophorus americanus (P)	392	13
Apoprionospio dayi (P)	384	19
Ceratocephale oculata (P)	216	23
Luconacia incerta (A)	208	26
Aricidea catherinae (P)	160	29
Armandia maculata (P)	152	31
Cyclaspis sp. A (C)	144	34
Aricidea taylori (P)	136	36
Leptochelia sp. A (T)	136	38
CRUISE III:		
Apoprionospio dayi (P)	624	13
Myriochele oculata (P)	152	17
Aricidea taylori (P)	144	20
Mediomastus californiensis (P)	144	23
Cumella sp. B (C)	136	26
Prionospio cristata (P)	112	28
Tellina versicolor (B)	96	30
Cirrophorus americanus (P)	88	32
Armandia maculata (P)	88	34
Lumbrineris verrilli (P)	64	35

A = amphipod
B = bivalve
C = cumacean
P = polychaete
T = tanaid.

TABLE 6.14. ABUNDANT INFAUNAL SPECIES AT STATION 49.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Nereis riisei (P)	232	6
Prionospio cristata (P)	184	10
Mediomastus californiensis (P)	176	14
Sphaerosyllis taylori (P)	168	18
Eudevenopus honduranus (A)	136	22
Axiothella sp. A (P)	120	25
Leptochelia sp. A (T)	104	27
Cirrophorus americanus (P)	96	29
Caulleriella alata (P)	96	32
Metharpinia floridana (A)	96	34
CRUISE III:		
Prionospio cristata (P)	720	13
Spio pettiboneae (P)	640	25
Spiophanes bombyx (P)	424	32
Eudevenopus honduranus (A)	296	38
Cooperella atlantica (B)	248	42
Armandia maculata (P)	192	46
Branchiostoma caribaeum (Ce)	192	49
Cirrophorus americanus (P)	144	52
Cyclaspis sp. A (C)	144	54
Synchelidium cf. *americanum* (A)	144	57

A = amphipod
B = bivalve
C = cumacean
Ce = cephalochordate
P = polychaete
T = tanaid.

Station 50: Mean abundance ranged from 4,200 m^{-2} (Cruise III) to 9,624 m^{-2} (Cruise II) (Table 6.6). The spionid polychaete *Prionospio cristata* was first or second in abundance on both cruises (Table 6.15). Syllid and paraonid polychaetes were particularly well represented in the Cruise II samples (seven species each); in the Cruise III samples, there were six species each of paraonids and spionids.

Station 52: Mean abundance ranged from 4,896 to 10,776 m^{-2} during Cruise II and from 9,104 to 10,928 m^{-2} during Cruise III (Table 6.6). During Cruise II, density was lowest at the live-bottom area, but during Cruise III densities in the live-bottom area were comparable to those at various distances from it. Tables 6.16 and 6.17 list the most abundant species at the live-bottom area and at the soft-bottom location most distant from live bottom (75 m). At the live-bottom area, densities were very low and fairly evenly apportioned among species in the Cruise II samples; however, there was a numerical dominant in all of the Cruise III samples--the nereid polychaete *Ceratonereis irritabilis*, a motile scavenger/carnivore. The most striking feature of infaunal species composition at Station 52 was the predominance of syllid polychaetes--17 species at both locations during Cruise II, 10 species at the live-bottom area during Cruise III, and 8 species at the 75-m location during Cruise III. *Haplosyllis spongicola*, a motile scavenger/carnivore feeding on sponges, hydroids, and other colonial invertebrates (Uebelacker and Johnson, 1984), was the most abundant of these syllids at all locations sampled during Cruise II.

Station 53: Mean abundance ranged from 5,840 m^{-2} (Cruise III) to 13,272 m^{-2} (Cruise II) (Table 6.6). A tanaid species was most abundant in the Cruise II samples; several bivalve molluscs were among the most abundant species in the Cruise III samples (Table 6.18). Syllid polychaetes were well represented in samples from both cruises (Cruise II--11 species; Cruise III--8 species). There were also four species of spionids in the Cruise II samples and six in the Cruise III samples.

Station 54: Mean abundance ranged from 6,512 m^{-2} (Cruise II) to 8,040 m^{-2} (Cruise III) (Table 6.6). Bivalves and spionid polychaetes were among the most abundant species from Cruise III (Table 6.19). The large number of syllid species collected at Stations 52 and 53 was not in evidence at Station 54 (only three syllid species were collected on each cruise). Instead, the most speciose polychaete families were Paraonidae (six species on Cruise II, seven on

TABLE 6.15. ABUNDANT INFAUNAL SPECIES AT STATION 50.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Myriochele oculata (P)	664	7
Prionospio cristata (P)	576	13
Armandia maculata (P)	552	19
Schistomeringos rudolphi (P)	312	22
Aricidea taylori (P)	296	25
Capitella capitata (P)	256	28
Ampelisca sp. B (A)	256	30
Caulleriella alata (P)	248	33
Lembos unifasciatus reductus (A)	224	35
Hydroides protulicola (P)	200	37
CRUISE III:		
Apoprionospio pygmaea (P)	472	11
Prionospio cristata (P)	216	16
Cyclaspis sp. A (C)	160	20
Diplodonta punctata (B)	120	23
Pettiboneia sp. A (P)	112	26
Aricidea fragilis (P)	88	28
Synchelidium cf. *americanum* (A)	88	30
Spio pettiboneae (P)	72	32
Natica pusilla (G)	72	33
Eudevenopus honduranus (A)	64	35

A = amphipod
B = bivalve
C = cumacean
G = gastropod
P = polychaete.

TABLE 6.16. ABUNDANT INFAUNAL SPECIES AT STATION 52, LIVE-BOTTOM AREA.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Goniadides carolinae (P)	144	3
Exogone dispar (P)	136	6
Nereis riisei (P)	136	8
Eunice vittata (P)	136	11
Armandia maculata (P)	136	14
Isolda pulchella (P)	128	17
Synelmis albini (P)	104	19
Sphaerosyllis glandulata (P)	104	21
Prionospio cristata (P)	104	23
Mediomastus californiensis (P)	104	25
CRUISE III:		
Ceratonereis irritabilis (P)	1,832	19
Crenella divaricata (B)	560	25
Armandia maculata (P)	424	29
Mooreonuphis nebulosus (P)	328	33
Cyclaspis sp. A (C)	320	36
Crassinella lunulata (B)	280	39
Diplodonta punctata (B)	224	41
Spio pettiboneae (P)	216	43
Prionospio cristata (P)	184	45
Mediomastus californiensis (P)	184	47

B = bivalve
C = cumacean
P = polychaete.

TABLE 6.17. ABUNDANT INFAUNAL SPECIES AT STATION 52, 75 m FROM LIVE BOTTOM.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Haplosyllis spongicola (P)	1,184	11
Mediomastus californiensis (P)	456	15
Ampelisca sp. B (A)	440	19
Axiothella sp. A (P)	360	23
Cirrophorus lyra (P)	224	25
Armandia maculata (P)	224	27
Ehlersia cornuta (P)	192	29
Exogone dispar (P)	184	30
Aricidea fragilis (P)	176	32
Cyclaspis sp. D (C)	144	33
CRUISE III:		
Ceratonereis irritabilis (P)	1,016	11
Kimbergonuphis simoni (P)	576	17
Mediomastus californiensis (P)	472	22
Crenella divaricata (B)	320	26
Cyclaspis sp. A (C)	304	29
Prionospio cristata (P)	256	32
Solemya occidentalis (B)	248	34
Aricidea fragilis (P)	240	37
Armandia maculata (P)	216	39
Axiothella sp. A (P)	216	42

A = amphipod
B = bivalve
C = cumacean
P = polychaete.

TABLE 6.18. ABUNDANT INFAUNAL SPECIES AT STATION 53.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Leptochelia sp. A (T)	1,152	9
Mediomastus californiensis (P)	1,088	17
Axiothella sp. A (P)	568	21
Cirrophorus americanus (P)	432	24
Ampelisca sp. B (A)	408	28
Lumbrineris verrilli (P)	376	30
Tharyx annulosus (P)	288	32
Nereis riisei (P)	280	35
Myriochele oculáta (P)	232	36
Exogone dispar (P)	208	38
CRUISE III:		
Crenella divaricata (B)	712	12
Diplodonta punctata (B)	432	20
Cirrophorus americanus (P)	224	23
Lucina nassula (B)	200	27
Sphaerosyllis taylori (P)	192	30
Armandia maculata (P)	192	33
Cyclaspis sp. A (C)	144	36
Nereis riisei (P)	120	38
Crassinella lunulata (B)	104	40
Goniadides carolinae (P)	104	42

A = amphipod
B = bivalve
C = cumacean
P = polychaete
T = tanaid.

TABLE 6.19. ABUNDANT INFAUNAL SPECIES AT STATION 54.

Species	Mean Abundance (No. m^{-2})	Cumulative Percent of Total Abundance
CRUISE II:		
Lumbrineris verrilli (P)	544	8
Phoronis architecta (Ph)	392	14
Neanthes micromma (P)	312	19
Ceratocephale oculata (P)	312	24
Linga amiantus (B)	304	29
Aricidea fragilis (P)	224	32
Mediomastus californiensis (P)	224	36
Dentalium texasianum (S)	176	38
Myriochele oculata (P)	168	41
Cirrophorus americanus (P)	152	43
CRUISE III:		
Lucina nassula (B)	816	10
Prionospio cristata (P)	704	19
Paraprionospio pinnata (P)	592	26
Synelmis albini (P)	376	31
Linga amiantus (B)	304	35
Nuculana concentrica (B)	288	38
Lumbrineris verrilli (P)	240	41
Diplodonta punctata (B)	160	43
Parasterope pollex (O)	160	45
Aricidea fragilis (P)	144	47

B = bivalve
O = ostracod
P = polychaete
Ph = phoronid
S = scaphopod.

Cruise III), Spionidae (three species on Cruise II, five on Cruise III), and Capitellidae (two species on Cruise II, five on Cruise III).

6.4.4 Cluster Analyses

Separate analyses were conducted for Cruise II, Cruise III, and both cruises combined. In these analyses, Station 52 was represented by the sampling area most distant (75 m) from live bottom, as the objective was to compare species composition of soft-bottom stations. Cluster analyses conducted using different distances from live bottom at Station 52 are presented in Section 6.4.6.

Cruise II: Figure 6.9 illustrates the results of normal cluster analysis conducted using Cruise II data. The analysis revealed three main station groupings oriented along a north-south axis. One group consisted of Station 40, which was distinctly different from all other stations in species composition. A second group consisted of Stations 41, 42, 43, 46, and 48, with Station 41 differing noticeably in species composition from the others in this group. The third group consisted of Stations 49, 50, 52, 53, and 54; within this group, Stations 52 and 53 were most similar to each other and Station 54 was most dissimilar to the others.

Examination of two-way tables from inverse cluster analysis provides some insight into the station groupings. A few species, such as the amphipods Acuminodeutopus naglei and Ampelisca sp. B and the polychaetes Aricidea catherinae, A. taylori, and Myriochele oculata, were widely distributed, occurring at similar abundance levels in all station groups. The distinctiveness of Station 40 reflected the predominance of two polychaete species--Paraprionospio pinnata and Mediomastus californiensis--and the corresponding absence of many species found at several of the other stations. There were few species with high fidelity and constancy for the second group (Stations 41, 42, 43, 46, and 48). Characteristic (but not particularly abundant) species associated with the third group (Stations 49, 50, 52, 53, and 54) included the polychaetes Ehlersia ferrugina and Isolda pulchella, as well as the bivalve Solemya occidentalis. Within the third group, Station 54 was distinguished by a relatively low abundance of syllid and serpulid polychaetes, which were abundant at the other stations in this group.

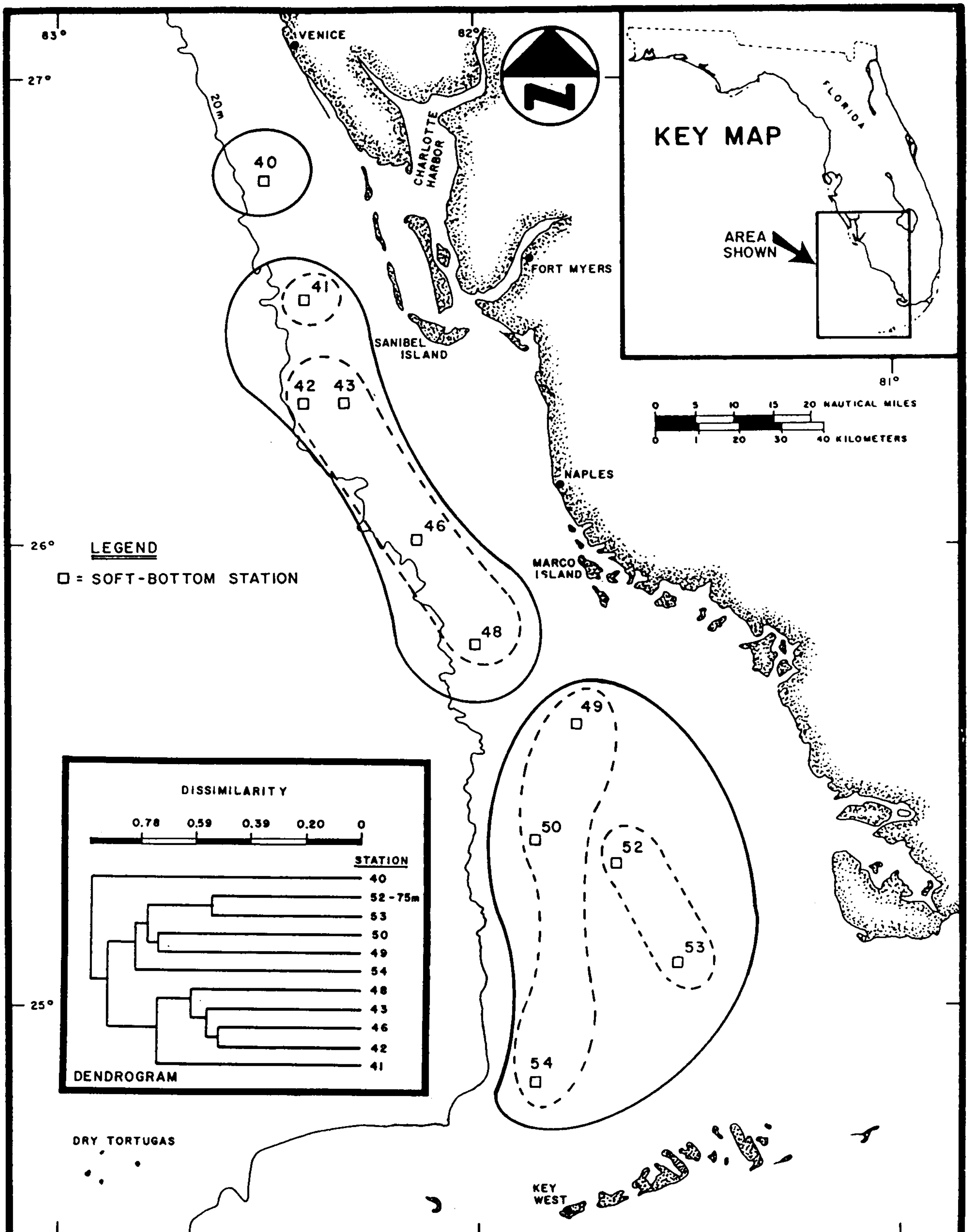


FIGURE 6.9. CLUSTER ANALYSIS RESULTS FOR INFAUNA, CRUISE II.

Cruise III: Figure 6.10 illustrates the results of cluster analysis conducted using Cruise III data. Three major groups are evident: one consisting of Stations 41 and 43, a second consisting of Stations 40 and 42, and the third consisting of a loose association of the remaining stations (Figure 6.10). Within the latter group, there was a north-south split, with Stations 52, 53, and 54 clustering apart from Stations 46, 48, 49, and 50.

Two-way occurrence tables indicates that several species occurred at similar abundance levels in the various station groups. Examples are an oweniid polychaete, Owenia fusiformis; a paraonid polychaete, Cirrophorus americanus; an opheliid polychaete, Armandia maculata, a sand-burrowing amphipod, Synchelidium cf. americanum; and an ostracod, Parasterope pollex. Species that occurred primarily or exclusively at Stations 41 and 43 included the bivalves Bushia elegans and Verticordia ornata, the isopod Eurydice littoralis, and the polychaetes Aricidea cerrutii and Hesionura elongata. In addition, Myriochele oculata, an oweniid polychaete that occurred at all stations, was most abundant at Stations 41 and 43. No species were particularly characteristic of the Station 40 and 42 group; many species found at most or all stations were absent or reduced in abundance at Stations 40 and 42. Species characteristic of the large southern station group (Stations 45, 48, 49, 50, 52, 53, and 54) included three spionid polychaetes, Paraprionospio pinnata, Prionospio cristata, and Spio pettiboneae; and a paraonid polychaete, Aricidea taylori.

Both Cruises: Figure 6.11 illustrates the results of cluster analysis conducted using data from both cruises. The dendrogram indicates that seasonal (between-cruise) variations in species composition at most stations were greater than or equal to spatial (between-station) differences. Between-cruise variability was particularly high at Stations 40, 42, 43, 46, 48, and 50. There was comparatively little between-cruise variation at Stations 41, 49, and 54, and Stations 52 and 53 showed moderate variation.

The large between-cruise difference at Station 40 reflects the previously mentioned predominance of Paraprionospio pinnata and Mediomastus californiensis during Cruise II (neither species was present in the Cruise III samples from this station). None of the other between-cruise differences are readily attributable to changes in abundance of one or two species. However, several bivalves (e.g., Crassinella lunulata, Crenella divaricata, Diplodonta punctata, Lucina nassula, and

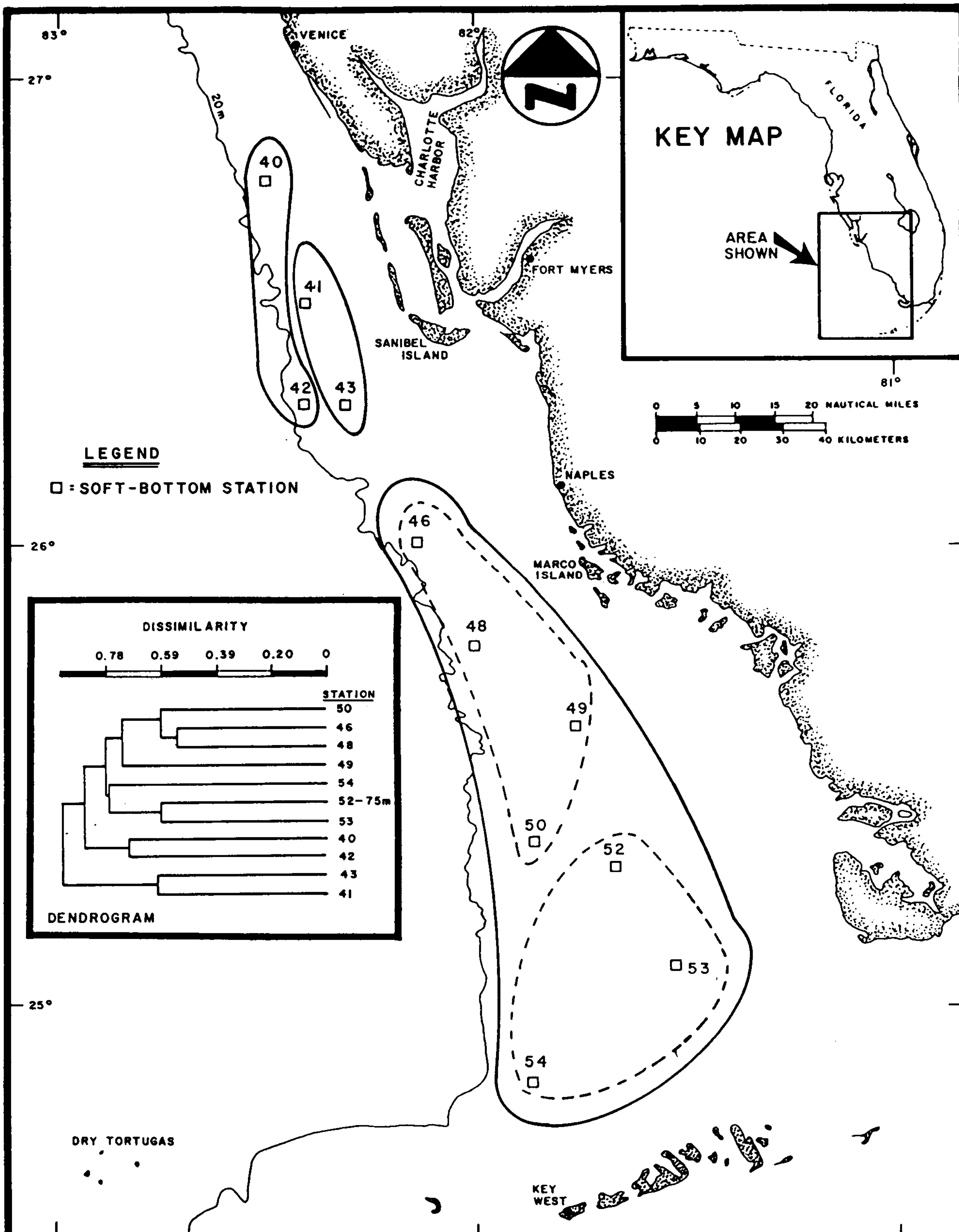


FIGURE 6.10. CLUSTER ANALYSIS RESULTS FOR INFAUNA, CRUISE III .

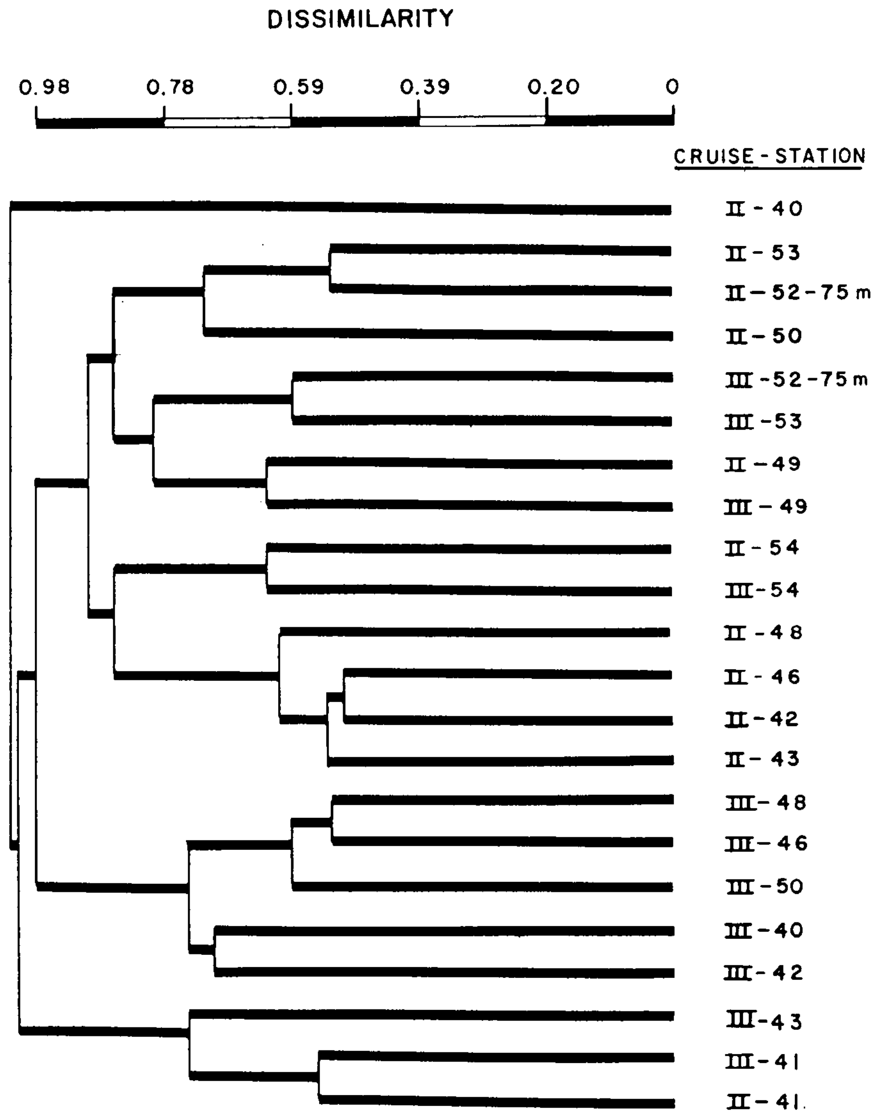


FIGURE 6.11. DENDROGRAM FROM CLUSTER ANALYSIS OF INFAUNAL DATA FROM CRUISES II AND III SHOWING BETWEEN-CRUISE DIFFERENCES IN SPECIES COMPOSITION.

Tellina versicolor) were more abundant in the Cruise III samples at various stations. Figure 6.12 illustrates between-cruise differences in abundance of total bivalves and two select species, Diplodonta punctata and Tellina versicolor. Total bivalves were more abundant at all stations during Cruise III than Cruise II; Station 43 had the highest numbers of bivalves, followed by Stations 54 and 53. Diplodonta punctata occurred at all stations except 40 and 49 during Cruise II but was most abundant at Station 43. During Cruise III, the species was found at all stations, with Stations 43 and 53 showing the highest population levels. Tellina versicolor occurred in very low numbers and at only five stations during Cruise II, but was very abundant at four stations (especially Station 43) during Cruise III.

Another example of strong variation in species composition between cruises is the change in numerical dominants at Station 52. During Cruise II, the syllid polychaete Haplosyllis spongicola was the most abundant species at 75 m from live bottom (and first in abundance or among the most abundant at all other distances). During Cruise III, the nereid polychaete Ceratonereis irritabilis was first in abundance and H. spongicola was either absent or much reduced in abundance at all distances from live bottom.

6.4.5 Relationships to Environmental Variables

Abundance, Species Richness, Diversity, and Equitability. To investigate possible relationships of infauna to environmental variables, plotting and simple correlations were performed with mean values of environmental and infaunal parameters from each station. Environmental variables used were water depth, sediment carbonate content, mean grain size, sorting, skewness, percent sand, percent silt, percent clay, and percent shell hash (defined here as particles >2 mm in diameter). Infaunal statistics used were mean abundance, diversity, equitability, and species richness. A few relationships were evident:

1) Species richness was positively correlated with sediment carbonate content on both cruises (Cruise II: $r=0.62$, $p<0.05$; Cruise III: $r=0.81$, $p<0.01$).

2) Diversity was positively correlated with carbonate content on Cruise III ($r=0.85$, $p<0.001$) and negatively correlated with skewness on Cruise II ($r=-0.72$, $p<0.05$).

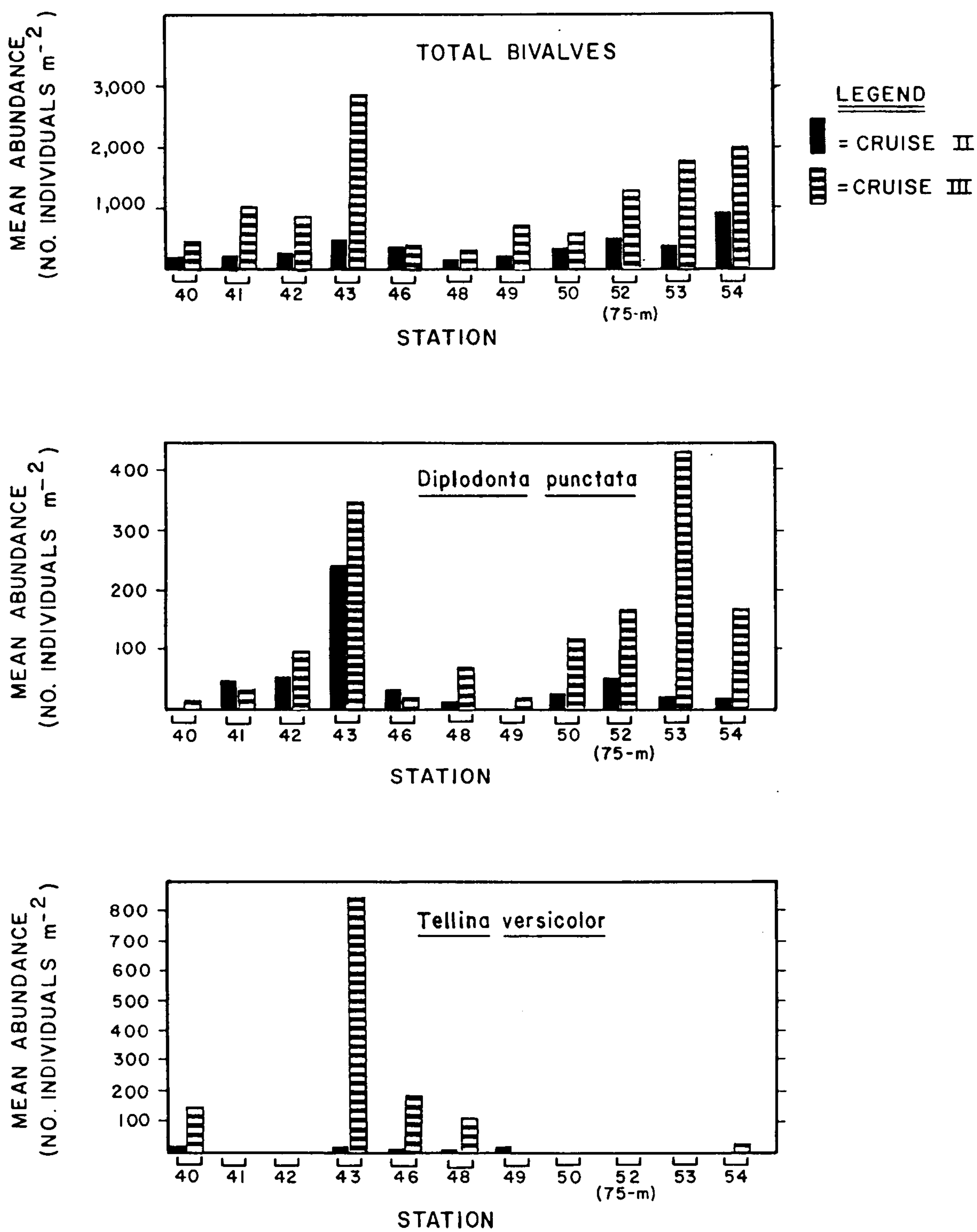


FIGURE 6.12. BETWEEN-CRUISE DIFFERENCES IN THE ABUNDANCE OF TOTAL BIVALVES AND SELECTED BIVALVE SPECIES.

Figure 6.13 illustrates the species richness vs. carbonate relationships. In general, stations with high sediment carbonate content had higher species richness than did stations with low sediment carbonate content.

It is unlikely that carbonate content per se influences infaunal species richness or diversity. Rather, the relationships noted above (if not spurious) may reflect underlying influences of grain size composition. In general, sediments that were high in carbonate tended to contain more coarse sand and shell hash than low-carbonate sediments. Weak positive correlations between species richness and both skewness and percent shell hash (>2 mm grain size) were noted on both cruises, but the only statistically significant relationship between infauna and grain size distribution was the negative one between skewness and diversity noted in the Cruise III data (coarse-skewed sediments tended to have higher diversity).

Species Composition. Station groupings from the Cruise II and Cruise III cluster analyses were examined to discern any obvious relationships between species composition and environmental variables (no statistical analyses were conducted). As the clusters in each case are oriented primarily on a north-south axis (Figures 6.9 and 6.10), water depth is of little use as an explanatory variable. Sediment grain size and carbonate are the other environmental factors available as explanatory variables.

In the Cruise II cluster analysis, Station 40 emerged as the most distinct in species composition. The polychaetes *Paraprionospio pinnata* and *Mediomastus californiensis* together accounted for 75% of all individuals at this station on Cruise II. In terms of sediment composition, Station 40 was distinguished by a low carbonate content (25%) and a low mean grain size (125 μm) with a coarse-skewed grain size distribution (however, the percentage of particles 2 mm or greater in size was very low--0.13%).

Although sediments at Station 40 were different in some respects from those at the other stations, it is difficult to argue that peculiarities of sediment composition were responsible for the species composition seen there during Cruise II. Although carbonate content was low, similar values were noted at two other stations (42 and 49) that were dissimilar in species composition (both from each other and from Station 40). In addition, sediment composition at Station 40 was similar

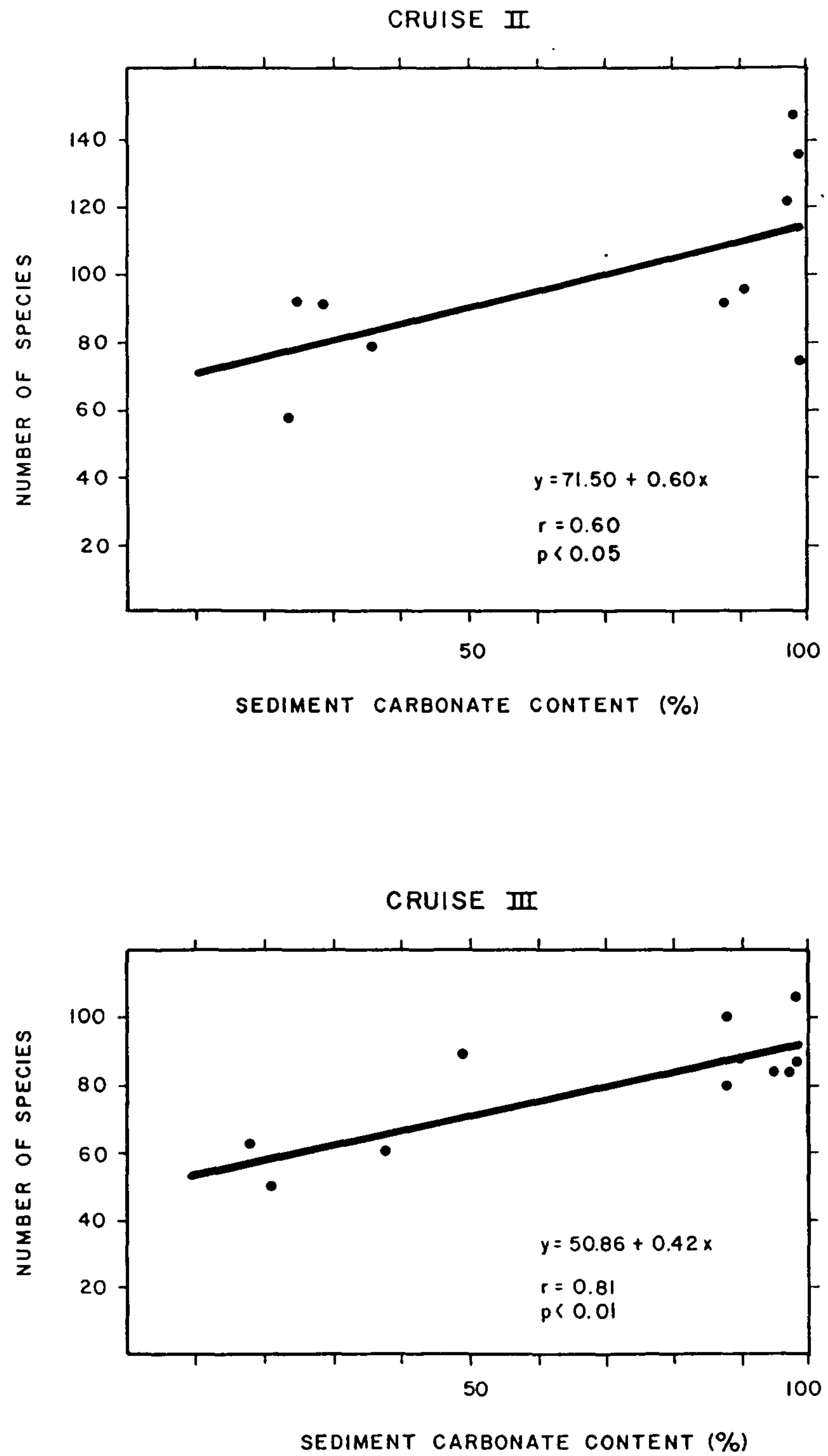


FIGURE 6.13. RELATIONSHIPS BETWEEN SEDIMENT CARBONATE CONTENT AND INFAUNAL SPECIES RICHNESS.

on both cruises even though species composition was distinctly different (P. pinnata and M. californiensis were not particularly abundant in the Cruise III samples). Both species occurred at several other stations during both cruises, though nowhere in the densities noted at Station 40 during Cruise II. A coincidence of environmental factors may have favored a population increase of the two polychaetes at this station during late fall.

There were two other major station groups in the Cruise II cluster analysis: one consisting of Stations 41, 42, 43, 46, and 48, the other consisting of Stations 49, 50, 52, 53, and 54. In general, stations in the first group were characterized by moderately sorted to moderately well-sorted sediments with a low silt/clay percentage (0.7 to 2.4) and a low percentage of shell hash (0.20 to 2.12). Stations in the second group were characterized by poorly sorted to very poorly sorted sediments with a moderate to high silt/clay percentage (1.5 to 29.8) and a higher percentage of shell hash (2.09 to 14.03). Within the first group, Station 41 was most dissimilar to the others in species composition; sediments at this station contained a higher proportion of shell hash particles than the other stations (2.12% at Station 41 vs. 0.20 to 0.93% for the others). Within the second group, Station 54 was most different from the others in species composition (there were many species of paraonids and spionids but comparatively few syllids). Sediments at Station 54 differed from those of the other stations in the group in having the highest silt/clay percentage and a correspondingly fine-skewed grain size distribution.

The three groups in the Cruise III cluster analysis were Stations 40 and 42, Stations 41 and 43, and the remaining stations (Figure 6.10). Water depth was slightly greater at Stations 40 and 42 (18 and 17 m, respectively) than at Stations 41 and 43 (both 16 m). In terms of sediment composition, the first group was uniquely characterized by a low percentage of shell hash (0.13 to 0.46), whereas the second group was characterized by a moderate percentage of shell hash (0.78 to 2.39). The third group was very heterogenous in sediment composition. A subgroup consisting of Stations 52, 53, and 54 was dissimilar to others in the group in species composition; these three stations were characterized by poor to very poor sorting, a high silt/clay percentage (4.8 to 41.1) and a high percentage of shell hash particles (8.13 to 18.44).

The results of these exploratory analyses suggest that differences in grain size distribution may influence the species composition of infaunal communities in the area. The degree of sorting--particularly as it reflects the relative contribution of silt/clay and shell hash--appears to bear some relation to patterns of species composition derived from cluster analyses. Carbonate content per se probably does not affect species composition.

6.4.6 Influence of Proximity to Live Bottom at Station 52

Data from the live-bottom area and four distances from live bottom (5, 8, 30, and 75 m) at Station 52 were collected to evaluate effects of proximity to live bottom on infaunal abundance, species composition, and community structure.

Data in Table 6.6 indicate that abundance and species richness were higher at Station 52 than at most or all other stations during both cruises; diversity and equitability were higher at Station 52 during Cruise II but not during Cruise III. Thus, one might expect these parameters to increase with increasing proximity to live bottom within the station.

Figures 6.14 and 6.15 summarize trends in total abundance, species richness, diversity, and equitability with distance from live bottom. Some trends were evident in the Cruise II data, but Cruise III data did not confirm them. For example, density values were lowest at the live-bottom area during Cruise II, but not during Cruise III. Diversity and equitability increased and species richness decreased (contrary to the expected trend) with increasing proximity to live bottom in the Cruise II samples, but the only trend in the Cruise III data was that the 75-m location had the highest diversity and equitability values.

Figure 6.16 shows changes in abundance with distance from live bottom for the numerically dominant species from each cruise. During Cruise II, the species was a syllid polychaete, *Haplosyllis spongicola*. During Cruise III, the numerical dominant was a nereid polychaete, *Ceratonereis irritabilis*. Both species are motile carnivore/scavengers. Both species were present at a few other stations but were only abundant at Station 52--and only on one cruise or the other. *Haplosyllis spongicola* showed an unexpected trend of increasing abundance with distance from live bottom, although the 75-m data point is based on a large number of individuals in only one core sample and may not be representative. *Ceratonereis irritabilis* showed little or no trend

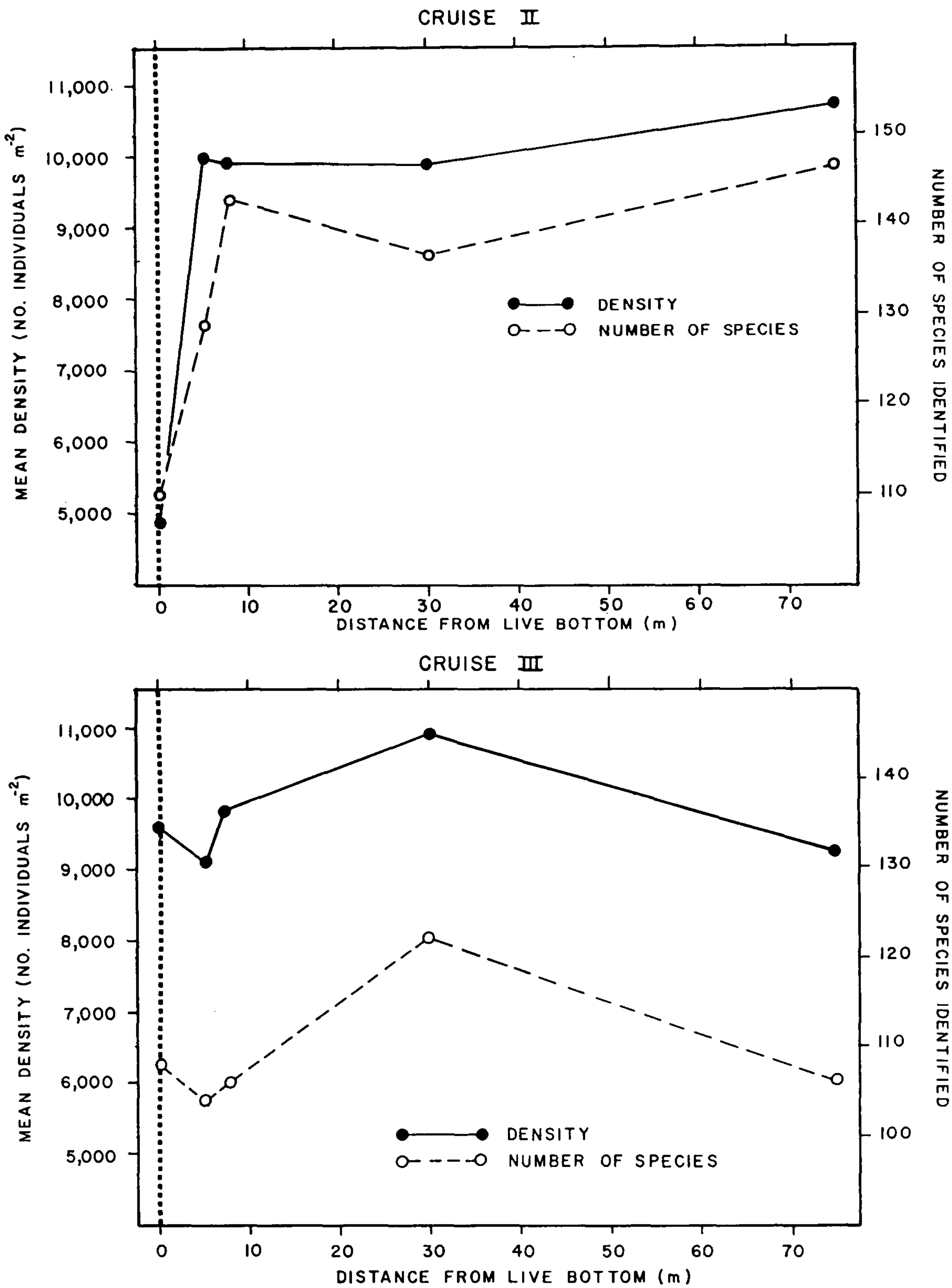


FIGURE 6.14. INFAUNAL DENSITY AND SPECIES RICHNESS vs. DISTANCE FROM LIVE BOTTOM AT STATION 52.

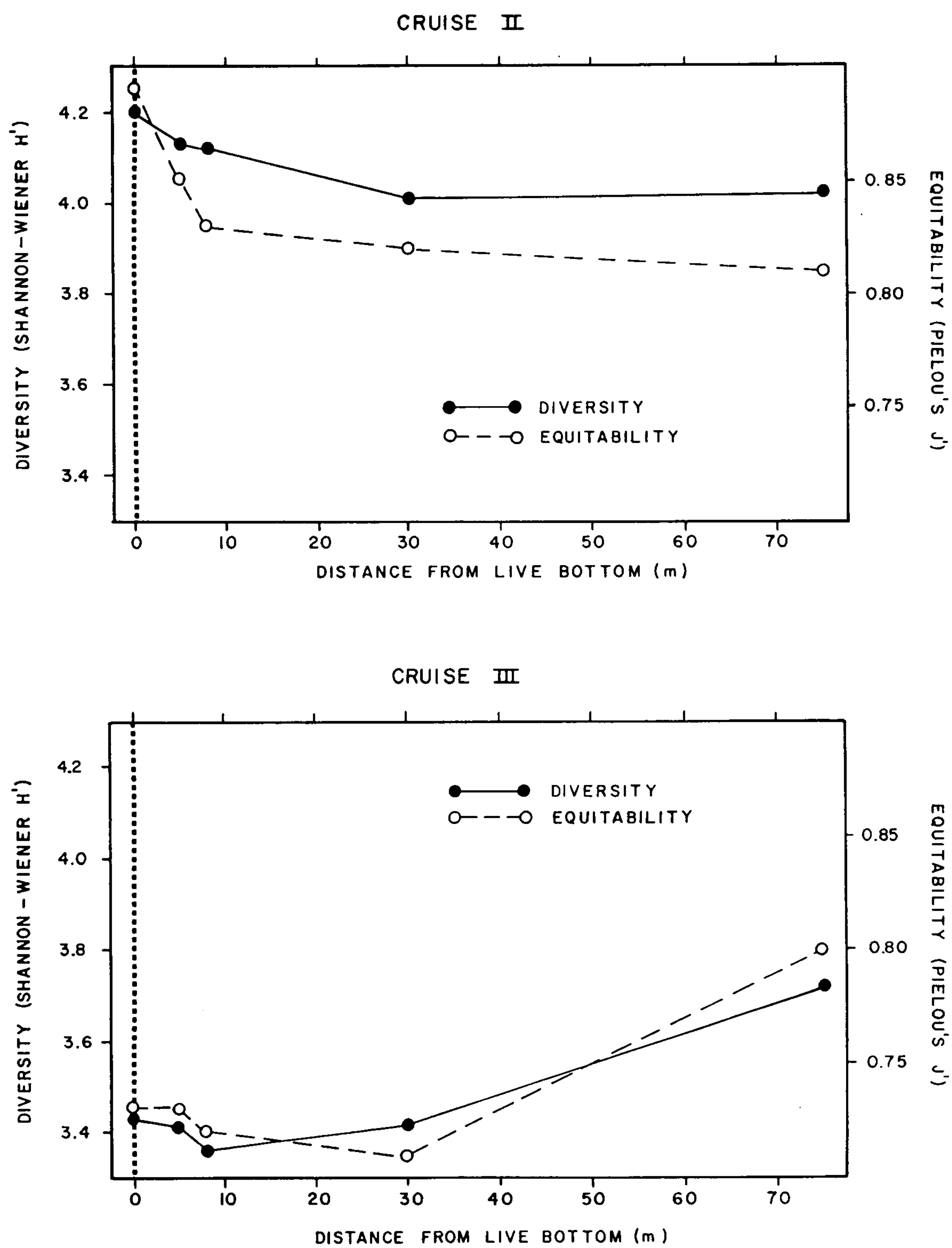


FIGURE 6.15. INFAUNAL DIVERSITY AND EQUITABILITY vs. DISTANCE FROM LIVE BOTTOM AT STATION 52.

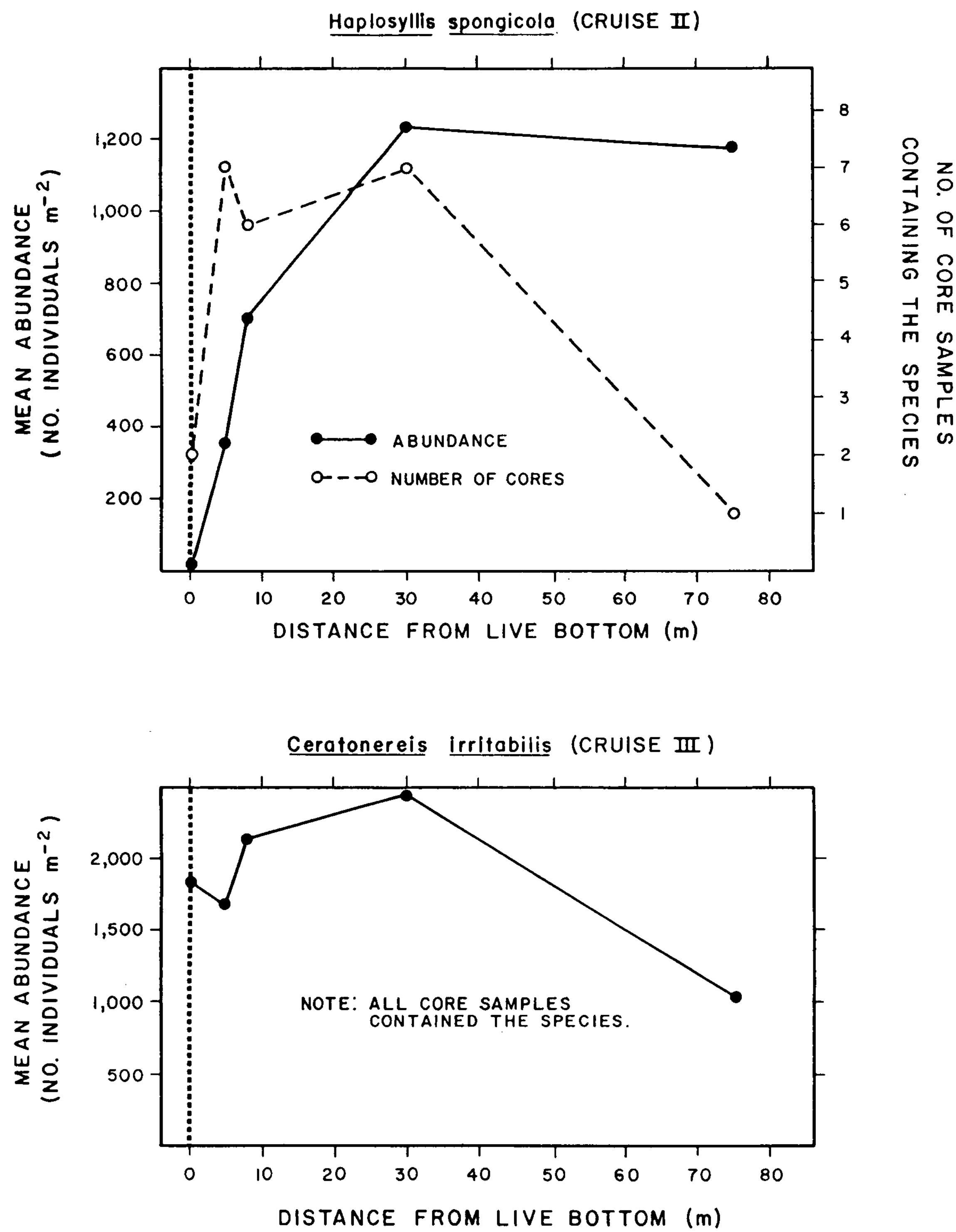


FIGURE 6.16. CHANGES IN ABUNDANCE OF NUMERICALLY DOMINANT SPECIES AT STATION 52 WITH DISTANCE FROM LIVE BOTTOM.

within 30 m of live bottom but was least abundant at 75 m from live bottom.

There were distinct trends in species composition on both cruises. Figure 6.17 shows results of cluster analysis conducted with the various distances from live bottom included. In the Cruise II analysis, the live-bottom area and the 5-m, 8-m, and 30-m sampling areas clustered apart from all other stations sampled, whereas the 75-m sampling area clustered most closely with nearby Station 53. The Cruise III analysis produced a "stair-step" dendrogram in which all of the Station 52 sampling areas clustered with Station 53 (Figure 6.17). The 75-m location and the 30-m location were most similar to Station 53 and dissimilar to the live-bottom area and the 5- and 8-m distances.

Examination of two-way occurrence tables for the Cruise II cluster analysis indicates that all of the areas sampled within Station 52 shared many species in common, particularly a large number of syllid polychaetes--species of Brania, Branchiosyllis, Ehlersia, Exogone, Sphaerosyllis, and Typosyllis, among others. A few species occurred at the live-bottom area and at distances of 5, 8, and 30 m (but not 75 m) from live bottom: a syllid polychaete, Plakosyllis quadrioculata; a nereid polychaete, Nematonereis unicornis; a serpulid polychaete, Pseudovermiliopsis occidentalis; a spionid polychaete, Aonides mayaguezensis; and an ostracod, Paranesidea gigacantha. In addition, the samples from the 75-m location included more species in common with the other stations than did samples from other locations within Station 52.

In the Cruise III samples, species associated primarily or exclusively with Station 52 included (aside from numerous syllids, as cited above) the polychaetes Eunice vittata (Eunicidae), Pectinaria gouldii (Pectinariidae), and Prionospio cirrifera (Spionidae), the amphipod Dulichia sp. A, and the scaphopod Dentalium laqueatum. In contrast to the Cruise II data, the different distances from live bottom included similar numbers of species in common with other stations; that is, the 75-m location was not much more similar to other stations than were the other distances. Several of the many syllid polychaetes found at Station 52 were also collected at Station 53, perhaps accounting in part for the pattern produced in the Cruise III cluster analysis.

The results of intensive sampling at Station 52 can be summarized as follows. Diversity, equitability, and species richness were high at

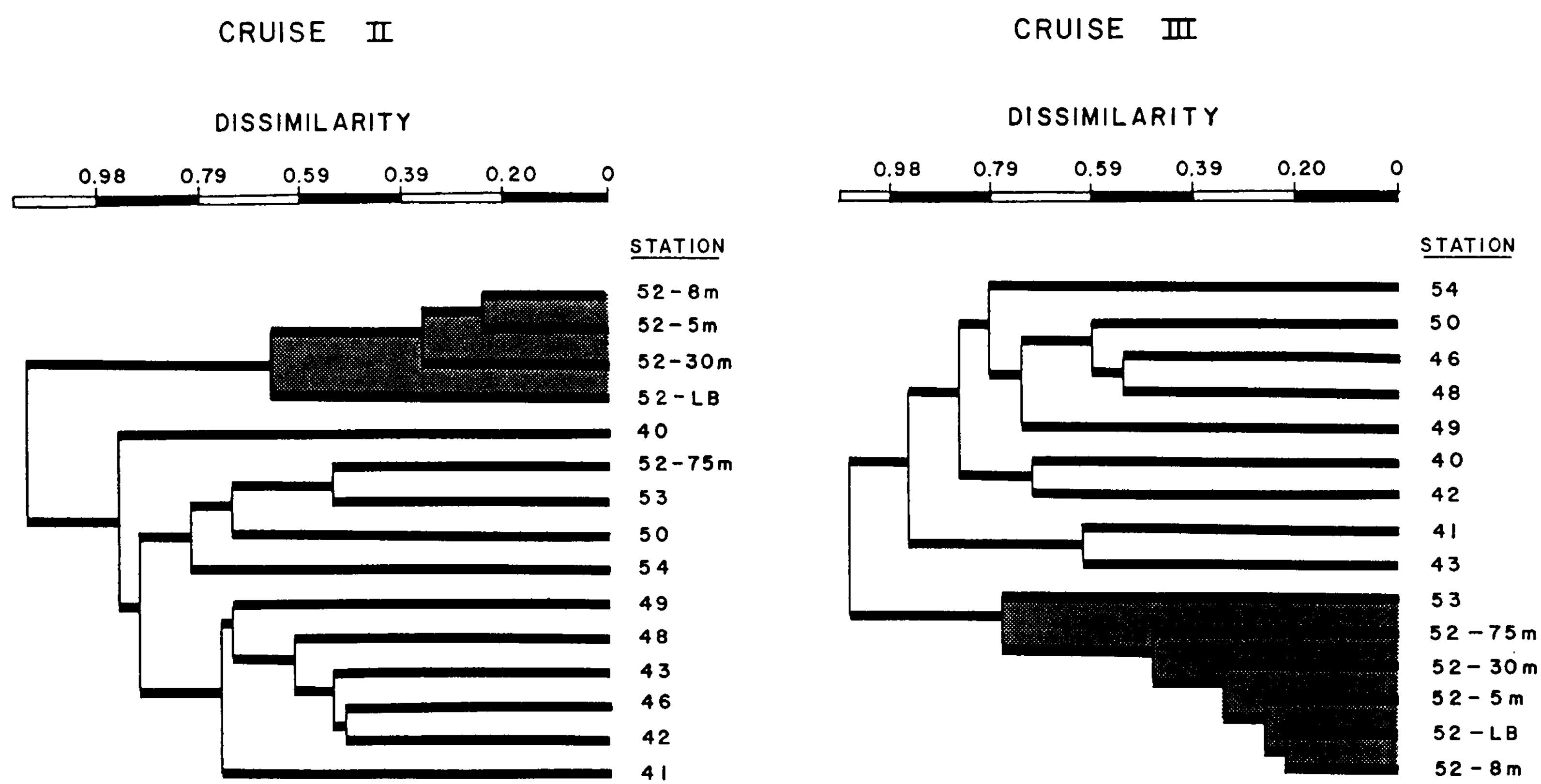


FIGURE 6.17. DENDROGRAMS FROM CLUSTER ANALYSIS OF CRUISE II AND III INFAUNAL DATA INCLUDING DIFFERENT DISTANCES FROM LIVE BOTTOM AT STATION 52.

Station 52 locations in comparison with values of these parameters at other stations; within the station, diversity and equitability increased and species richness decreased with increasing proximity to live bottom on Cruise II but not on Cruise III. Total abundances (and abundances of polychaetes and bivalves) at Station 52 were generally among the highest observed among stations, but there was no evidence for increasing density with increasing proximity to live bottom within the station. Similarly, when the abundances of two numerically abundant species (*Haplosyllis spongicola* and *Ceratonereis irritabilis*) were considered, the values at all Station 52 locations were much higher than at any other station, but there was no consistent evidence of increased abundance in proximity to a live-bottom patch (*H. spongicola* in fact showed the opposite trend). Cluster analyses indicated there were distinct trends in species composition with distance from live bottom. The Cruise II analysis indicated the presence of a distinct infauna within at least 30 m of live bottom, whereas the Cruise III analysis indicated more of a gradient in species composition with distance from live bottom, with no break between the 30- and 75-m distances.

6.5 DISCUSSION

6.5.1 Sediments

The soft-bottom stations sampled during Year 3 are in a region of transition between predominantly carbonate and quartz sediments. The quartz sands are derived from beaches, rivers, and older coastal plain sediments, whereas carbonate sands and shell hash on the inner shelf are primarily remains of mollusc shells (Gould and Stewart, 1955). Except for a narrow band of quartz sands along the coastline, sediments overlying most of the west Florida shelf are carbonate sands (see Section 6.6). Within the Year 3 study area, Stations 40 and 49 are in a predominantly quartz zone (<25% carbonate), Stations 41 and 42 are in a transitional zone (25 to 75% carbonate), and the remaining stations are in a predominantly carbonate zone (>75% carbonate).

The most notable trend in grain size composition within the Year 3 study area was the poor sorting at the southernmost stations--a reflection of high proportions of shell hash and silt/clay. The shell hash percentage was greatest at Station 52 in the immediate proximity to live bottom, and the high proportion of shell hash at Stations 53 and 54 may reflect a greater incidence of live bottom in the southern portion of the study area (see habitat mapping results in Chapter 4).

Percentages of silt and clay were highest at the northern (Station 40) and southern (Stations 52, 53, and 54) ends of the study area. The high values at Station 40 probably are due to input of fine terrigenous sediment from the nearby Charlotte Harbor estuary. In contrast, fine sediments toward the south are primarily carbonate muds--probably consisting of comminuted algal and mollusc remains (Ginsburg, 1972). The high percentage of silt/clay at the southernmost stations (especially Station 54) may help to explain the high turbidity frequently noted at stations and transects in this area (see Chapter 3). The presence of sand waves at some stations and more direct evidence from sediment traps, wave gauges, and current meters indicate that sediment resuspension and transport occur in the nearshore area, primarily due to wave surge (Danek & Lewbel, 1986). Silts and clays are more readily suspended than sand or shell hash particles.

There is apparently little temporal variability in sediment grain size composition and carbonate within the study area. Sediments from Stations 40 and 54, where the percentages of silt and clay were relatively high, were more seasonally variable in silt and clay content than sediments from the other stations.

6.5.2 Infauna

Comparison with Previous Studies. Results of the present study indicate that the nearshore macroinfauna off the coast of southwest Florida is a diverse mixture of temperate, subtropical, and tropical species. As in other open shelf environments, abundances are generally less than 15,000 m^{-2} (Rabalais and Boesch, 1985). Most species are rare, and even the most abundant species typically contribute less than 10% of the total abundance at a given station. Many of the frequently collected species in the study area are also common in other continental shelf environments such as the South Atlantic Bight (Tenore, 1979) and the south Texas continental shelf (Flint and Rabalais, 1981).

Infauna were previously sampled in the area during the MAFLA baseline studies (Dames & Moore, 1979). Blake (1979) and Bishof (1980) reported MAFLA infaunal mollusc data. Heard (1979) summarized the crustacean data and Vittor (1979) presented the polychaete data. There is no synthesis of the data available; however, Barry A. Vittor & Associates, Inc. are completing a review of the polychaete data. Vittor

(1979) reported polychaete densities ranging from 262 to 2,686 m^{-2} at two stations (2101 and 2102) located in 10- to 20-m depths off Sanibel Island. The ranged of polychaete densities was higher during the present study (1,304 to 7,632 m^{-2}). Unpublished MAFLA data provided by Barry A. Vittor (personal communication) indicate that the most abundant polychaete species on the inner west Florida shelf (water depths of approximately 20 m) are Synelmis albini, Aricidea wassi, Protodorvillea kefersteini, and Goniadides carolinae. Other typical species include Parapionsyllis longicirrata, Exogone dispar, Nereis riisei, Magelona pettiboneae, Eunice vittata, and Ceratonereis mirabilis. All of these species were present in our samples and most were among the more abundant species collected.

The MAFLA mollusc data were originally summarized by Blake (1979). Bishof (1980) reported MAFLA mollusc data from two transects off Tampa Bay and Sanibel Island, respectively. Two stations located in water depths of 11 and 18 m near Sanibel Island were very close to the location of our Stations 42 and 43, and many of the same species were abundant in our collections and those of Bishof. Numerically dominant molluscs at the 11-m station were the bivalves Solemya occidentalis, Parvilucina cf. multilineata, Plicatula gibbosa, and Tellina versicolor, the Ischnochiton papillosus (chiton). At the 18-m station, T. versicolor was most abundant, followed by the gastropods Eulimostraca hemphilli, Olivella spp., and Acteocina candei and the bivalve Varicorbula operculata.

Numerical dominance typically is low in continental shelf infaunal communities. Therefore, it is not very informative to compare lists of the most abundant species collected in different locations or in different studies. A more rigorous approach would be to conduct classification analyses, which could include a large number of species and which could incorporate abundance data. One approach that has been used with some success is to first reorganize the data base by grouping species on the basis of feeding/motility types--then conduct the cluster analyses (Maurer and Leathem, 1981). This level of analysis was considered beyond the scope of the present study, but some formal integration of the MAFLA and Southwest Florida infaunal data sets (particularly for polychaetes) would be desirable.

Feeding/Motility Types. Many of the polychaete species collected are surface deposit feeders or scavengers. The spionids (e.g., Prionospio cristata, Paraprionospio pinnata, Spio pettiboneae) are tubicolous surface deposit feeders or suspension feeders (Fauchald and Jumars, 1979). Many syllids, especially those in the subfamilies Autolytinae (Autolytus) and Syllinae (e.g., Dentatisyllis, Ehlersia, Haplosyllis, Typosyllis) are motile carnivores/scavengers feeding primarily on hydroids, bryozoans, sponges, or other colonial invertebrates (Fauchald and Jumars, 1979). Syllids are common in shallow reef habitats and were most common in our study area in the vicinity of live bottom (Station 52). Other families that are considered motile scavengers/carnivores include Nereidae (e.g., Ceratonereis, Nereis) and Dorvilleidae (e.g., Protodorvillea kefersteini). Species in other well-represented polychaete families, such as Paraonidae (Aricidea, Cirrophorus) and Capitellidae (Mediomastus californiensis) are burrowing, subsurface deposit feeders (Fauchald and Jumars, 1979).

Most of the numerically abundant mollusc species collected are bivalves. Both filter feeders (Crassinella lunulata, Crenella divaricata, Diplodonta punctata, Solemya occidentalis) and deposit feeders (Semele nuculoides, Tellina versicolor) were well represented in the collections.

The presence of sand waves at several stations indicates that disturbance of bottom sediments due to tidal currents or surface waves (the predominant influence in shallow water) is probably an important factor affecting the macroinfauna. Conditions such as poor sorting and frequent bottom disturbance should favor motile or discretely motile forms (the latter refers to animals that inhabit tubes or burrows but are capable of relocating) over sessile forms. Fauchald and Jumars (1979) and Maurer and Leathem (1981) suggest that sessility is associated with relatively stable sedimentary conditions found in deep water--a prediction that is supported by these data.

Spatial and Temporal Variability. Spatial variations in abundance were evident within the rather narrow depth range examined here (10 to 20 m). In general, the range of abundances is similar to the range noted during the two previous study years, which encompassed a much wider range of water depths (23 to 148 m). There is no indication that infaunal abundance is related to either water depth or sediment type within the Year 3 study area.

Within the Year 3 study area, species composition varied primarily along a north-south axis, with the variations relatable in part to gradations in sediment grain size composition. When a wide range of water depths is considered, both water depth and sediment texture are important influences on the species composition of southwest Florida shelf macroinfauna (Vittor, 1979; Bishof, 1980; Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985; also see Section 6.6). Water depth is essentially an alias for numerous depth-related environmental factors such as temperature, light, nutrient concentrations, particulate organic matter inputs, and (to some extent) sediment texture. Sediment texture influences on infaunal species composition reflect the importance of sediment as habitat for all infauna and as food source for most.

Temporal variations in macroinfaunal abundance probably reflect both life-history patterns of various species and variations in influential environmental variables such as temperature and organic matter inputs. In general, one would expect a greater degree of seasonal variability in environmental parameters with increasing water depth, and also a slight decrease in temperature range with decreasing latitude. Hydrographic profiles recorded at the live-bottom stations during Cruises II and III showed approximately 1°C difference in near-bottom temperature between the northernmost and southernmost stations.

Between-cruise variations in abundance were greatest at Stations 40, 42, 46, 50, and 53 and do not appear to be related to water depth or latitude within the Year 3 study area. In terms of species composition, stations in the northern part of the area (40, 42, 43, 46, 48, and 50) were more variable than the three southernmost stations (52, 53, and 54).

Between-cruise variations in infaunal abundance and species composition population also do not appear to be related to changes in the sediment parameters measured in this study. For example, there was little change in sediment composition at Station 43 between Cruise II and Cruise III, but the infaunal populations were very different. Other sediment composition variables not measured in this study, such as organic carbon and nitrogen content and standing stock of microalgae, are important influences upon macroinfauna and may exhibit seasonality.

The most striking seasonal difference noted was the change in abundance and species composition at Station 40, where two polychaete species accounted for 80% of the individuals identified to species during Cruise II but were not even collected during Cruise III. The cause for the population explosion of the two species during Cruise II is unknown. However, many of the infaunal species sampled have short generation times and can be regarded as opportunists readily able to take advantage of suddenly favorable conditions--e.g., a disturbance affecting other species or a pulse of food (Hanson et al., 1981).

The consistent pattern of increased bivalve abundance in the Cruise III samples suggests a seasonal pattern of spring recruitment. Additional data would be needed to determine whether this is repeated each year. Data presented by Bishof (1980) for three sampling periods in 1975-1976 do not indicate a similar pattern in abundances of the common bivalves. However, Blake (1979) reported that Tellina versicolor, a common nearshore species in the study area, showed peaks of abundance during summer at several MAFLA stations, indicating that recruitment occurs during spring or early summer.

Effects of Proximity to Live Bottom. The intensive sampling at Station 52 was conducted to evaluate effects of live bottom on surrounding infaunal communities. Data from within the station can be used to evaluate effects of live-bottom proximity on a scale of tens of meters. Data from the station as a whole can also be compared with data from nearby stations to determine whether there are effects on a larger scale.

The infauna at Station 52 differed in several respects those of the other stations. Abundances at Station 52 were higher than those at most other stations, especially during Cruise III. Numbers of species collected at all locations within Station 52 generally were among the highest. During Cruise II, diversity, equitability, and expected species number were higher at Station 52 than at most or all other stations. In terms of species composition, Station 52 was distinguished by two features: (1) there was a single numerical dominant on each cruise--a species that was rare or absent at all other stations; and (2) there was an extraordinarily large number of syllid polychaete species.

If the distinguishing features of Station 52 represent an influence of live bottom, one might expect certain trends to hold within the station. Abundance (total and numerical dominants), species richness, diversity, and equitability would be expected to decrease with increasing distance from live bottom. Species composition would be expected to resemble that of the nearby stations more and more with increasing distance from live bottom.

Most results of the within-station sampling did not conform to expectations. There was no indication of decreasing abundance with increasing distance from live bottom, either for total infauna or the numerical dominants. Diversity and equitability decreased with increasing distance from live bottom during Cruise II, but not during Cruise III. Species richness increased with increasing distance from live bottom during Cruise II (the opposite of the expected trend), and there was no trend in the Cruise III species richness data. Only with respect to species composition were the within-station results approximately as expected--that is, increasing dissimilarity to the live bottom area with increasing distance from live bottom. There was no particular trend within 8 m of live bottom, but the 30-m and 75-m locations were most dissimilar to the live-bottom area and most similar to the other stations on both cruises. The Cruise II data indicated a major break in species composition between the 30- and 75-m locations, whereas the Cruise III data indicated more of a gradual change.

The results suggest that proximity to live bottom may influence the characteristics of macroinfaunal communities on a scale larger than the maximum distance of 75 m examined here. This would explain the lack of consistent trends in certain parameters within the station as opposed to between stations. Cluster analysis proved the most sensitive indicator of the influence of live bottom, probably because the analysis uses the largest amount of information--the identities and abundances of the various species. Summary statistics and community structure indices incorporate less information and are not as likely to reflect subtle differences in characteristics of the infaunal community.

Assuming that proximity to live bottom influences infauna, how could the effect be mediated? Sediment composition data show that Station 52 is characterized by a very high percentage of shell hash particles (>2 mm diameter). The percentage was lowest at the greatest distance from live bottom and highest within the live-bottom area (Cruise III) or very close to it (Cruise II--5 m). The layer of unconsolidated sediments (sand and shell hash) overlying bedrock is thin; sediment thickness within the live-bottom area ranged from 0 to 5 cm (see Chapter 5). The thin layer of poorly sorted sediments favors the predominance of motile, free surface-dwellers such as syllids, nereids, dorvilleids, and others. The presence of encrusting epibiota such as sponges, hydroids, bryozoans, ascidians, etc. living on shell fragments, exposed hard bottom, and thinly covered hard bottom provides an abundance of food for these species, which are primarily scavengers and carnivores.

It is important to note that live bottom is widespread and patchy within the study area. No remote photographic surveys were conducted at the soft-bottom stations (other than 52); therefore, other soft-bottom sampling locations may have been within the range of influence of live-bottom patches.

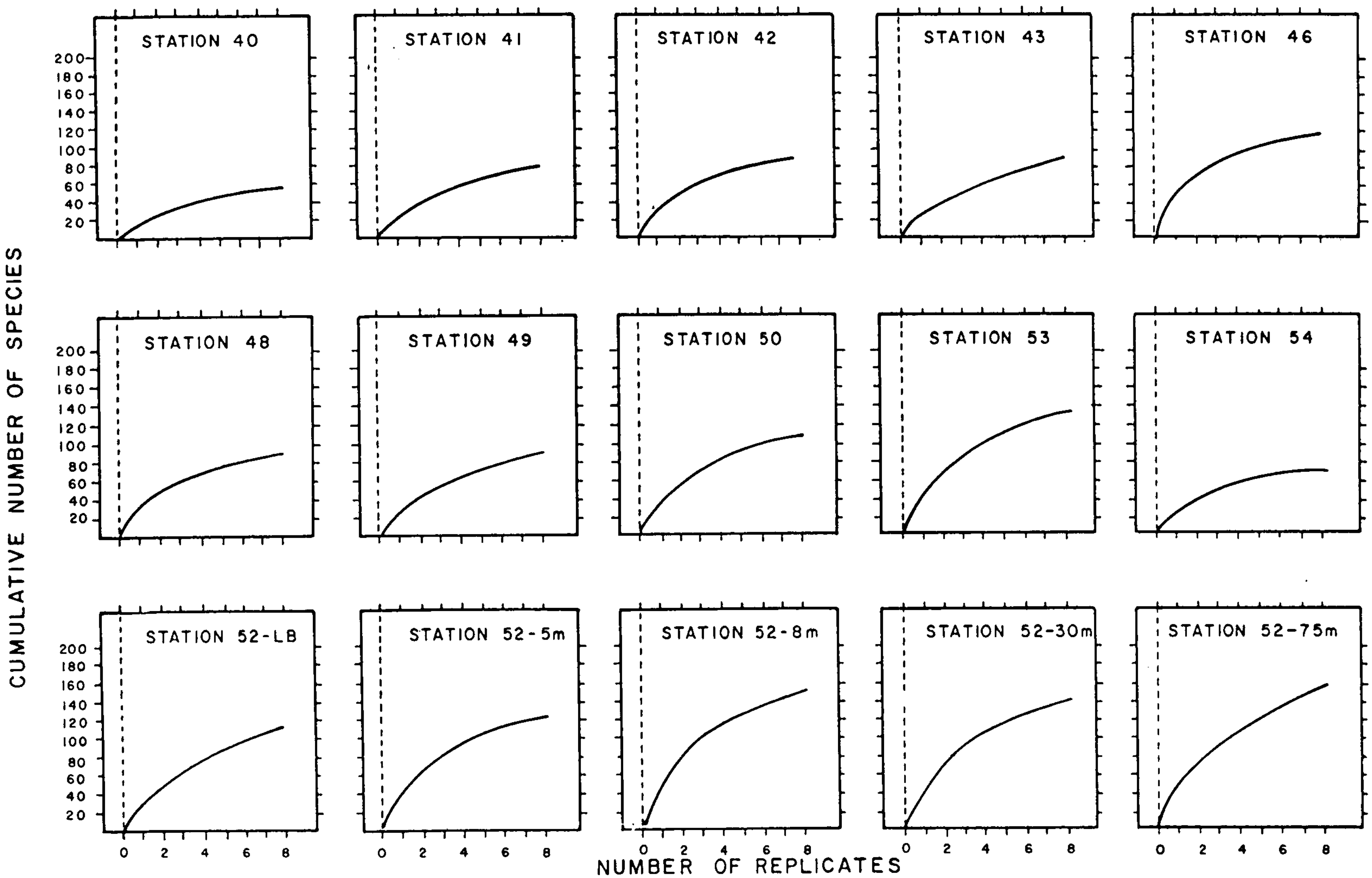
6.5.3 Methodology Evaluation

Sampling Gear. A diver-operated corer was used to sample infauna in this study. Since its first use by Saloman (1971) in Tampa Bay, the corer has been used in numerous studies along the west Florida coast. The main advantage of the diver-operated corer over remotely operated box corers used during the Year 1 and 2 studies is that a diver can make sure that consistent, intact samples are obtained. In addition, a diver can insure that samples are collected from a visually homogenous area of the seafloor; with a remotely operated box corer, sample placement is essentially "blind" with respect to small-scale patchiness in sediment type.

Sieve Size. A 0.5-mm mesh sieve was used in this study. This is considered adequate for retaining the majority of macroinfauna (Reish, 1959; Mahadevan and Patton, 1979). During the Year 1 study, an experiment showed that when samples were processed using a 1.0-mm sieve, only about 60% of the species and 20% of the individuals collected using a 0.5-mm sieve were obtained (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a).

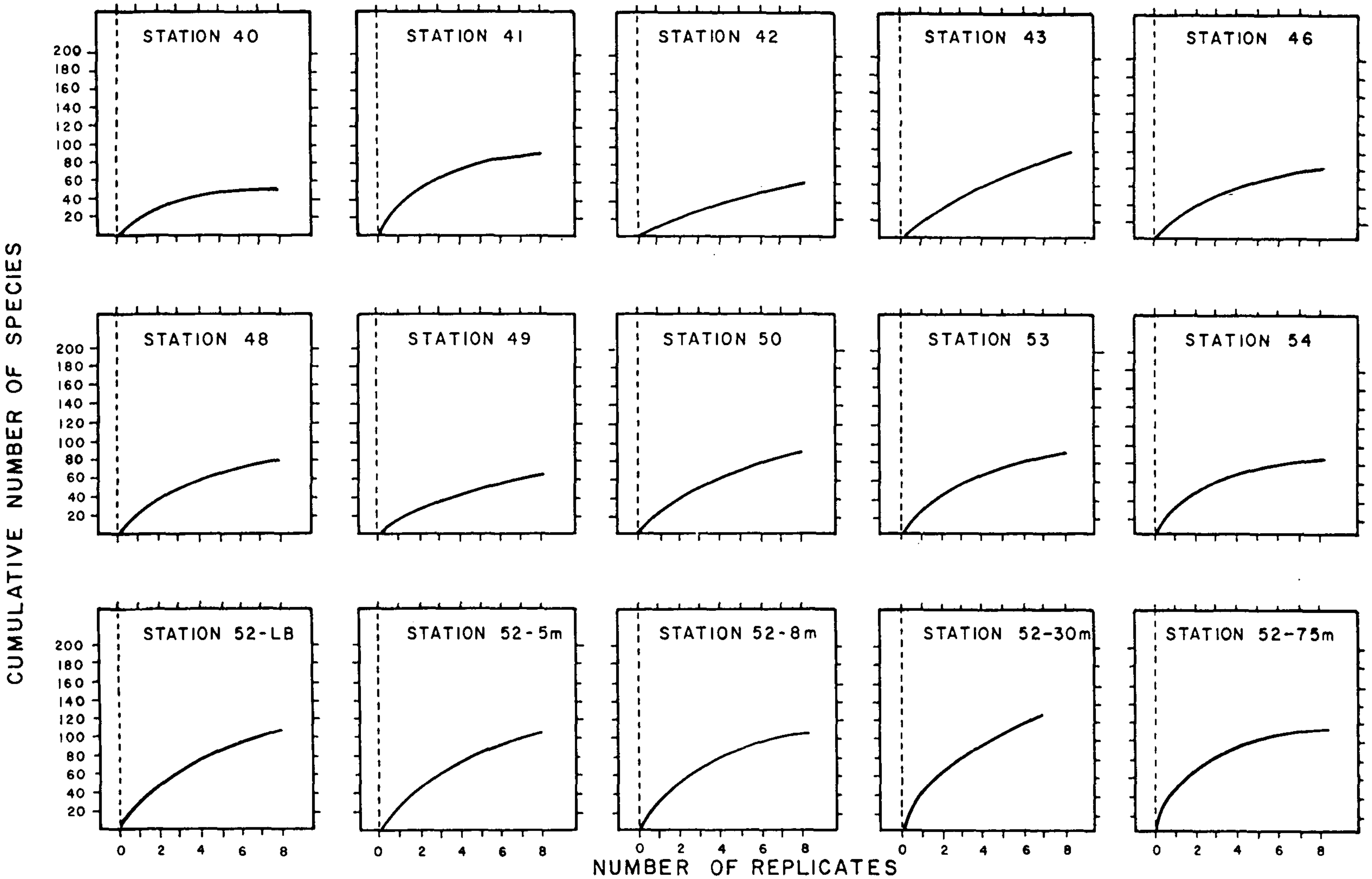
Replication. Figures 6.18 and 6.19 show species saturation curves for Cruises II and III, respectively. Each curve represents an average of 100 randomly selected orderings of the eight replicates. None of the curves approach a slope of zero, indicating that the numbers of species collected at each station are underestimates of true species richness. However, on average, only about 17% of the species in a given replicate were unique to that replicate in a set of eight; that is, 83% of the species collected in an average eighth replicate would have been collected in one of the previous seven replicates. Analysis of additional replicates would have provided increasingly less new information, and the level of replication was considered adequate to describe macroinfaunal communities in the area.

Sampling Frequency. Sampling was conducted during two periods, December 1982 and May-June 1983. Results indicate there is significant



NOTE: EACH CURVE REPRESENTS THE AVERAGE OF 100 RANDOMLY SELECTED PERMUTATION OF THE EIGHT REPLICATES AT EACH STATION.

FIGURE 6.18. SPECIES SATURATION CURVES FOR INFAUNAL DATA, CRUISE II.



NOTE: EACH CURVE REPRESENTS THE AVERAGE OF 100 RANDOMLY SELECTED PERMUTATION OF THE EIGHT REPLICATES AT EACH STATION.

FIGURE 6.19. SPECIES SATURATION CURVES FOR INFAUNAL DATA, CRUISE III.

seasonal variation in macroinfaunal populations in the water depth range of 10 to 20 m on the southwest Florida shelf. Additional sampling during other seasons over a period of years would be needed to determine whether there is a predictable seasonal pattern.

6.6 COMPARISON AND INTEGRATION WITH YEAR 1 AND 2 DATA

The Year 3 soft-bottom station collections complement those from 19 soft-bottom stations sampled during Years 1 and 2. Locations of all soft-bottom stations are shown in Figure 6.20. Sampling dates and water depths for each station are provided in Table 6.20. The following sections summarize the three-year sediment and infaunal data sets. Otter trawl samples were collected only at Year 1 and 2 soft-bottom stations, and because those results were summarized in the Year 2 final report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985), no further discussion is presented here. For raw infaunal and sediment data from Years 1 and 2, refer to the Year 2 final report. Year 3 data are in Appendices I (infauna) and J (sediment grain size and carbonate) of this report.

6.6.1 Sediments

Table 6.21 summarizes sediment composition variables for all soft-bottom stations. Selected shelfwide patterns are illustrated in Figures 6.21 through 6.24.

Grain Size and Texture. The shelfwide distribution of sediment textures [terminology of Shepard (1954)] is illustrated in Figure 6.21. Sediments at all but two Year 1 and 2 stations and one Year 3 station typically consisted of at least 75% particles greater than 62.5 μm in diameter and can be classified as sand [terminology of Shepard (1954)]. Sediments at Stations 25 and 26, located in the area of the Tortugas pink shrimp grounds, contained about 60% silt and 30-35% sand and can be classified as sandy silt. Farther inshore toward the Florida Bay area (Station 53), sediments were predominantly sand, with Station 54 intermediate in texture (silty sand).

Patterns in silt/clay content are shown in Figure 6.22. As noted above, sediments high in silt/clay predominated in the Dry Tortugas area (Stations 25, 26, and to a lesser extent, 54). Generally, sediments with 10 to 20% silt/clay were the most widely distributed on the shelf. Sediments containing <10% silt/clay occurred on the middle shelf along Transect A, on the outer shelf in the southwestern portion of the study

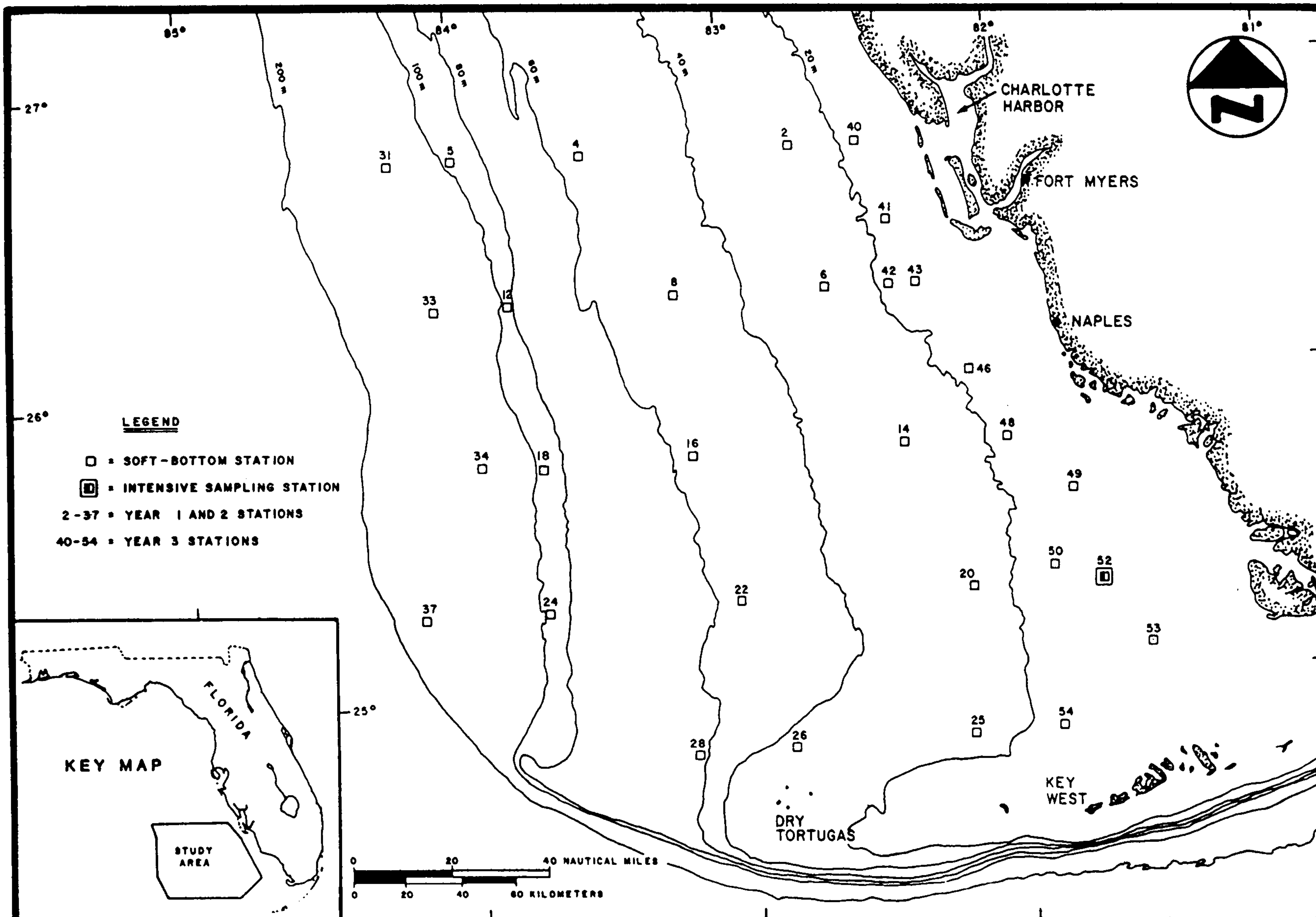


FIGURE 6.20. LOCATIONS OF SOFT-BOTTOM STATIONS SAMPLED DURING YEARS 1, 2, AND 3.

TABLE 6.20. WATER DEPTHS AND SAMPLING DATES FOR YEAR 1, 2, AND 3 SOFT-BOTTOM STATIONS.

			Sampling Date*					
		Water Depth	Year 1 Cruises		Year 2 Cruises		Year 3 Cruises	
Station	Transect	(m)	III	IV	II	III	II	III
2	A	25	X	X				
4	A	55	X	X	X†	X†		
5	A	90	X	X	X†	X†		
6	B	26	X	X	X†	X†		
8	B	48	X	X				
12	B	90	X	X	X†	X†		
14	C	26	X	X	X†	X†		
16	C	54	X	X	X†	X†		
18	C	86	X	X				
20	D	23	X	X	X†	X†		
22	D	52	X	X	X†	X†		
24	D	88	X	X	X†	X†		
25	E	24	X	X	X†	X†		
26	E	38	X	X				
28	E	59	X	X	X	X		
31	A	142			X	X		
33	B	146			X	X		
34	C	136			X	X		
37	D	148			X	X		
40	A	18					X	X
41	none	16					X	X
42	B	17					X	X
43	B	16					X	X
46	G	18					X	X
48	C	16					X	X
49	none	12					X	X
50	none	16					X	X
52§	D	14					X	X
53	none	10					X	X
54	E	17					X	X

During Year 1 and 2 sampling, five 0.057 m^2 box core infaunal samples were collected per station; subsamples were removed for grain size and carbonate analyses. During Year 3 sampling, ten 0.016 m^2 box core infaunal samples were collected per station (eight were processed, the other two archived); separate core samples (three per station during Cruise II, two per station during Cruise III) were collected for grain size and carbonate analyses.

*Sampling dates:
Year 1, Cruise III = October-November 1980
Year 1, Cruise IV = April-May 1981
Year 2, Cruise II = July-August 1981
Year 2, Cruise III = January-February 1982
Year 3, Cruise II = December 1982
Year 3, Cruise III = May-June 1983.

†Infauna and grain size analyses only (no carbonate).

§Intensive sampling station. Box cores were collected in a live-bottom area and at four distances from live bottom.

TABLE 6.21. SEDIMENT COMPOSITION DATA FROM YEAR 1, 2, AND 3 SOFT-BOTTOM STATIONS.

Station	Grain Size (μm) Mean*	Grain Size (μm) Range*	Sediment Texture§	Percent Carbonate Mean*	Percent Carbonate Range*
2	294	155-432	sand	56	41-72
4	496	361-611	sand	98	97-99
5	535	511-551	sand	96	94-97
6	117	104-133	sand	84	83-86
8	161	147-176	sand	94	93-96
12	192	170-218	sand	96	96-97
14	137	129-143	sand	95	94-96
16	278	183-420	sand	95	94-96
18	337	316-358	sand	99	98-99
20	526	480-611	sand	98	98-99
22	224	182-279	sand	95	94-96
24	294	257-321	sand	97	96-98
25	59	56-61	sandy silt	91	90-91
26	61	60-61	sandy silt	92	91-93
28	220	206-235	sand	96	94-98
31	182	167-196	sand	88	80-97
33	189	155-224	sand	89	82-96
34	299	297-301	sand	96	96-96
37	401	374-429	sand	95	95-95
40	134	125-142	sand	23	21-24
41	512	476-547	sand	42	36-49
42	324	285-364	sand	34	29-38
43	340	338-343	sand	88	88-88
46	285	227-343	sand	96	95-97
48	197	175-219	sand	90	88-91
49	230	190-271	sand	21	18-25
50	214	212-215	sand	86	82-90
52-LB	608	484-733	sand	97	97-98
52-5m	526	347-704	sand	98	98-98
52-8m	502	431-574	sand	97	97-98
52-30m	440	364-516	sand	98	98-98
52-75m	347	313-381	sand	98	98-98
53	351	319-383	sand	99	98-99
54	176	137-214	silty sand	98	97-99

*Each station was sampled on two or four cruises. Station means for each cruise were used to calculate grand mean and range.

†Classification based on Folk (1974). Abbreviations: F=fine, M=medium, C=coarse.

§Classification based on Shepard (1954).

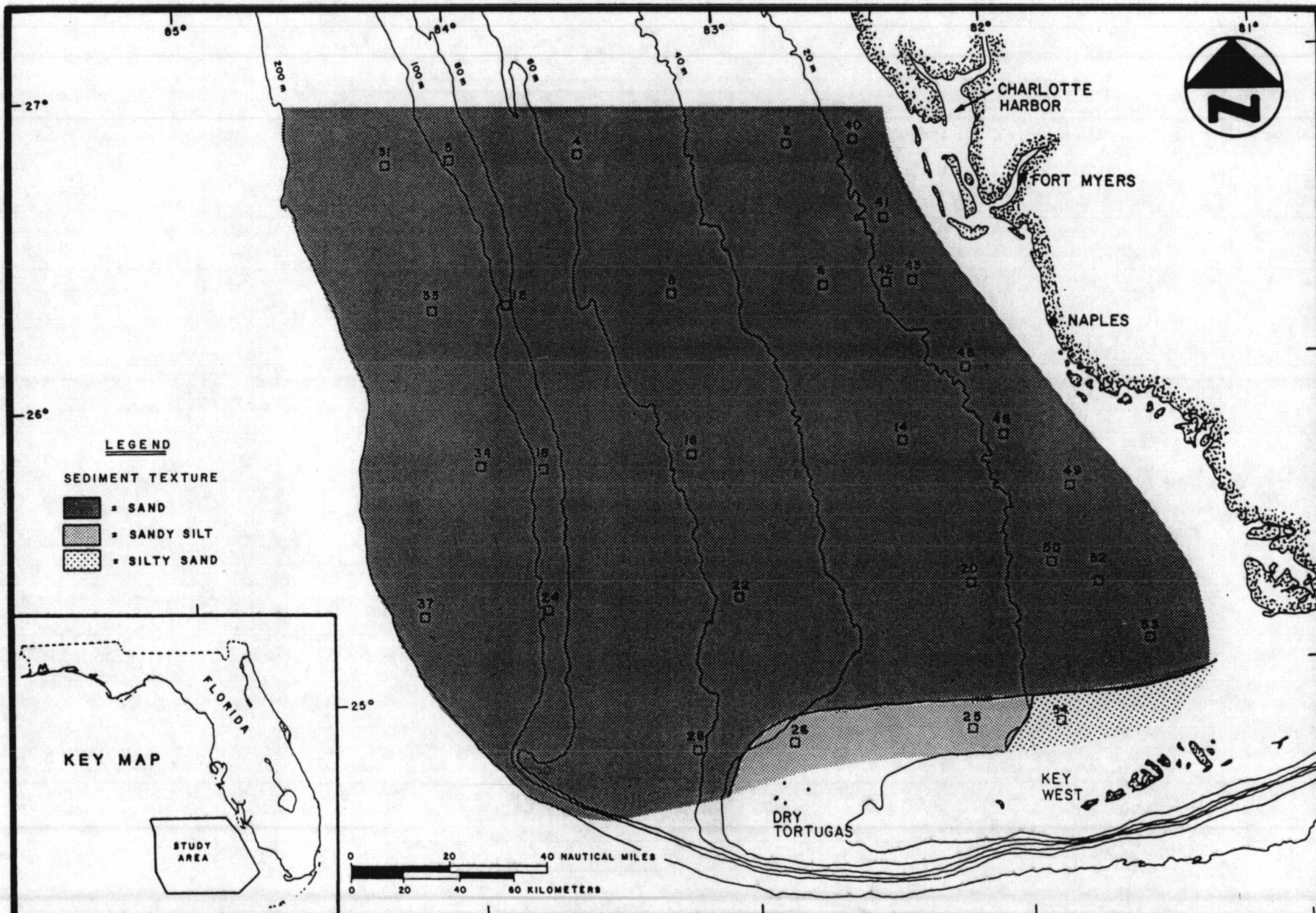


FIGURE 6.21. GENERAL DISTRIBUTION OF SEDIMENT TEXTURES BASED ON YEAR 1, 2, AND 3 DATA.

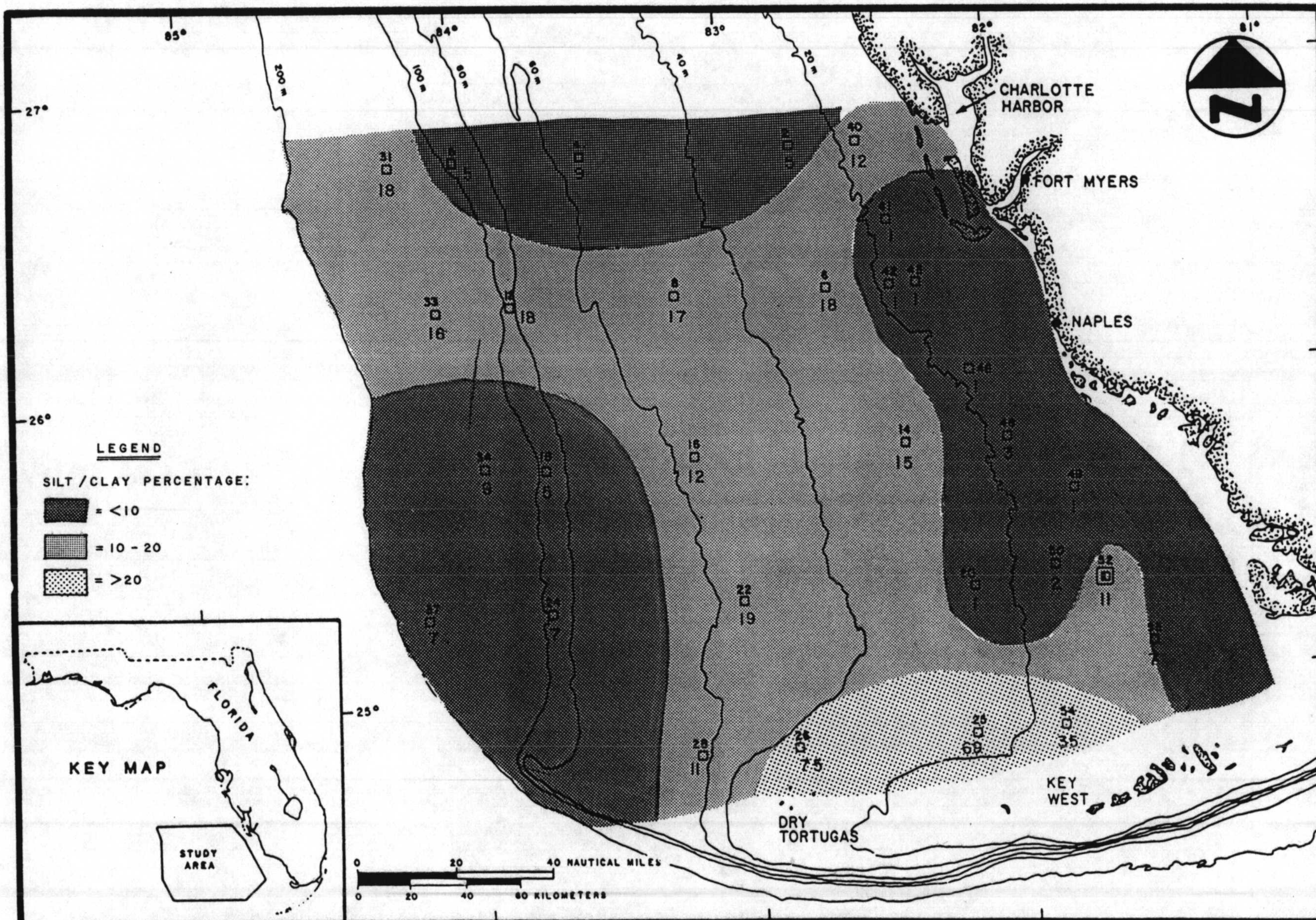


FIGURE 6.22. GENERAL DISTRIBUTION OF SILT/CLAY PERCENTAGES BASED ON YEAR 1, 2, AND 3 DATA.

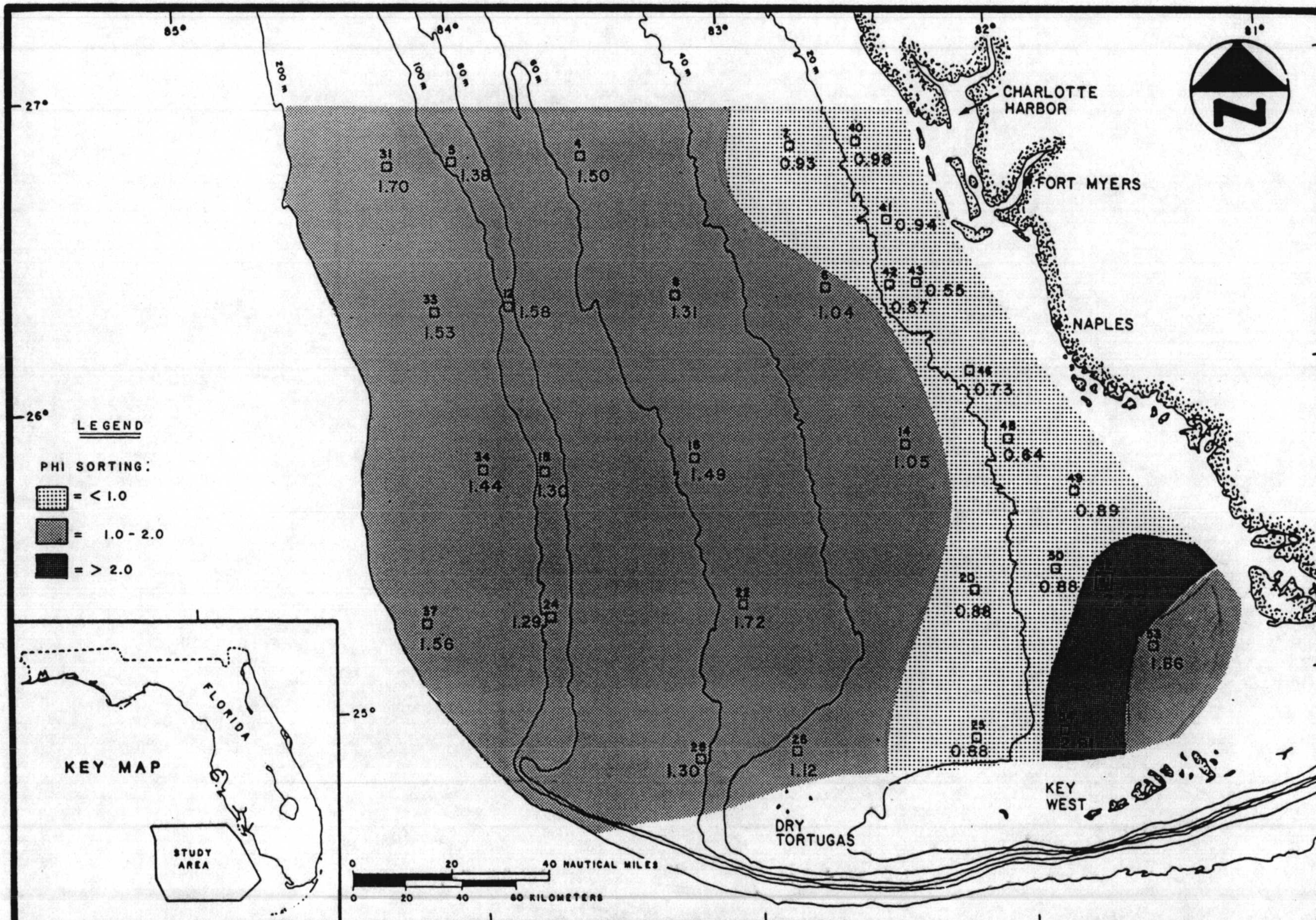


FIGURE 6.23. GENERAL DISTRIBUTION OF PHI SORTING VALUES BASED ON YEAR 1, 2, AND 3 DATA.

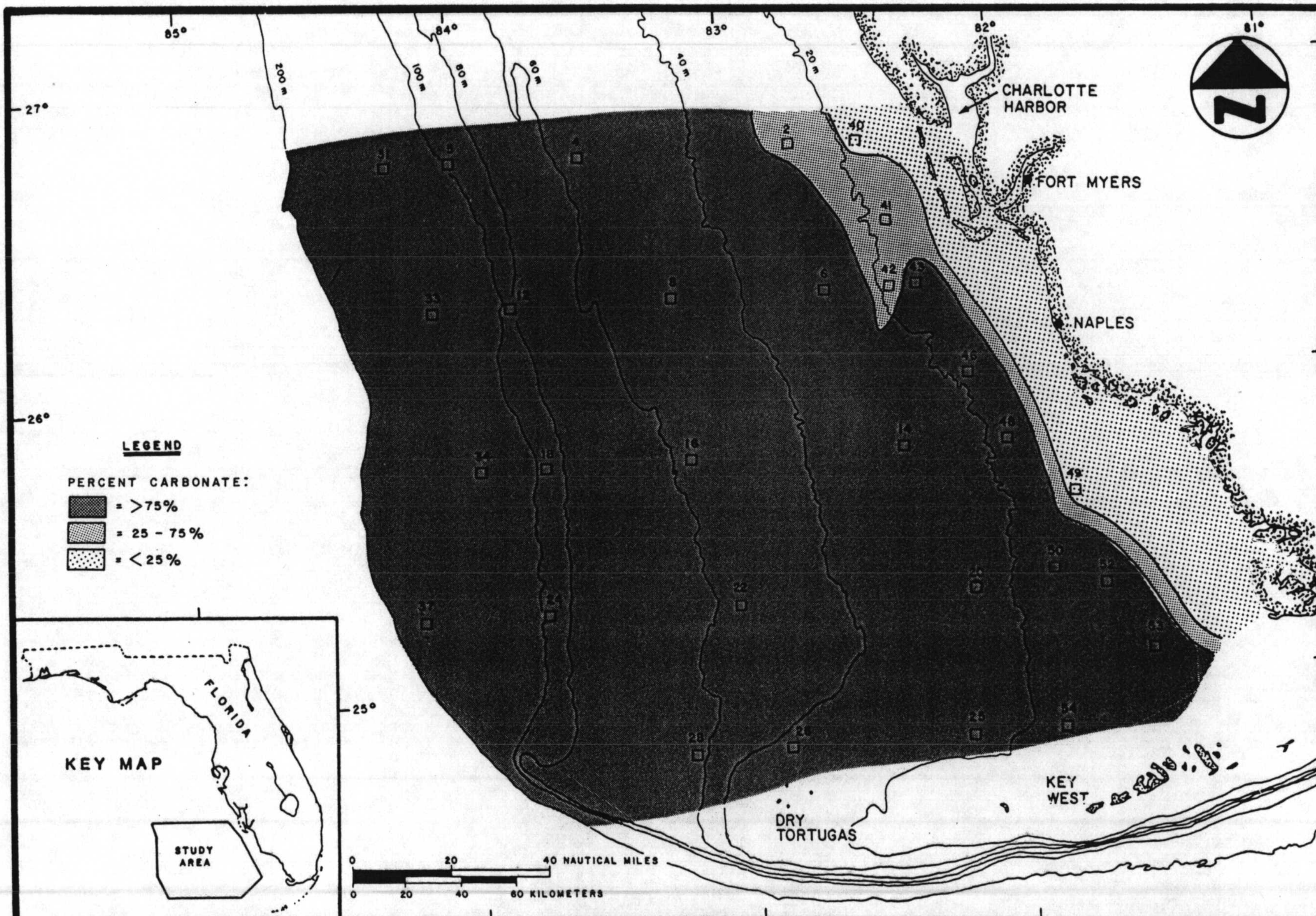


FIGURE 6.24. SEDIMENT CARBONATE CONTOURS BASED ON YEAR 1, 2, AND 3 DATA.

area, and especially on the inner shelf south of Charlotte Harbor (most values <5%).

Patterns in mean grain size reflect variations in silt/clay content (as described above) and differences in grain size composition within the sand fraction. Mean grain sizes in the coarse silt range occurred at Stations 25 and 26 near the Dry Tortugas. Mean grain sizes in the fine sand category (125 to 250 μm) were noted both landward and seaward of the zone of silty sediments, and in general, sediments at many stations could be categorized as fine sand (Table 6.21). However, medium sand (250 to 500 μm) and/or coarse sand (500 μm to 1 mm) predominated at certain locations. Along Transect A, Stations 2, 4, and 5 (in order of increasing water depth) were characterized by increasingly coarse sand. Also, most nearshore stations (e.g., Stations 20, 41, 42, 43, 46, 52, and 53) were characterized by medium to coarse sand. Finally, sediments on the middle to outer shelf in the southwestern portion of the study area (Stations 16, 18, 24, 34, and 37) had mean grain sizes in the medium sand range.

Phi sorting values varied in a consistent pattern across the shelf (Figure 6.23). Generally, nearshore sediments were moderately sorted to moderately well sorted--probably due to winnowing by strong tidal currents (note the low silt/clay content shown in Figure 6.22). However, nearshore sediments in the southeastern corner of the study area were poorly to very poorly sorted, containing a mixture of sand, silt, clay, and shell hash. Sediments at stations deeper than about 25 m were, in general, poorly sorted (phi sorting 1.0 to 2.0).

Carbonate Content. Figure 6.24 shows carbonate content contours drawn from the soft-bottom station data. Carbonate content groupings were selected to correspond with those used by Doyle and Sparks (1980).

A zone of predominantly quartz sediments (<25% carbonate) roughly parallels the coast, extending to about 30 to 50 km (15 to 30 NM) from shore (Figure 6.24). The detrital quartz sediments are derived from adjacent beaches and rivers, as well as from reworking of former coastal plain sediments that have become submerged as a result of sea level rise (Gould and Stewart, 1955). As noted by Doyle and Sparks (1980), the quartz zone widens south of Cape Romano, but our data from more southerly stations than those sampled by Doyle and Sparks show this trend does not continue southward: carbonate sediments penetrate fairly close to shore even in the Florida Bay region (Stations 50, 52, and 53).

Transitional sediments (25 to 75% carbonate) occur in a narrow zone that widens off Charlotte Harbor (Figure 6.24). Gould and Stewart (1955) attributed the greater seaward extent of quartz sands off Tampa Bay and Charlotte Harbor to the action of strong tidal currents that transport coastal sediments offshore.

Beyond this transitional zone, carbonate sediments predominate over most of the middle and outer shelf (Figure 6.24). Contributing sources are molluscan shell fragments, coralline algal sand, oolite sand, and foraminiferal sand and silt (Gould and Stewart, 1955). Molluscan shell hash is the major constituent on the inner and middle shelf to a depth of about 60 m, whereas algal sands predominate in the 60 to 80 or 100 m depth range. Remains of pelagic foraminera are important constituents of carbonate sands on the outer shelf and slope (Gould and Stewart, 1955).

6.6.2 Infauna

In all, 1,121 species were identified during the three years of infaunal collections. The total includes 413 polychaete species, 452 crustacean species, and 231 mollusc species. Polychaetes accounted for about 45% of the total number of species collected within each depth range on the shelf with the exception of the outer shelf (60%). The most speciose polychaete families were Syllidae (70 species), Paraonidae (35 species), and Spionidae (31 species).

Table 6.22 lists the 25 most abundant infaunal species collected. Most of the species listed were widely distributed; notable exceptions are *Filograna implexa*, a serpulid polychaete that was very abundant at a few outer shelf stations during the summer cruise, and *Ceratonereis irritabilis*, a nereid polychaete that was very abundant at Station 52 during the Year 3 spring cruise. The most abundant species, *Prionospio cristata*, occurred at most stations in water depths less than 100 m but was most abundant at Stations 2, 6, 14, and 25, all in water depths of 20 to 30 m. *Synelmis albini*, the second most abundant species, occurred at nearly all stations but was most abundant on the middle shelf at Stations 5, 12, 18, 22, 24, and 28. *Mediomastus californiensis*, a capitellid polychaete, occurred at all stations but was most abundant at about 20 m depth (Stations 6, 14, 40, and 53). *Mediomastus*

TABLE 6.22. THE MOST ABUNDANT INFAUNAL SPECIES IN THE COMBINED YEAR 1, 2, AND 3 DATA SET.

Species	No. Stations	Grand Mean Abundance* (No. m^{-2})
Prionospio cristata (P)	26	334
Synelmis albini (P)	29	314
Mediomastus californiensis (P)	30	160
Paraprionospio pinnata (P)	25	142
Armandia maculata (P)	30	112
Cirrophorus americanus (P)	26	109
Myriochele oculata (P)	30	108
Filograna implexa (P)	8	91
Aricidea fragilis (P)	24	84
Haplosyllis spongicola (P)	21	83
Lucina radians (B)	12	79
Prionospio cirrifera (P)	23	67
Cyclaspis sp. A (C)	20	66
Goniadides carolinae (P)	15	66
Magelona pettiboneae (P)	18	62
Lumbrineris verrilli (P)	25	48
Leptochelia sp. A (T)	21	47
Aricidea catherinae (P)	26	44
Levinsenia gracilis (P)	19	43
Axiothella sp. A (P)	28	42
Ceratonereis irritabilis (P)	4	42
Aricidea taylori (P)	18	41
Ceratocephale oculata (P)	21	41
Sigambra tentaculata (P)	18	41
Tharyx annulosus (P)	28	39

B = bivalve
C = cumacean
P = polychaete
T = tanaid.

*Mean abundance was calculated for each station, then averaged over stations.

californiensis was frequently a secondarily abundant species in samples dominated by P. cristata or other spionids.

Most of the species listed in Table 6.22 are polychaetes; particularly well represented in the list are paraonids (Aricidea catherinae, A. fragilis, A. taylori, Cirrophorus americanus, and Levinsenia gracilis). The paraonids, as well as some other species on the list, such as the capitellid Mediomastus californiensis, are considered burrowing, subsurface deposit feeders. Spionids, which are typically tubicolous, surface deposit feeders or suspension feeders, are also well represented (Prionospio cristata, Paraprionospio pinnata, and Prionospio cirrifera).

Infaunal density, diversity, and equitability values for each Year 1, 2, and 3 collection are listed in Tables 6.23 through 6.25. Patterns in these data are discussed below.

Infaunal density ranged from 1,280 to 13,272 m^{-2} and generally declined with increasing water depth and distance from shore (Figure 6.25). Pronounced seasonality was evident, with densities being highest during summer at six of the ten stations sampled during all four seasons during Year 1 and 2 and at all four of the Year 2 stations sampled only during summer and winter. Although some inner shelf stations exhibited a large degree of seasonality--often attributable to population explosions of spionids such as Prionospio cristata, Paraprionospio pinnata, or Prionospio steenstrupi, there is no indication of a consistent decline in seasonality with increasing water depth. For example, the polychaete Haploscoloplos sp. appeared in higher densities during the winter cruise than during any other cruise at all Year 1 and 2 stations, with Station 37 (water depth: 148 m) having the highest density (1,702 m^{-2}).

Diversity values ranged from 1.66 to 4.39, with most values in the 3.00 to 4.00 range. Because the Shannon-Wiener diversity index is affected by the number of species collected, which in turn depends on abundance and sampling intensity, the data should be interpreted with caution. Generally, the highest diversity values were noted on the middle shelf at Stations 4, 16, 20, 22, and 28 (all in 50 to 60 m depth except Station 20--23 m depth). High diversity at these stations reflects both high equitability of distribution of individuals among species (see below) as well as high species richness due to the overlapping ranges of various inner and outer shelf species. Temporal

TABLE 6.23. YEAR 1, 2, AND 3 INFAUNAL ABUNDANCE DATA.

		Abundance* (No. m^{-2})						
	Water Depth	Year 1		Year 2		Year 3		
Station	(m)	Fall	Spring	Summer	Winter	Fall	Spring	Mean
2	25	5,046	6,670	--	--	--	--	5,858
4	55	2,596	4,730	3,428	5,224	--	--	3,994
5	90	2,242	3,811	2,551	2,877	--	--	2,870
6	26	8,709	2,807	13,302	7,772	--	--	8,148
8	48	4,396	4,474	--	--	--	--	4,435
12	90	3,347	3,926	2,186	3,288	--	--	3,187
14	26	8,881	7,782	12,681	12,505	--	--	10,462
16	54	4,361	6,596	6,253	4,386	--	--	5,399
18	86	3,846	4,888	--	--	--	--	4,367
20	23	5,091	5,288	7,688	6,140	--	--	6,052
22	52	6,098	8,421	10,154	4,656	--	--	7,332
24	88	3,849	4,253	8,137	3,926	--	--	5,041
25	24	5,547	8,660	6,719	3,810	--	--	6,184
26	38	4,347	7,933	--	--	--	--	6,140
28	59	5,554	6,923	10,140	3,561	--	--	6,544
31	142	--	--	3,098	2,628	--	--	2,863
33	146	--	--	2,737	1,663	--	--	2,200
34	136	--	--	3,217	1,280	--	--	2,248
37	148	--	--	5,067	4,575	--	--	4,821
40	18	--	--	--	--	8,800	3,000	5,900
41	16	--	--	--	--	6,088	10,160	8,124
42	17	--	--	--	--	6,112	3,456	4,784
43	16	--	--	--	--	4,984	8,024	6,504
46	18	--	--	--	--	8,520	3,696	6,108
48	16	--	--	--	--	6,176	4,656	5,416
49	12	--	--	--	--	4,136	5,536	4,836
50	16	--	--	--	--	9,624	4,200	6,912
52†	14	--	--	--	--	10,776	9,280	10,028
53	10	--	--	--	--	13,272	5,840	9,556
54	17	--	--	--	--	6,512	8,040	7,276

*Values do not include nematodes, oligochaetes, or copepods, which were included in Year 1 and 2 abundances presented in the Year 2 report. These are considered meiofaunal taxa.
†Values at Station 52 are from the area most distant from live bottom (75 m).

TABLE 6.24. YEAR 1, 2, AND 3 INFAUNAL DIVERSITY DATA.

	Water	Diversity (Shannon-Wiener H')*						
	Depth	Year 1		Year 2		Year 3		
Station	(m)	Fall	Spring	Summer	Winter	Fall	Spring	Mean
2	25	3.86	2.87	--	--	--	--	3.36
4	55	3.95	4.10	3.95	3.96	--	--	3.99
5	90	3.16	3.72	3.30	3.41	--	--	3.40
6	26	3.13	3.06	2.40	2.88	--	--	2.87
8	48	3.47	3.38	--	--	--	--	3.42
12	90	3.65	3.22	3.57	3.56	--	--	3.50
14	26	3.59	3.43	3.68	3.30	--	--	3.50
16	54	4.10	3.83	4.39	3.73	--	--	4.01
18	86	3.31	3.45	--	--	--	--	3.38
20	23	3.79	3.86	4.16	3.93	--	--	3.94
22	52	3.83	4.05	4.06	3.75	--	--	3.92
24	88	3.44	3.56	3.27	3.50	--	--	3.44
25	24	2.92	2.99	3.04	2.82	--	--	2.94
26	38	2.92	3.24	--	--	--	--	3.08
28	59	4.21	4.38	3.50	4.05	--	--	4.04
31	142	--	--	3.31	3.23	--	--	3.27
33	146	--	--	3.52	3.26	--	--	3.39
34	136	--	--	3.58	2.86	--	--	3.22
37	148	--	--	2.72	3.51	--	--	3.11
40	18	--	--	--	--	1.66	3.35	2.51
41	16	--	--	--	--	3.09	3.28	3.18
42	17	--	--	--	--	3.80	3.35	3.58
43	16	--	--	--	--	3.77	3.55	3.66
46	18	--	--	--	--	3.99	3.73	3.86
48	16	--	--	--	--	3.77	3.65	3.71
49	12	--	--	--	--	3.91	3.20	3.56
50	16	--	--	--	--	3.88	3.80	3.84
52†	14	--	--	--	--	4.02	3.72	3.87
53	10	--	--	--	--	3.85	3.60	3.72
54	17	--	--	--	--	3.48	3.48	3.48

*Diversity values were calculated on a truncated data set consisting of individuals identified to species. Previously reported Year 1 and 2 diversity values were calculated using a slightly different truncated data set and do not match those listed here.

†Values for Station 52 are from the area most distant from live bottom (75 m).

TABLE 6.25. YEAR 1, 2, AND 3 INFAUNAL EQUITABILITY DATA.

Station	Water Depth (m)	Equitability (Pielou's J')*						
		Year 1		Year 2		Year 3		
		Fall	Spring	Summer	Winter	Fall	Spring	Mean
2	25	0.79	0.66	--	--	--	--	0.72
4	55	0.83	0.84	0.81	0.81	--	--	0.82
5	90	0.71	0.77	0.73	0.74	--	--	0.74
6	26	0.70	0.75	0.51	0.65	--	--	0.65
8	48	0.76	0.78	--	--	--	--	0.77
12	90	0.79	0.70	0.79	0.80	--	--	0.77
14	26	0.77	0.74	0.74	0.67	--	--	0.73
16	54	0.83	0.76	0.87	0.77	--	--	0.81
18	86	0.71	0.71	--	--	--	--	0.71
20	23	0.83	0.82	0.83	0.80	--	--	0.82
22	52	0.77	0.80	0.80	0.79	--	--	0.79
24	88	0.75	0.73	0.67	0.76	--	--	0.73
25	24	0.72	0.71	0.67	0.74	--	--	0.71
26	38	0.71	0.74	--	--	--	--	0.72
28	59	0.83	0.87	0.67	0.87	--	--	0.81
31	142	--	--	0.74	0.76	--	--	0.75
33	146	--	--	0.79	0.81	--	--	0.80
34	136	--	--	0.76	0.70	--	--	0.73
37	148	--	--	0.58	0.76	--	--	0.67
40	18	--	--	--	--	0.41	0.86	0.64
41	16	--	--	--	--	0.71	0.73	0.72
42	17	--	--	--	--	0.84	0.82	0.83
43	16	--	--	--	--	0.83	0.77	0.80
46	18	--	--	--	--	0.83	0.84	0.84
48	16	--	--	--	--	0.83	0.83	0.83
49	12	--	--	--	--	0.86	0.77	0.82
50	16	--	--	--	--	0.82	0.85	0.84
52†	14	--	--	--	--	0.81	0.80	0.80
53	10	--	--	--	--	0.79	0.81	0.80
54	17	--	--	--	--	0.81	0.79	0.80

*Based on truncated data set (see Table 6.23).
†Values for Station 52 are from the area most distant from live bottom (75 m).

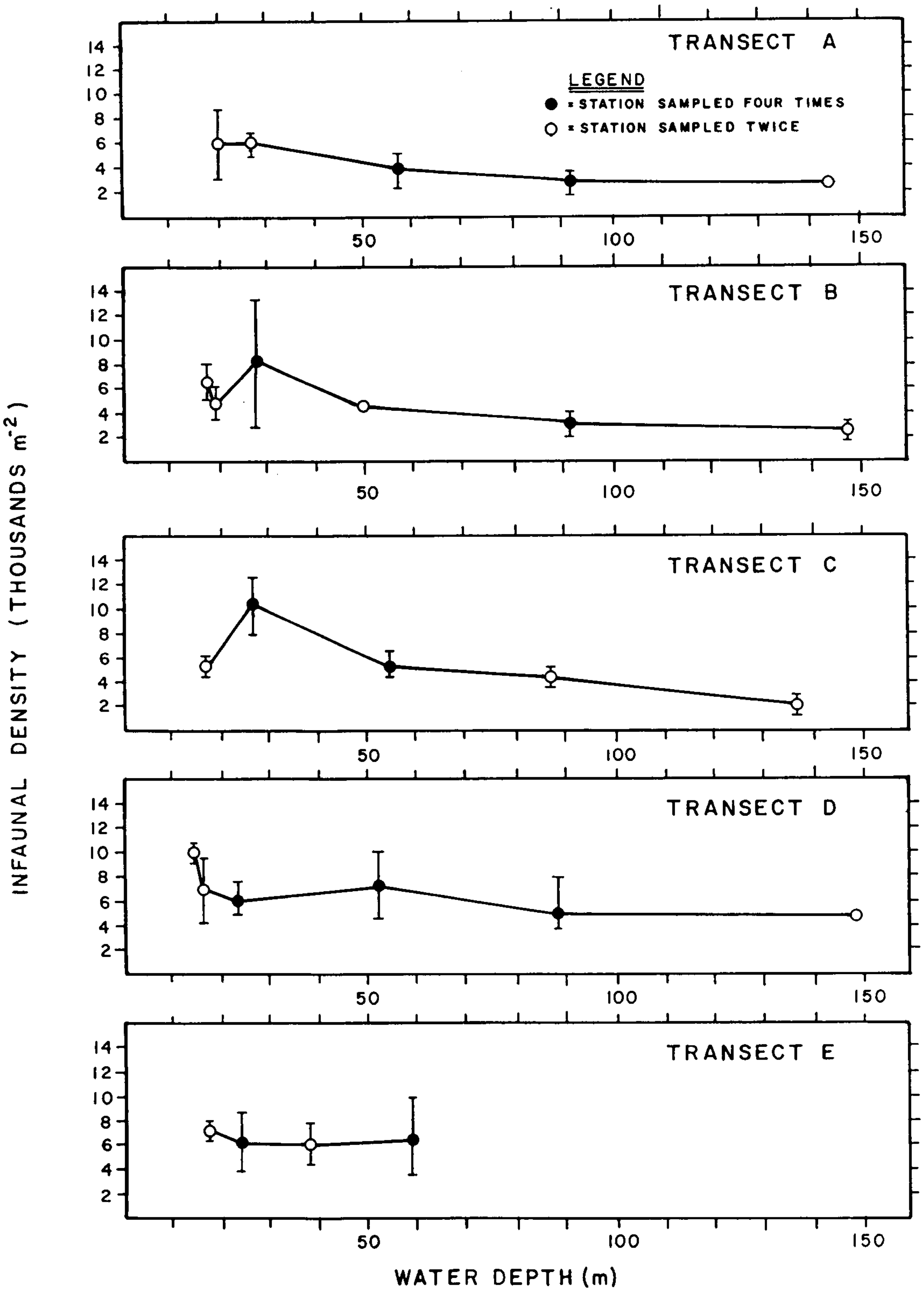


FIGURE 6.25. INFAUNAL ABUNDANCE VS. WATER DEPTH, BASED ON YEAR 1, 2, AND 3 DATA.

variations in diversity often appeared to reflect equitability changes attributable to seasonal population increases of particular species, as described below.

Equitability values ranged from 0.41 (Station 40, Year 3, fall cruise) to 0.87 (Station 16, Year 2, summer cruise; also Station 28, Year 1 spring cruise and Year 2 winter cruise). In general, individuals were most equitably apportioned among species at the Year 3 nearshore stations and at middle shelf stations 4, 16, 20, 22, and 28. Values less than 0.70 were due to seasonal population increases of one or a few species at various stations (Table 6.26). For example, spionid polychaetes such as *Prionospio cristata* or *Paraprionospio pinnata* were especially abundant at Stations 2, 6, 25, and 40 during one or more seasons. On the outer shelf, the serpulid polychaete *F. implexa* accounted for a substantial proportion of the total population at Stations 22, 24, 28, and 37 during the summer cruise. No individuals of *F. implexa* were collected at any station during any other sampling period.

Normal and inverse cluster analysis was conducted using the combined Year 1, 2, and 3 infaunal data set. For the analysis, each sampling of each station was considered an entity (that is, individual seasons were represented). Because of computer program limitations, the data set had to be truncated. This was accomplished as follows. All species were ranked by grand mean abundance, and the top 230 species were included in the analysis. Lower-ranked species that occurred at 10 or more of 30 stations were also included. The total number of species included was 251.

The normal cluster analysis showed that stations grouped primarily by water depth, with the major breaks in species composition occurring at the 20-m and 50-m isobaths (Figure 6.26). Other station groupings in the dendrogram (Figure 6.27) apparently reflect seasonality, sediment composition, or both. For example, five middle-to-outer shelf stations in the southwest corner of the study area (Stations 16, 22, 24, 28, and 37) grouped across depth contours during the Year 2 summer cruise (see shaded area in Figure 6.26). A contributing factor was the abundance of the serpulid polychaete *F. implexa* at all of the stations. The influence of sediment composition is apparent in the clustering of Station 20 (water depth: 23 m) with the nearshore (<20 m) stations (Figure 6.27). Station 20 would have been expected to group with Stations 2, 6, 14, and 25 based on similar water depths; instead, it grouped with the nearshore

TABLE 6.26. INSTANCES OF LOW EQUITABILITY IN YEAR 1, 2, AND 3 INFAUNAL DATA.

Season	Station	Equitability (Pielou's J')	Particularly Abundant Species	Percent of Total Abundance
Summer	6	0.51	*Prionospio cristata*	35
			Fabricia sp.	16
			Mediomastus californienis	9
	24	0.67	*Filograna implexa*	19
			Synelmis albini	11
	25	0.67	*Prionospio cristata*	18
			Prionospio cirrifera	12
	28	0.67	*Filograna implexa*	27
	37	0.58	*Filograna implexa*	34
			Synelmis albini	12
Fall	40	0.41	*Paraprionospio pinnata*	53
			Mediomastus californiensis	22
Winter	6	0.65	*Mediomastus californiensis*	17
			Prionospio cristata	14
	14	0.67	*Haplosyllis spongicola*	20
			Aricidea fragilis	7
Spring	2	0.66	*Prionospio cristata*	24
			Fabricia sp.	12

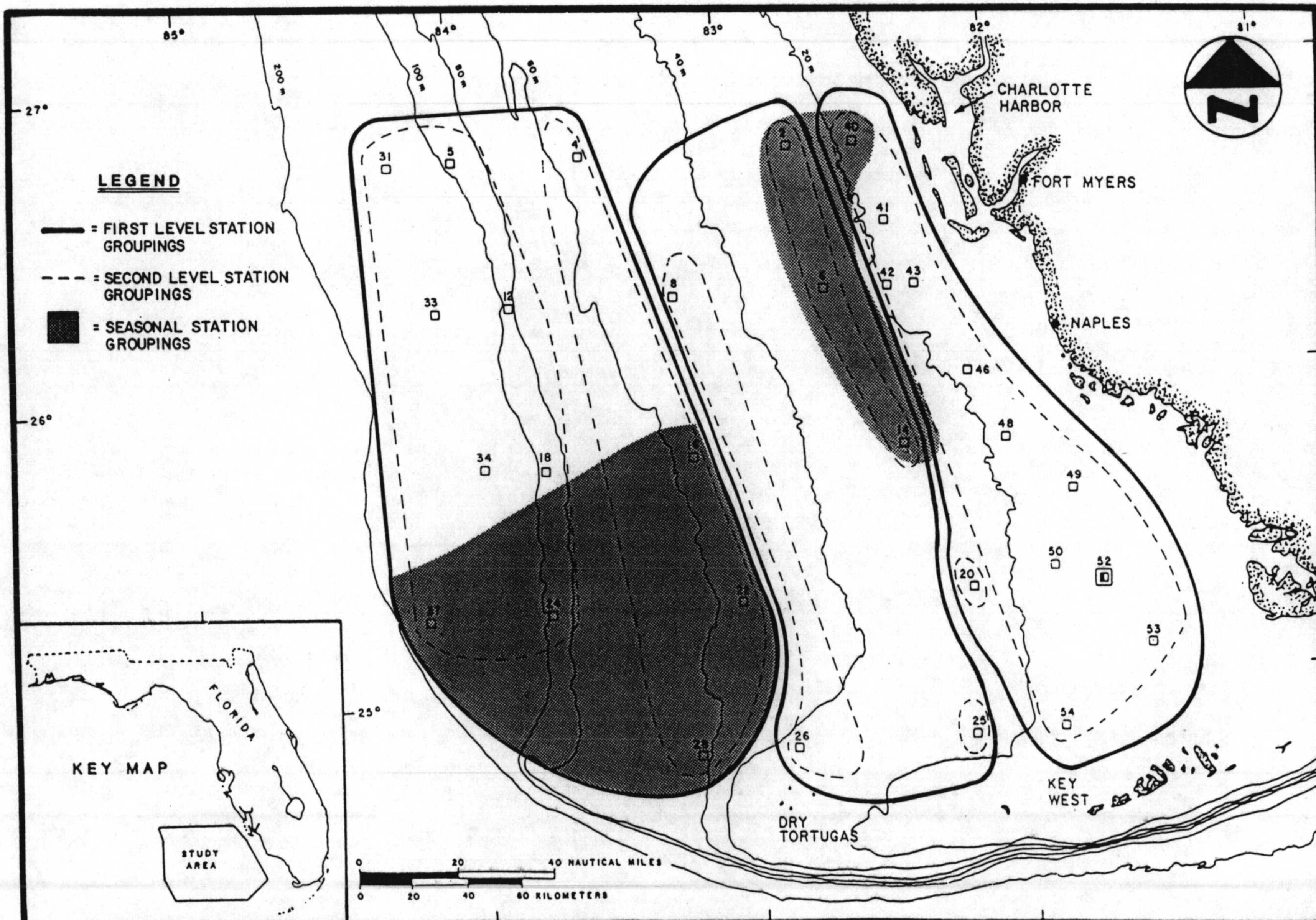


FIGURE 6.26. CLUSTER ANALYSIS RESULTS FOR YEAR 1, 2, AND 3 INFAUNAL DATA.

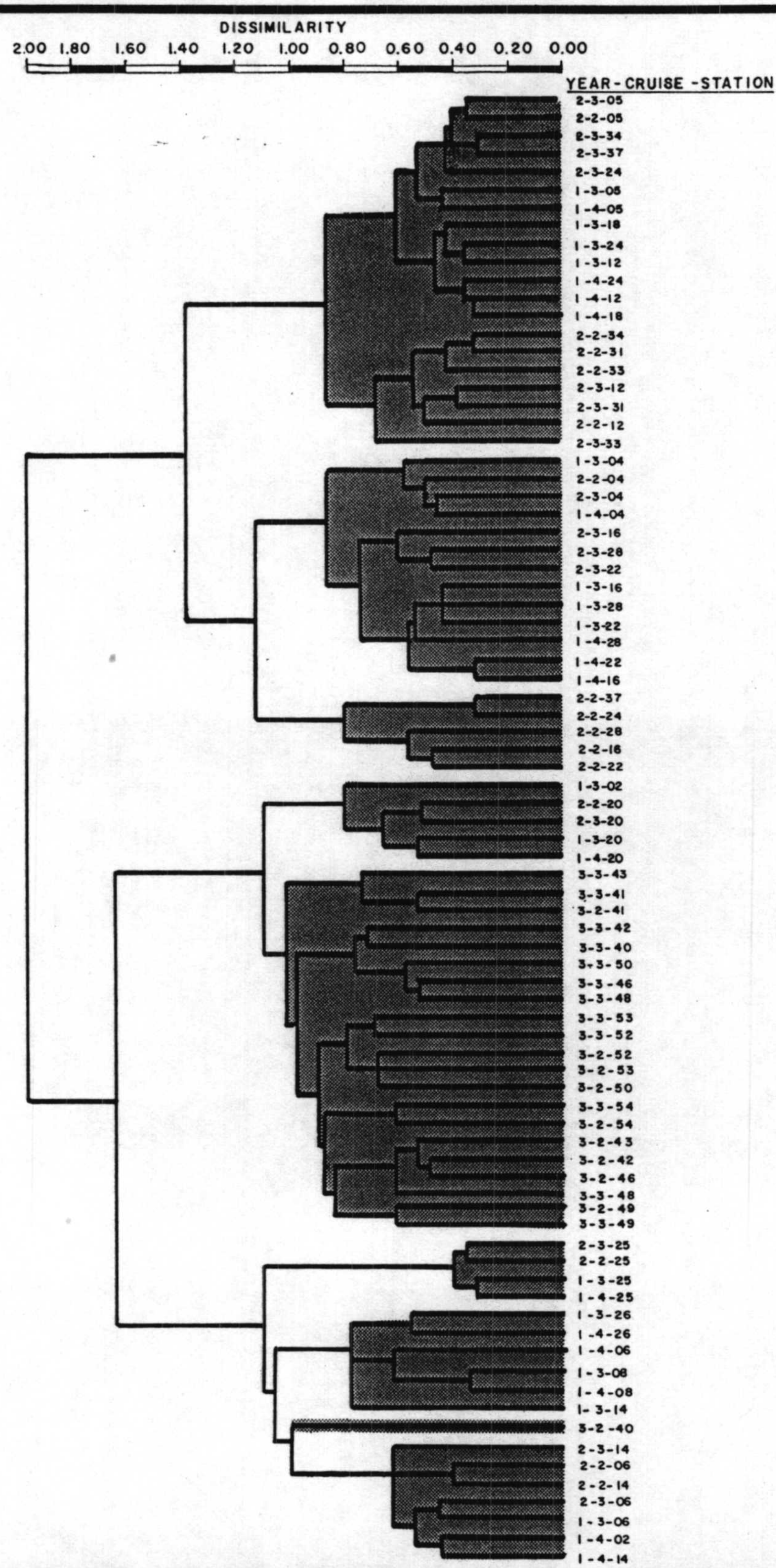


FIGURE 6.27. DENDROGRAM FROM CLUSTER ANALYSIS OF YEAR 1, 2, AND 3 INFAUNAL DATA.

stations, to which it was generally more similar in sediment composition (silt/clay content: 1.4%). Station 20 was characterized by a distinctive suite of species (e.g., Ancistrosyllis hartmanae, Apseudes propinquus, Aricidea cerrutii, and Cirrophorus lyra) and also lacked several of the more abundant species seen at Stations 2, 6, 14, and 25, such as several spionids and Mediomastus californiensis, which were typically associated with sediments containing at least 5% silt/clay.

Another example of the influence of sediment on species composition is the distinctiveness of Station 25 within its cluster. The characteristic suite of species at Station 25 included Prionospio cristata, P. cirrifera, Magelona cf. cincta, M. pettiboneae, and Mediomastus californiensis. Although P. cristata, Magelona pettiboneae, and Mediomastus californiensis were equally or more characteristic of Stations 2, 6, and/or 14, P. cirrifera and Magelona cf. cincta generally were more abundant at Station 25 than elsewhere on the shelf. Although the spionids and Mediomastus californiensis showed considerable seasonality at several other stations (usually reaching a peak of abundance in summer), there was little seasonal variation in this assemblage at Station 25.

Sediment composition (in terms of mean grain size and silt/clay percentage) was similar at Stations 25 and 26, but the stations did not cluster closely, possibly due to the difference in water depth (24 m vs. 38 m) or some other influence. Species that occurred primarily or were most abundant at Station 26 included the polychaetes Sigambra tentaculata and Aricidea wassi and the bivalves Caecum pulchellum and Lyonsia hyalina floridana. Other abundant species at Station 26, such as P. cristata, Magelona pettiboneae, and Mediomastus californiensis, were more widely distributed.

Stations 2, 6, 14, and 40 exhibited considerable seasonality in species composition (Figure 6.27), primarily due to seasonal population variations in Prionospio cristata or Paraprionospio pinnata. Stations 6 and 14 were sampled during all four seasons, and at both stations, Prionospio cristata was the most abundant species during summer. Station 2 was sampled during fall and spring, with Prionospio cristata being much more abundant during spring than fall. Station 40 was sampled during fall and spring; Paraprionospio pinnata accounted for over 50% of all individuals during fall but was absent in the spring samples. Sediment composition data from the four stations provides no insight into the cause for the seasonal population fluctuations; sediment composition (e.g., silt/clay content) did not change substantially between sampling periods. Increases in benthic microalgal production and/or inputs of particulate organic matter from the water column during summer are possible causes that cannot be evaluated without further data. It is interesting that large populations of one or the other of these species were not seen at nearby stations such as 20, 41, 42, 43, 46, or 48, all of which had very low silt/clay content (maximum 2.8% at Station 48; all others <1.5%). This suggests that, whatever the cause for seasonal fluctuations of the two spionid species, a certain level of silt/clay content is necessary for a large population to develop. Also, pronounced seasonality in populations of Prionospio cristata was not evident at the more southerly Station 25, despite a very high silt/clay content (70%). Perhaps proximity to the Charlotte Harbor estuary, a likely source of organic matter and sediment inputs to the shelf, is also an important factor.

Table 6.27 lists representative species from groups emerging from the inverse cluster analysis. In general, each species group has fairly distinct depth affinities or affinities for a particular station or season. Distributions of several species in the tables have already been discussed above.

6.6.3 Summary

Sampling at 30 soft-bottom stations on the southwest Florida shelf provides a baseline description of sediments and infauna. Nineteen stations in water depths ranging from 20 to 148 m were sampled two or four times during 1980-1982. Eleven additional stations in water depths of 10 to 20 m were sampled twice during 1982-1983. Sediments and infauna were collected on each sampling date, with the sediments being analyzed for grain size composition and carbonate content.

Most sediments on the shelf can be characterized as carbonate sands. Only three stations, all in the southeast corner of study area north and northeast of the Dry Tortugas, had sediments containing <75% sand (particles >62.5 μm in diameter). Mean grain size (averaged over sampling periods) ranged from 59 μm to 535 μm, with sediments at most stations falling in the fine-to-medium sand range (125 μm to 500 μm). Silt/clay content was typically <20%, with particularly low values (<3%) occurring near shore south of Charlotte Harbor; however, values of 65 to 75% were noted at two stations near the Dry Tortugas. Nearshore sediments (<25 m water depth) generally were moderately to moderately well

TABLE 6.27. SPECIES GROUPINGS FROM INVERSE CLUSTER ANALYSIS OF YEAR 1, 2, AND 3 INFAUNAL DATA.

Group	Representative Species	Station/Depth Affinities
A	Calozodion wadei (T) Isolda pulchella (P) Sphaerosyllis glandulata (P) Syllis gracilis (P)	Stations 52 and 53 (<20 m depth).
B	Cyclaspis sp. D (C) Diplodonta punctata (B) Eudevenopus honduranus (A) Metharpinia floridana (A)	Primarily stations <20 m depth.
C	Ehlersia ferrugina (P) Haplosyllis spongicola (P) Phoronis architecta (Ph) Parasterope pollex (O)	Not strongly associated with any station group.
D	Aricidea taylori (P) A. wassi (P) Lucina radians (B) Magelona pettiboneae (P) Mediomastus californiensis (P) Paraprionospio pinnata (P) Prionospio cristata (P) Prionospio cirrifera (P) Sigambra tentaculata (P)	Primarily stations <80 m depth. Most abundant at one or more of Stations 2, 6, 14, 25, 26, or 40.
E	Ampelisca sp. D (A) Erichthonius brasiliensis (A) Microdeutopus myersi (A) Photis sp. A (A)	Abundant at Station 14, Fall cruise.
F	Armandia maculata (P) Exogone dispar (P) Myriochele oculata (P) Nereis riisei (P) Pionosyllis gesae (P)	Widely distributed (nearly ubiquitous). Most abundant at one or more stations <25 m depth.
G	Ancistrosyllis hartmanae (P) Apseudes propinquus (T) Aricidea cerrutii (P) Rutiderma darbeyi (O) Cirrophorus lyra (P)	Occurring primarily at and most abundant at Station 20.

TABLE 6.27. (CONTINUED).

Group	Representative Species	Station/Depth Affinities
H	Aricidea fragilis (P) A. philbinae (P) Lumbrineris ernesti (P) Rutiderma licinum (O) Synchelidium americanum (A)	Primarily occurring at middle shelf stations 20 to 60 m depth). Most abundant at Station 2, 6, or 14.
I	Aglaophamus verrilli (P) Aplacophora sp. A (S) Euchone incolor (P) Notomastus americanus (P) Synelmis albini (P) Tharyx marioni (P)	Widely distributed at stations >20 m depth. Most abundant middle to outer shelf (>50 m depth).
J	Amaena trilobata (P) Amphicteis scaphobranchiata (P) Cossura soyeri (P) Odontosyllis enopla (P) Scoloplos rubra (P)	Not strongly associated with any station group.
K	Exogone atlantica (P) Lumbrineris coccinea (P) Pholoe minuta (P) Protodorvillea minuta (P) Scoloplos capensis (P)	Primarily occurring middle to outer shelf (>40 m depth). Generally most abundant in 50 to 80 m depth.
L	Callianassa marginata (D) Platidia clepsydra (Br) Polydora socialis (P) Prionospio cirribranchiata (P) Spiophanes wigleyi (P)	Primarily occurring middle to outer shelf (>40 m depth). Most abundant in depths >80 m.

A = amphipod
B = bivalve
Br = brachiopod
C = cumacean
D = decapod
O = ostracod
P = polychaete
Ph = phoronid
T = tanaid.

sorted, whereas sediments in deeper water were poorly sorted. Nearshore sediments in the southeast corner of the study area also were poorly sorted mixtures of sand, silt, and shell hash.

Carbonate content of sediments at most stations was >75%. Predominantly quartz sands (<25% carbonate) occurred at two nearshore stations, and sediments of intermediate carbonate content were collected at three other stations. Contouring of carbonate values suggests that quartz sediments are restricted to within about 25 to 50 km of the coast and transitional sediments occur within a narrow band seaward of the quartz zone. The transitional zone apparently widens off Charlotte Harbor, presumably reflecting the influence of tidal currents.

Infaunal communities were dominated numerically by polychaetes. Crustaceans and polychaetes each accounted for about 40% of the 1,121 species identified. Various feeding types are represented in the collections, with the most common being surface deposit feeders, subsurface deposit feeders, and scavenger/carnivores. Abundances estimated during the study ranged from about 1,000 to 14,000 m^{-2} and generally declined with increasing water depth and distance from shore. The shelf infauna was diverse, and equitability (distribution of individuals among species) was typically high; however, the data show that some species are capable of rapid population increases (often apparently seasonal) that can result in localized areas of low equitability. Species composition of the infauna apparently varies in relation to water depth and (secondarily) sediment composition and seasonal factors.

CHAPTER 7
HYDROCARBON ANALYSIS OF SURFICIAL SEDIMENTS

7.1 INTRODUCTION

Previous hydrocarbon investigations of sediments of the eastern Gulf of Mexico have been obtained through the Mississippi, Alabama, Florida (MAFLA) OCS Baseline Environmental Surveys (Gearing et al., 1976; Calder, 1977; Lytle and Lytle, 1977; Bieri, 1979; Boehm, 1979; Jeffrey, 1979) and the Southwest Florida Shelf Ecosystems Study (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a, 1985). Additional studies in the region have focused on pelagic tar (Van Vleet et al., 1983, 1984) and hydrocarbons in Charlotte Harbor, the major estuary situated at the junction of the MAFLA and southwest Florida shelf study areas (Pierce et al., 1983). The shelf studies have delineated three distinct geochemical provinces on the basis of hydrocarbon sources. The southwest Florida shelf (20 to 100 m depth) contains carbonate sediment with no indication of petrogenic input. The deep, west-central Florida shelf is characterized by mostly biogenic hydrocarbons with some anthropogenic input apparently associated with fine particulates of Mississippi River origin. Finally, the Mississippi-Alabama shelf region is characterized by significant levels of anthropogenic hydrocarbons from the Mississippi River as well as oil production operations.

A summary of hydrocarbon analyses of southwest Florida shelf sediment collected during Years 1 and 2 of the Southwest Florida Shelf Ecosystems Study showed that most of the soft-bottom stations exhibited little or no petroleum contamination (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). A study of sediment hydrocarbon content in the Charlotte Harbor estuary during 1982 and 1983 revealed isolated sites of localized petroleum contamination, but no apparent export of petrochemicals to the shelf (Pierce et al., 1983). The present study provides information about hydrocarbons from nearshore sediment (20-m isobath and landward) filling the gap between the offshore and estuarine areas studied previously.

Year 3 sediment hydrocarbon analyses and interpretation were performed by Dr. Richard H. Pierce and Mr. Robert C. Brown of Mote Marine Laboratory, Sarasota, Florida.

7.2 METHODS

7.2.1 Sample Collection

Divers used aluminum coring devices to collect surface sediment (to 5 cm depth) from the 10 soft-bottom stations shown in Figure 7.1. The core samples were collected during Cruise II (December 1982) and Cruise III (May-June 1983) from the same area in which benthic infaunal samples were collected at each station (see Chapter 6). A composite of three core samples was obtained to provide at least 600 g wet wt of sediment from each station. The samplers were sealed underwater and taken aboard ship in a special container to prevent loss of surface sediment and contamination from the ship's atmosphere. The sealed containers were marked and stored in a specially designed freezer container for transport to the laboratory.

7.2.2 Sample Analysis

Extraction. Sediment subsamples from each site were thawed and thoroughly mixed in a clean glass tray. Aliquots (ca 150 g wet wt) of sediment were placed in a Soxhlet extraction apparatus with internal standard hydrocarbons (5 α-androstane for the aliphatic hydrocarbon fraction, and o-terphenyl for the aromatic/olefinic fraction). An aliquot of methyl stearate also was added to verify complete saponification. All samples were analyzed in duplicate.

Extraction and saponification were performed simultaneously by 48-h Soxhlet extraction using a benzene/KOH-methanol solvent system according to the procedures of Farrington and Tripp (1975), Boehm (1981), and Pierce et al. (1983). The extracts were washed with 1% aqueous NaCl solution and the lipid material was recovered in the benzene layer. Benzene was replaced with hexane by evaporation under N_2 gas and the hydrocarbons were recovered as the saturated (f_1) and unsaturated (f_2) fractions by elution through a column of silica gel and alumina.

Gas Chromatograph-Flame Ionization Detection Analysis. Gas chromatographic (GC) analysis of each column chromatography elution fraction was carried out using a Varian Vista 6000 gas chromatography system coupled with a Vista 401 chromatography data system. The instrument was equipped with dual flame ionization detectors (FID) and linear temperature programing. The columns were 30 m x 0.25 mm internal diameter glass capillary, one coated with SE-30 and a second coated with SE-54 (Supelco, Inc.). The system was operated in the splitless

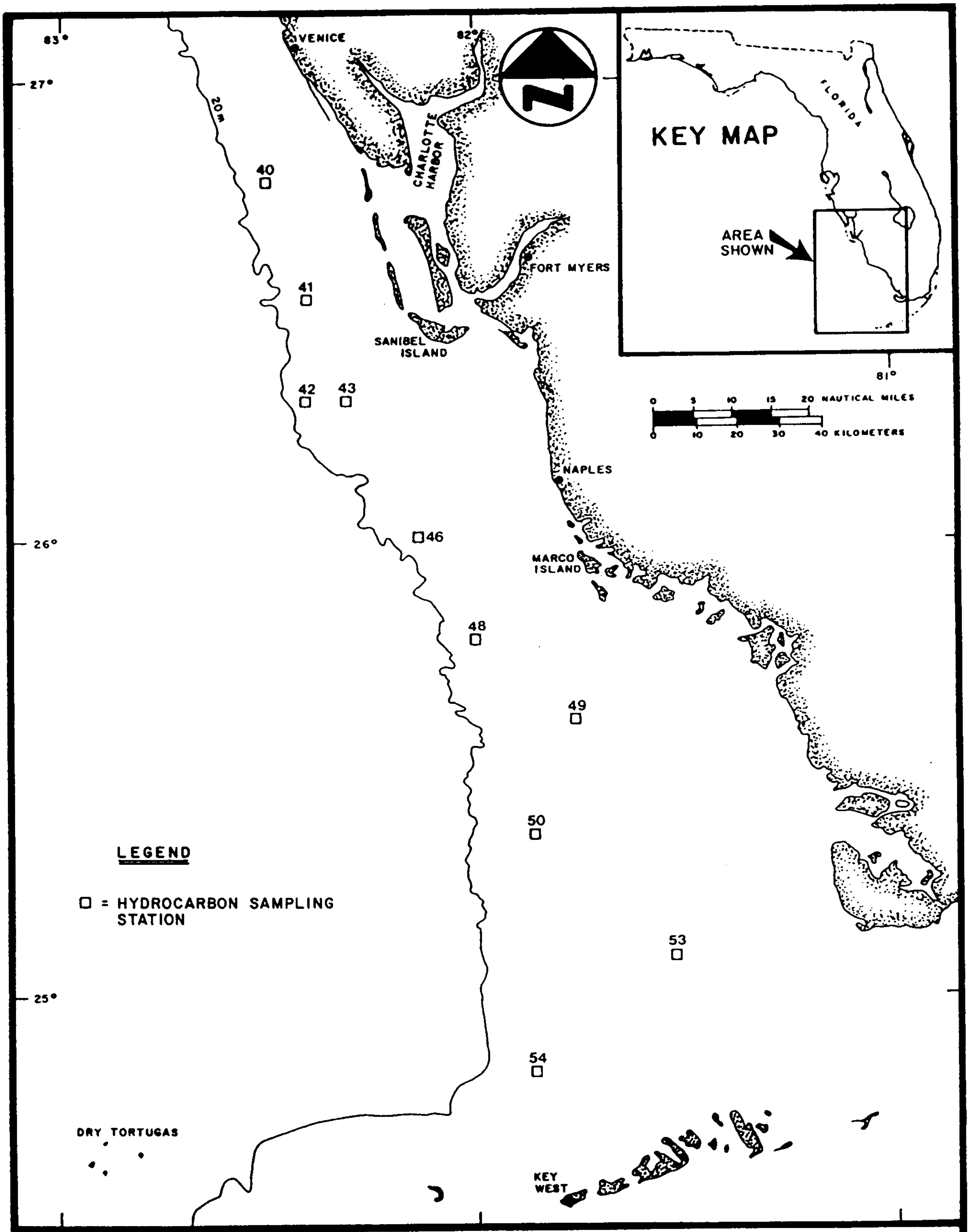


FIGURE 7.1. LOCATIONS OF SEDIMENT HYDROCARBON SAMPLING STATIONS.

injection mode for low concentrations. The carrier gas was N_2, with N_2 make-up gas as the detector. Data were reported as hard copy chromatograms with qualitative and quantitative printout; data were also stored on floppy discs. The instrument was temperature programed to recover n-alkanes from n-C_{14} through n-C_{32}. The column proved capable of resolving n-C_{17} from pristane and the FID sensitivity was consistently in the range of 1×10^{-10} g s^{-1} (approximately 1 to 10 ng g^{-1} sample).

Gas Chromatograph/Mass Spectrometry Analysis. Mass spectrometry (MS) analyses were performed by Dr. E. S. Van Vleet of the Department of Marine Science, University of South Florida. The instrument used was a Hewlett Packard 5992B gas chromatograph/mass spectrometry system consisting of a Hewlett Packard 5700A glass capillary gas chromatograph, a hyperbolic quadropole mass analyzer, and a Hewlett Packard 9825-A computer with selected ion monitoring and library search capabilities.

Verification by GC/MS was performed on three samples from Cruise II and four samples from Cruise III. Analyses also were performed on the samples of Duwamish River sediment for the interlaboratory calibration exercise (Section 7.2.3).

Analytical Quality Control. Chain-of-custody was established upon field collection of each sample and continued into the laboratory by custody sheets and verification of sample log number. Upon removal from the freezer for analysis, each sample number was recorded in the lab notebook for samples processed each day. A label with the sample identification number and lab notebook page number accompanied each sample throughout the extraction process, and each fraction remained clearly labeled. All hard-copy chromatograms and stored data were identified by sample identification number and lab notebook page number for cross-referencing results with analytical methodologies. For all nonanalyzed samples, the amounts remaining were marked and logged, and the samples were archived in the freezer for future reference.

As a check on handling procedures and purity of solvents and reagents, procedural blanks were run with each set of eight samples analyzed. Verification of the extraction and analysis scheme was accomplished by carrying samples spiked with known amounts of standard petroleum through the entire analytical scheme. Analytical precision was established by triplicate analyses of samples spiked with a standard hydrocarbon mix. Saponification efficiency was verified by the addition of methyl stearate to the samples along with the internal standards and subsequent GC/MS analysis of select samples to verify the presence or absence of esters, as well as to identify specific polynuclear aromatic hydrocarbons (PNAH) for hydrocarbon source identification.

Intra- and interlaboratory calibration of sample analysis was incorporated as part of the analytical quality control program to ensure that hydrocarbon data generated from this study could be compared with those from past and future investigations. Verification of instrumentation and data system compatibility was established by intercomparison of analyses on standard hydrocarbon mixtures. Sample extraction and separation techniques were verified by analysis of a standard intercalibration sediment sample (Duwamish River sediment) available through NOAA, Seattle, Washington.

7.2.3 Calibration

Standard Hydrocarbon Calibration. Standard solutions of aliphatic and aromatic hydrocarbons were prepared and analyzed in comparison with the internal standards, 5 α-androstane and o-terphenyl. These data were used to establish relative response factors and retention times for the Vista 401 chromatography data system.

The aliphatic standards (Table 7.1) contained six n-alkanes and two isoprenoids (pristane and phytane), along with the internal standard, 5 α-androstane. This mixture was analyzed seven times to provide response factors relative to androstane and an estimate of precision.

Table 7.1 shows the results of the aliphatic standard calibration. Precision was excellent for the low to middle molecular weight hydrocarbons (n-C_{14} to n-C_{25}), but not as good for the higher molecular weight hydrocarbons (n-C_{30}). The latter is a result of (1) band broadening experienced by compounds having higher boiling points and (2) tuning of the 401 data system to respond specifically to the narrow peaks for the lower boiling homologous series (n-C_{14} to n-C_{25}).

Aromatic standards (Table 7.2) consisted of five polynuclear aromatic hydrocarbons (PNAH) and the internal standard, o-terphenyl. These samples were analyzed five times to obtain precision estimates. Precision was excellent throughout the entire range (Table 7.2).

Verification of the accuracy of the analytical instrumentation procedures was obtained by analysis of the standard aliphatic and

TABLE 7.1. RESPONSE FACTORS OF STANDARD ALIPHATIC HYDROCARBONS RELATIVE TO 5 α-ANDROSTANE.

Sample No.	Compound							
	C_{14}	C_{17}	Pristane	C_{18}	Phytane	C_{20}	C_{25}	C_{30}
1	1.025	1.017	1.002	1.034	0.955	1.074	1.696	3.186
2	0.864	0.959	0.916	1.026	0.930	1.219	2.520	6.217
3	0.867	0.990	0.938	1.032	0.944	1.176	2.277	5.568
4	0.712	0.911	0.862	0.987	0.896	1.246	2.726	8.206
5	0.736	0.922	0.876	1.014	0.908	1.302	2.882	7.356
6	0.969	0.973	0.957	1.002	0.947	1.067	1.651	2.981
7	0.731	0.907	0.871	0.995	0.917	1.187	2.153	4.288
Mean	0.843	0.954	0.917	1.013	0.928	1.182	2.272	5.400
Standard Deviation	0.123	0.042	0.052	0.019	0.022	0 086	0.478	2.016

TABLE 7.2. RESPONSE FACTORS OF STANDARD AROMATIC HYDROCARBONS RELATIVE TO o-TERPHENYL.

Sample No.	Compound				
	Naphthalene	Dibenzothiophene	Phenanthrene	1-Methyl Phenanthrene	Pyrene
1	0.97	1.77	1.40	1.56	2.00
2	0.95	1.56	1.26	1.42	1.82
3	0.94	1.63	1.32	1.49	1.94
4	1.10	1.68	1.34	1.45	1.82
5	0.75	1.62	1.32	1.58	2.13
Mean	0.94	1.65	1.33	1.50	1.94
Standard Deviation	0.12	0.08	0.05	0.06	0.13

aromatic mixtures. Using the average response factor calculated for each standard hydrocarbon, the concentration for each, as determined by the GC data system, was compared with the actual (prepared) concentration. The results (Tables 7.3 and 7.4) show that accuracy and precision were excellent.

Interlaboratory Calibration with Duwamish-I Sediment. Standard intercalibration samples of Duwamish River intertidal sediment were obtained from Dr. William MacLeod at the NOAA Northwest and Alaska Fisheries Center, Seattle, Washington. Frozen samples containing about 100 g wet wt were shipped to Mote Marine Laboratory. These samples were analyzed in triplicate according to the following procedure:

1) Soxhlet extraction--saponification with benzene/0.5 N KOH-Methanol (50/50, v/v).

2) Water wash to remove aqueous phase.

3) Replacement of benzene with hexane.

4) Silica-alumina column cleanup and separation into saturated (f_1) and unsaturated (f_2) fractions.

5) GC-FID analysis using 30 m x 0.25 mm SE-30 glass capillary column, temperature program 100 to 280°C at 8° min^{-1}.

6) GC/MS analysis of select aromatic (f_2) samples.

Analyses were performed with a Varian Vista 6000 gas chromatograph, coupled with a Vista 401 chromatography data system, utilizing FID. Quantitative and qualitative analyses were obtained through the 401 data system by comparison of each compound with a known internal standard: 5 α-androstane, for f_1; and o-terphenyl, for f_2. Retention times and response factors for the n-alkane homologous series (n-C_{14} to n-C_{30}) and for select isoprenoid and aromatic hydrocarbons were established from standard mixtures prior to sediment analysis described above.

Sample chromatograms for f_1 and f_2 fractions of Duwamish-I sediment are presented in Figure 7.2. The chromatogram of the f_1 extract is represented by a dual plot; the two plots integrate the same chromatogram in different modes. The lower plot integrates with respect to a

TABLE 7.3. ACCURACY AND PRECISION OF STANDARD HYDROCARBON ANALYSIS, ALIPHATIC HYDROCARBONS. INTERNAL STANDARD: 50 $\mu g\ ml^{-1}$ 5 α-ANDROSTANE.

Sample No.	Compound							
	C_{14}	C_{17}	Pristane	C_{18}	Phytane	C_{20}	C_{25}	C_{30}
1	44	51	53	49	41	55	67	84
2	53	54	58	49	42	48	45	43
3	52	52	57	49	41	50	49	48
4	64	56	62	51	43	47	41	32
5	62	56	61	50	43	45	39	36
6	47	53	56	50	41	55	68	90
7	62	57	61	51	42	50	52	62
Mean	54	54	58	50	42	50	51	55
Standard Deviation	7.9	2.3	3.2	0.9	0.9	3.8	7.2	23.0
Coefficient of Variation (%)	14.7	4.2	5.5	1.8	2.1	7.6	14.1	41.9
Prepared Standard	54	54	58	50	42	50	50	50

TABLE 7.4. ACCURACY AND PRECISION OF STANDARD HYDROCARBON ANALYSIS, AROMATIC HYDROCARBONS. INTERNAL STANDARD: 100 $\mu g\ ml^{-1}$ o-TERPHENYL.

	Compound				
Sample No.	Naphthalene	Dibenzothiophene	Phenanthrene	1-Methyl Phenanthrene	Pyrene
1	99	106	105	106	107
2	97	92	94	96	97
3	100	101	101	100	99
4	99	99	100	103	107
5	106	101	101	94	91
Mean	100	100	100	100	100
Standard Deviation	3.4	5.1	4.0	4.9	6.9
Coefficient of Variation (%)	3.4	5.1	4.0	4.9	6.9
Prepared Standard	100	100	100	100	100

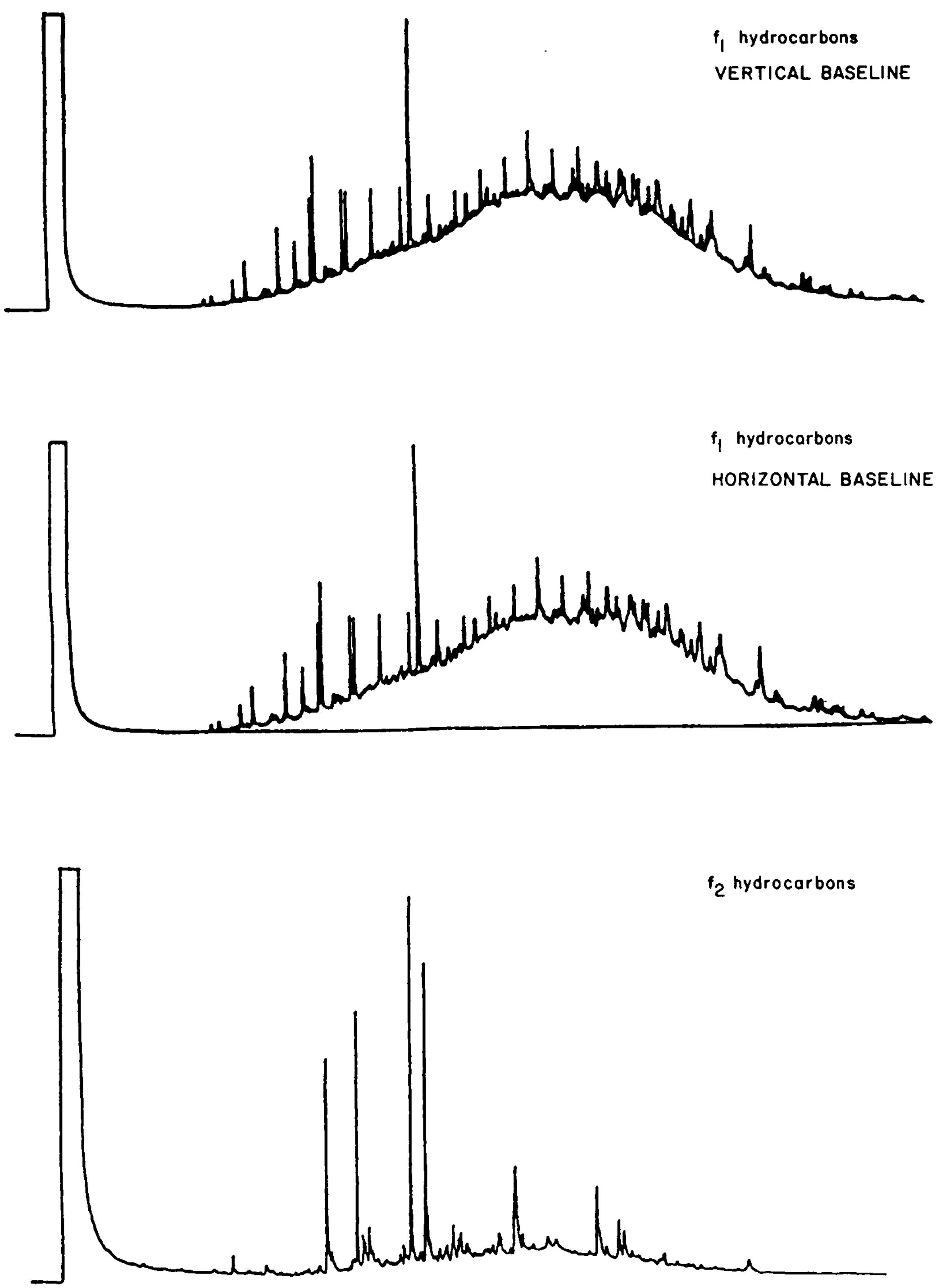


FIGURE 7.2. SAMPLE CHROMATOGRAMS FOR f_1 AND f_2 FRACTIONS OF DUWAMISH-I SEDIMENT.

horizontal baseline, which is established after subtracting background noise. This integration yields the total amount of material, i.e., resolved plus unresolved. The upper plot integrates with respect to a baseline that connects the valley of each peak, thereby providing an estimate of the area of the resolved peaks only. The difference in the area between these two integration modes yields the amount of unresolved material. The concentrations of the individual components (i.e., n-alkanes) were determined from the vertical baseline report. This was done so as not to include any of the unresolved material in the results. Concentrations within each chromatogram were calculated by area counts relative to the area of the appropriate internal standard. A valley baseline plot was forced for the internal standard in the horizontal baseline plot to remove interference from the unresolved complex mixture.

Hydrocarbon characterization parameters obtained from the above GC-FID chromatograms (Figure 7.2) for triplicate Duwamish sediment sample analyses are given in Table 7.5. These results show the unresolved complex mixture and n-alkane homologous series (n-C_{15} to n-C_{30}) characteristic of crude oil contamination. The odd carbon preference index (CPI) greater than 1.0 (1.4) and the abundance of the aliphatic hydrocarbon with Kovats index of 2085 are indicative of the presence of biogenic hydrocarbons, as expected.

The triplicate analyses reported above (Table 7.5) show that intralaboratory precision was excellent. An indication of the accuracy and precision of our results is presented in Tables 7.6 and 7.7 for aliphatic and select aromatic hydrocarbons, respectively. The means and standard deviations for individual compounds are well within the range of those reported by other laboratories utilizing similar extraction and analysis techniques (MacLeod et al., 1982). The GC/MS results also presented in Table 7.7 verify the presence and concentrations of the compounds reported from GC-FID analysis of the Duwamish-I sediment.

7.3 RESULTS

7.3.1 Cruise II

Total saturated (f_1) and unsaturated (f_2) hydrocarbon content of surface sediment collected during Cruise II ranged from a low of 0.3 $\mu g\ g^{-1}$ dry sediment at Station 41 to a high of 4.3 $\mu g\ g^{-1}$ at Station 40. Total f_1/f_2 hydrocarbon concentrations are shown in Figure 7.3 for each station. Characteristic hydrocarbon parameters

TABLE 7.5. RESULTS OF GC-FID HYDROCARBON ANALYSIS OF DUWAMISH-I SEDIMENT.

Sample No.	Total Hydrocarbons ($\mu g\ g^{-1}$)		Ratios				Key Hydrocarbons ($ng\ g^{-1}$)				n-Alkanes	
	f_1	f_2	Resolved/ Unresolved	Pristane/ Phytane	C_{17}/ Pristane	C_{18}/ Phytane	1500	1700	2085	2900	Homologous Series	CPI*
I-A	31.7	6.5	0.10	1.1	0.8	1.2	24.7	48.5	5.4	181.0	C_{15}-C_{30}	1.4
I-B	28.9	7.0	0.10	1.2	0.8	1.2	23.8	56.8	5.2	100.2	C_{15}-C_{30}	1.4
I-C	26.7	7.1	0.10	1.5	0.7	1.2	21.5	49.6	2.3	86.1	C_{15}-C_{30}	1.3
Mean	29.1	6.9	0.10	1.3	0.8	1.2	23.3	50.0	4.3	122.4	C_{15}-C_{30}	1.4

*Carbon preference index.

TABLE 7.6. INTERLABORATORY CALIBRATION WITH DUWAMISH-I SEDIMENT: ALIPHATIC (f_1) HYDROCARBONS. COMPARISON WITH PUBLISHED RESULTS.

	Laboratory	
Compound	Mote Marine Laboratory*	Standard Reference†
C14	6 ± 2	5 ± 4
C15	23 ± 2	14 ± 6
C16	33 ± 4	33 ± 9
C17	49 ± 6	40 ± 9
Pristane	66 ± 7	53 ± 13
C18	65 ± 12	43 ± 23
Phytane	54 ± 9	46 ± 11
C19	81 ± 15	65 ± 16
C20	66 ± 14	54 ± 11
C21	53 ± 19	40 ± 11
C22	68 ± 26	48 ± 14
C23	71 ± 25	55 ± 20
C24	63 ± 21	56 ± 18
C25	170 ± 17	85 ± 32
C26	105 ± 4	88 ± 50
C27	157 ± 34	95 ± 84
C28	58 ± 42	178 ± 118
C29	122 ± 51	124 ± 127
Total Aliphatic	29.1 ± 2	

Values are μg hydrocarbons g^{-1} dry wt sediment, mean ± standard deviation.

*Present study. n = 3 replicates analyzed.
†From: MacLeod et al., 1982; mean and standard deviation of average values reported from four laboratories (NAF_2, A_1, G_2, and H) using similar extraction and analysis techniques.

TABLE 7.7. INTERLABORATORY CALIBRATION WITH DUWAMISH-I SEDIMENT: AROMATIC (f_2) HYDROCARBONS. COMPARISON WITH GC/MS ANALYSIS RESULTS AND PUBLISHED RESULTS OF INTERLABORATORY CALIBRATION EXERCISE (ADAPTED FROM: MACLEOD ET AL., 1982).

	Laboratory		
Compound	Mote Marine Laboratory*	University of South Florida†	Standard Reference§
Dibenzothiophene	24 ± 8	33 ± 25	28 ± 20
Phenanthrene and Anthracene	323 ± 6	468 ± 357	423 ± 180
Methyl Phenanthrene	70 ± 7	54 ± 43	98 ± 10
Pyrene	722 ± 122	730 ± 525	572 ± 392
Total Aromatic	6.8 ± 0.4		

Values are μg hydrocarbons g^{-1} dry wt sediment, mean ± standard deviation.

*GC-FID analysis; n = 3 replicates.
†GC/MS verification of Mote Marine Laboratory sample; n = 3 replicates.
§Published intercalibration results (MacLeod et al., 1982); mean and standard deviation of average values from four laboratories (NAF_2, A_1, G_2, and H) using similar extraction and analysis techniques.

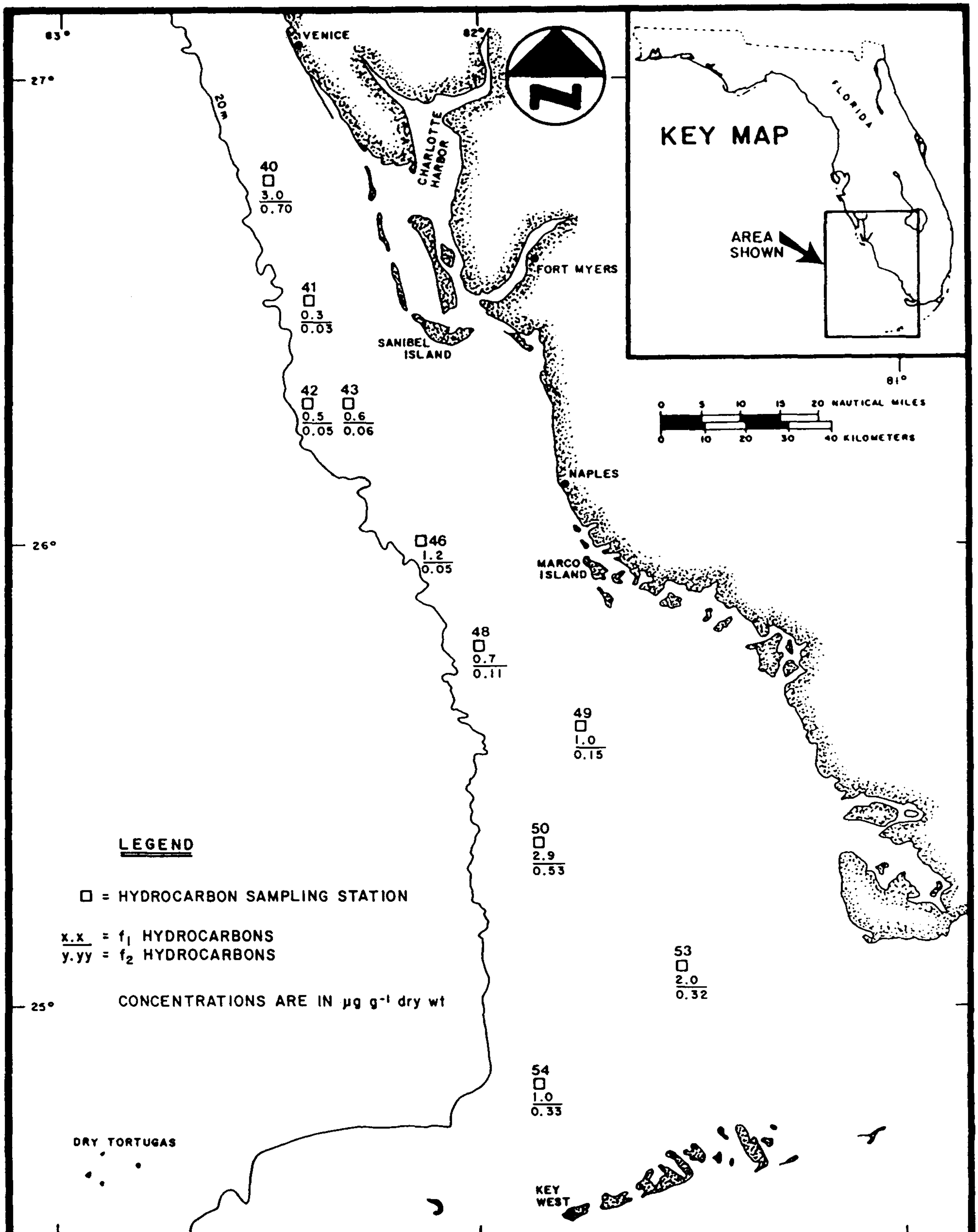


FIGURE 7.3. GEOGRAPHIC PATTERN OF AVERAGE TOTAL f_1 AND f_2 HYDROCARBON CONCENTRATIONS FOR CRUISE II SAMPLES.

obtained from GC-FID analyses are listed in Table 7.8 for duplicate and triplicate analyses of each sediment sample. These data show a predominance of biogenic hydrocarbons. Sediment exhibiting higher hydrocarbon concentrations also contained larger amounts of biogenic material.

Representative GC-FID chromatograms are presented in Figure 7.4 for Station 46. The f_1 fractions had no unresolved complex mixture and no continuous n-alkane homologous series. The absence of these parameters indicates no detectable petroleum hydrocarbons. Major hydrocarbons included odd n-alkanes in the n-C_{15} through n-C_{21} (Kovats Indices 1500-2100) range with a preponderance of the 2085 hydrocarbon, all of which are indicative of marine biogenic material (Farrington and Meyers, 1975). Terrigenous biogenic hydrocarbons were not prevalent, as suggested by the absence of higher boiling n-alkanes in the 2500 through 2900 range.

Table 7.9 lists the major PNAH peaks and probable hydrocarbon sources for the three stations (Stations 42, 46, and 53) for which GC/MS analyses of the f_2 fraction were obtained from Cruise II samples. None of these samples were found to exhibit petroleum contamination. The sum of the concentrations of the aromatic hydrocarbons ranged from 13.9 to 36.7 ng g^{-1}. Plots of the relative abundance of alkyl homologues of select PNAH from sediment at Station 46 are shown in Figure 7.5. These graphs show the amount of the parent PNAH compound relative to the mono (C_1), di (C_2), and tri (C_3) methyl-substituted homologues for naphthalene, phenanthrene, pyrene, and benzanthracene. The naphthalenes and phenanthrenes were represented by their alkyl homologues, which are indicative of petrogenic material. The pyrenes and benzanthracenes, however, were represented by the parent PNAH compound, indicating a pyrogenic hydrocarbon source. The low concentrations and the mix of pyrogenic and petrogenic PNAH indicate that there is no definitive petroleum contamination at this station.

7.3.2 Cruise III

The hydrocarbon content of surficial sediment samples collected during Cruise III ranged from a low of 1.3 $\mu g\ g^{-1}$ at Station 41 to a high of 4.5 $\mu g\ g^{-1}$ at Station 40. These concentrations are shown in Figure 7.6. Characteristic hydrocarbon parameters from GC-FID analyses are listed in Table 7.10. There was a predominance of biogenic hydrocarbons as described above for Cruise II; however, a distinct n-alkane homologous series was present at certain stations (40, 43, 46, and 48),

TABLE 7.8. HYDROCARBON CHARACTERIZATION OF SURFICIAL SEDIMENT SAMPLES, CRUISE II (DECEMBER 1982).

Station Sample No.	Total Hydrocarbons* ($\mu g\ g^{-1}$)		Ratios			Key Hydrocarbons ($\mu g\ g^{-1}$)				n-Alkanes	
	f_1	f_2	Pristane/ Phytane	C_{17}/ Pristane	C_{18}/ Phytane	1500	1700	2085	2100	Homologous Series	CPI
40-A†	1.8	0.40	1.1	0.3	0.6	--	0.003	0.263	0.876	--	--
40-B	3.7	1.10	1.3	--	--	--	--	0.094	0.225	--	--
40-C	3.3	0.59	1.1	--	--	--	--	0.034	0.575	--	--
41-A	0.3	0.03	1.3	--	--	--	--	0.050	0.101	--	--
41-B	0.3	0.04	1.3	--	--	--	--	0.042	0.081	--	--
42-A	0.5	0.05	0.9	0.7	1.3	--	0.010	0.045	0.062	--	2.34
42-B	0.5	0.05	1.3	0.9	1.5	--	0.009	0.040	0.043	17-28	1.50
43-A	0.6	0.04	0.9	1.0	1.8	--	0.015	0.122	0.285	--	--
43-B	0.6	0.08	1.7	1.0	0.8	--	0.008	0.095	0.207	--	--
46-A†	1.5	0.09	--	--	--	--	--	0.215	0.232	--	--
46-B	0.5	0.03	--	2.5	--	--	0.006	0.110	0.794	--	--
46-C	1.5	0.03	--	--	--	--	0.025	0.139	0.199	--	--
48-A	0.5	0.04	1.2	0.7	0.7	--	0.004	0.170	0.101	--	--
48-B	0.9	0.17	1.6	0.5	1.4	--	0.005	0.229	0.103	--	--
49-A	1.1	0.12	4.1	1.4	1.0	--	0.065	0.435	0.109	--	--
49-B	0.9	0.17	1.6	0.5	1.4	--	0.005	0.229	0.103	--	--
50-A	3.3	0.69	3.3	0.3	1.5	--	0.017	1.706	0.275	17-24	2.82
50-B	2.5	0.36	4.5	0.7	1.8	--	0.049	1.265	0.180	17-24	2.61
53-A	2.1	0.23	2.2	1.1	1.6	--	0.070	0.408	0.243	--	--
53-B	1.8	0.40	2.0	1.1	1.4	--	0.079	0.423	0.282	--	--
54-A	1.0	0.41	1.3	1.6	1.3	--	0.016	0.390	0.151	--	--
54-B	1.0	0.25	1.5	0.8	0.7	--	0.012	0.298	0.127	--	--

*f_1 = saturated hydrocarbon fraction; f_2 = unsaturated hydrocarbon fraction.
†Samples analyzed in triplicate due to low precision between duplicate samples.

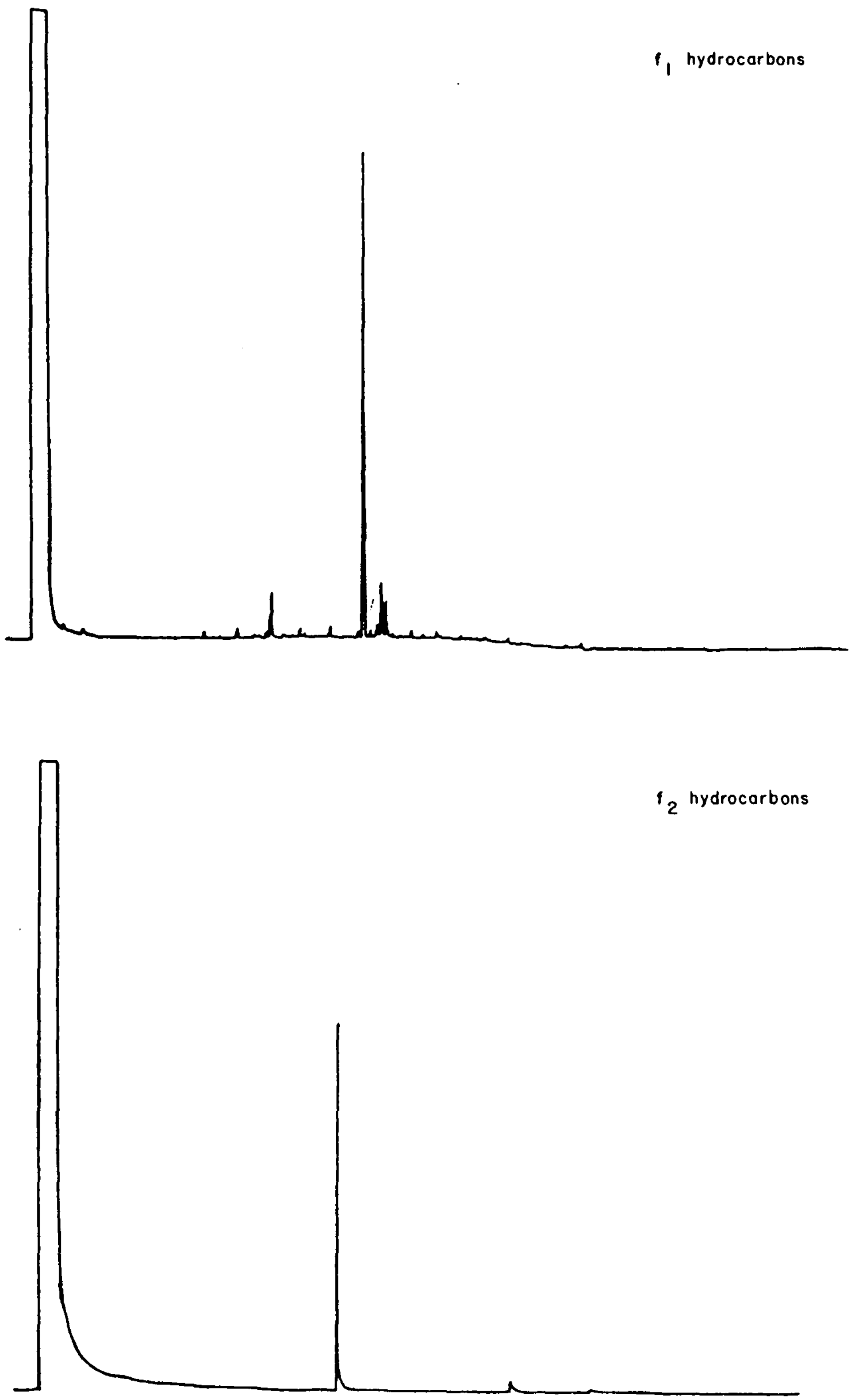


FIGURE 7.4. GC-FID CHROMATOGRAMS FOR f_1 AND f_2 HYDROCARBONS FROM STATION 46, CRUISE II.

TABLE 7.9. SUMMARY OF GC/MS ANALYSES OF SEDIMENT SAMPLES FROM CRUISES II AND III.

Sample Identification	Total GC/MS Aromatics*	Major Peaks†	Probable Source§
Cruise II, Dec 1982			
MMS-42-9AR	36.7 ng g^{-1} dry wt	C_0PyD	Pyrogenic
MMS-46-8AR	13.9 ng g^{-1} dry wt	C_0BaA, C_3N	Mixed
MMS-53-8AR	15.7 ng g^{-1} dry wt	C_3N, C_2N, C_2P	Mixed
Cruise III, May-Jun 1983			
MMS-40I-19AR	10.8 ng g^{-1} wet wt	C_3P, C_2P	Mixed
MMS-42I-19AR	5.3 ng g^{-1} wet wt	C_2P, C_3P	Mixed
MMS-46I-21AR	7.1 ng g^{-1} wet wt	C_2P, C_3P, C_2Py	Mixed
MMS-49I-23AR	5.8 ng g^{-1} wet wt	C_3P, C_2P	Petrogenic

*Total GC/MS Aromatics = Sum of C_0-C_3 Naphthalenes, C_0-C_3 Phenanthrenes + Anthracenes, C_0-C_3 Pyrenes, C_0-C_2 Benz(a)anthracenes, and dibenzothiophene.

†BaA = Benz(a)anthracene, N = Naphthalene, P = Phenanthrene, Py = Pyrene, C = unsubstituted parent compound, C_1 = methyl homologues, C_2 = dimethyl and/or ethyl homologues, C_3 = trimethyl and/or (methyl + ethyl) and/or propyl homologues, D = dibenzothiophene.

§Mixed source indicates characteristics of both petrogenic and pyrogenic sources.

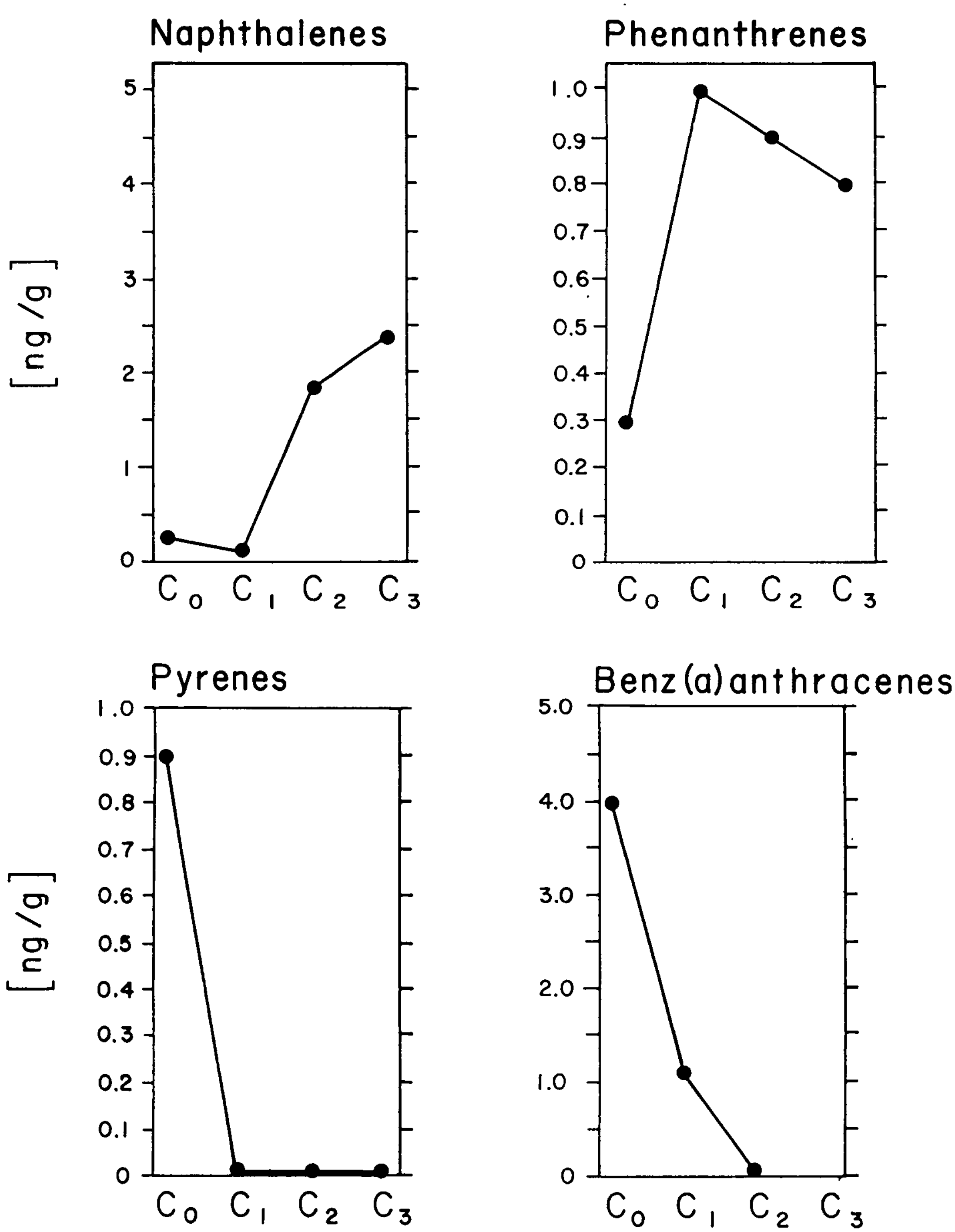


FIGURE 7.5. RELATIVE ABUNDANCE OF ALKYL HOMOLOGUES FROM SELECT PNAH, STATION 46, CRUISE II.

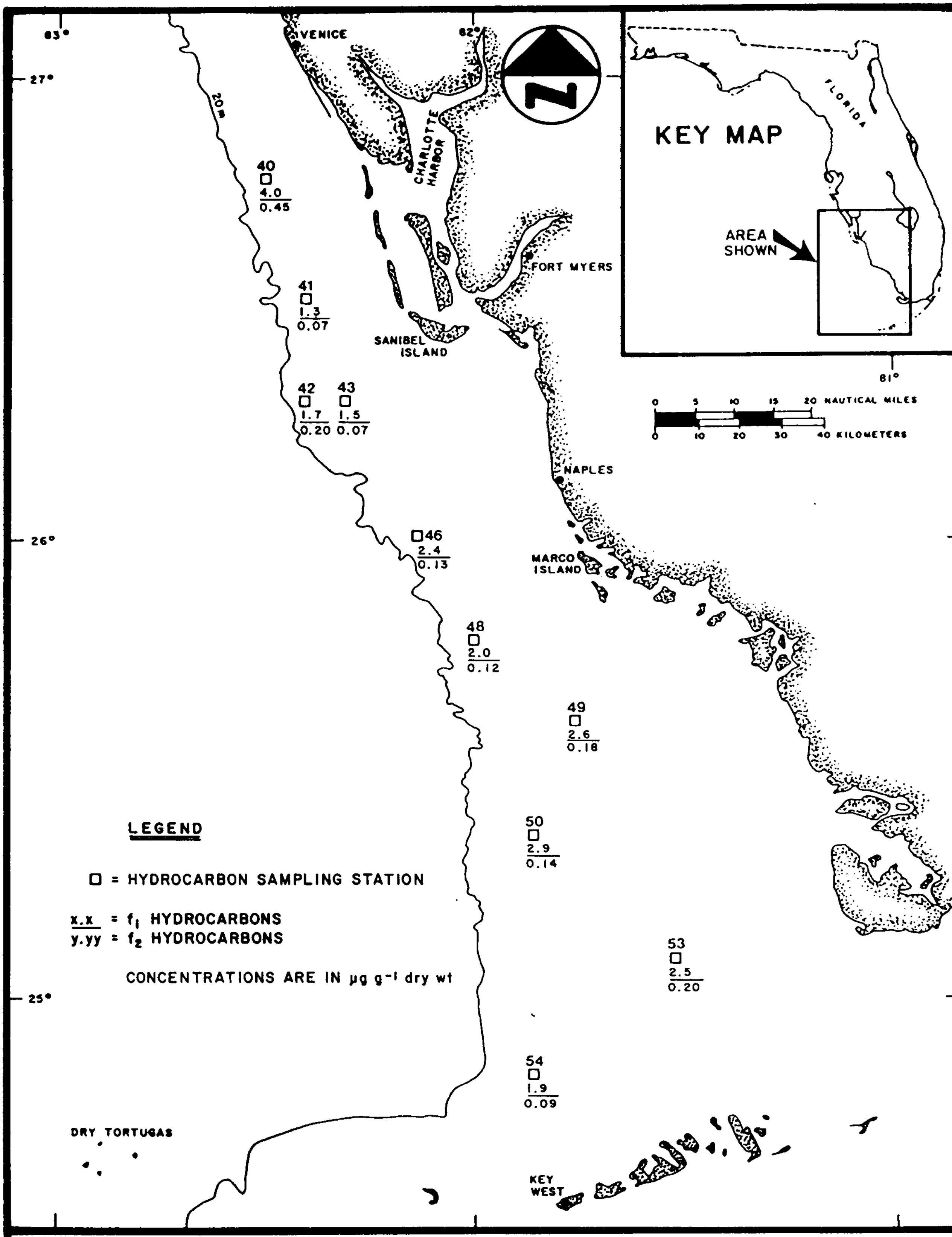


FIGURE 7.6. GEOGRAPHIC PATTERN OF AVERAGE TOTAL f_1 AND f_2 HYDROCARBON CONCENTRATIONS FOR CRUISE III SAMPLES.

TABLE 7.10. HYDROCARBON CHARACTERIZATION OF SURFICIAL SEDIMENT SAMPLES, CRUISE III (MAY-JUNE 1983).

Station Sample No.	Hydrocarbons* ($\mu g\ g^{-1}$)		Ratios				Key Hydrocarbons ($\mu g\ g^{-1}$)				n-Alkanes	
	f_1	f_2	Resolved/ Unresolved	Pristane/ Phytane	C_{17}/ Pristane	C_{18}/ Phytane	1500	1700	2085	2100	Homologous Series	CPI
40-I	4.0	0.49	--	--	--	1.67	--	0.024	0.113	0.628	17-24	6.46
40-II	3.9	0.41	--	--	--	1.84	--	0.012	0.124	0.574	17-24	7.82
41-I	1.0	0.08	--	0.92	1.41	1.45	--	0.025	0.034	0.047	--	--
41-II	1.5	0.06	--	0.97	1.26	1.43	--	0.026	0.040	0.022	--	--
42-I	1.2	0.10	--	--	--	--	--	0.025	0.172	0.071	--	--
42-II	1.3	0.08	--	--	--	--	--	0.056	0.148	0.060	--	--
43-I	1.4	0.07	--	0.40	2.91	1.51	--	0.024	0.088	0.065	17-22	2.17
43-II	1.6	0.08	--	--	--	1.42	--	0.028	0.094	0.146	17-22	2.00
46-I	2.5	0.13	--	--	--	1.39	--	0.050	0.155	0.173	16-23	2.30
46-II	2.2	0.14	--	--	--	1.39	--	0.044	0.136	0.187	16-23	2.76
48-I	2.1	0.12	--	--	--	1.22	--	0.046	0.284	0.176	17-24	2.84
48-II	1.9	0.12	--	--	--	1.23	--	0.048	0.265	0.174	17-24	3.02
49-I	2.4	0.17	--	0.55	2.60	0.97	--	0.052	0.352	0.117	16-23	2.62
49-II	2.8	0.20	--	0.40	3.08	1.24	--	0.045	0.370	0.151	16-23	2.48
50-I	2.8	0.14	--	--	--	0.98	--	0.055	0.609	0.085	--	--
50-II	3.0	0.14	--	--	--	1.38	--	0.056	0.588	0.113	--	--
53-I	2.6	0.18	--	0.72	1.96	1.61	--	0.056	0.324	0.170	--	--
53-II	2.5	0.23	--	0.54	2.52	1.34	--	0.053	0.295	0.123	--	--
54-I	1.8	0.08	--	0.74	0.93	0.90	--	0.026	0.264	0.139	17-22	2.88
54-II	1.9	0.10	--	1.04	0.94	1.40	--	0.026	0.280	0.140	17-22	1.77

*f_1 = saturated hydrocarbon fraction; f_2 = unsaturated hydrocarbon fraction.

ranging from n-C_{17} through n-C_{25} (Kovats Indices 1700-2500), although these represent a minor portion of the total hydrocarbon content. Samples from Station 40, for example, contained approximately 92 ng g^{-1} of 2200-2500 n-alkanes relative to a total f_1 hydrocarbon content of 4,000 ng g^{-1}. Representative GC-FID chromatograms for the f_1 and f_2 fractions are shown in Figure 7.7 for Station 46. Characterization of hydrocarbon source material indicates predominantly biogenic hydrocarbons at all stations, as described above for Cruise II.

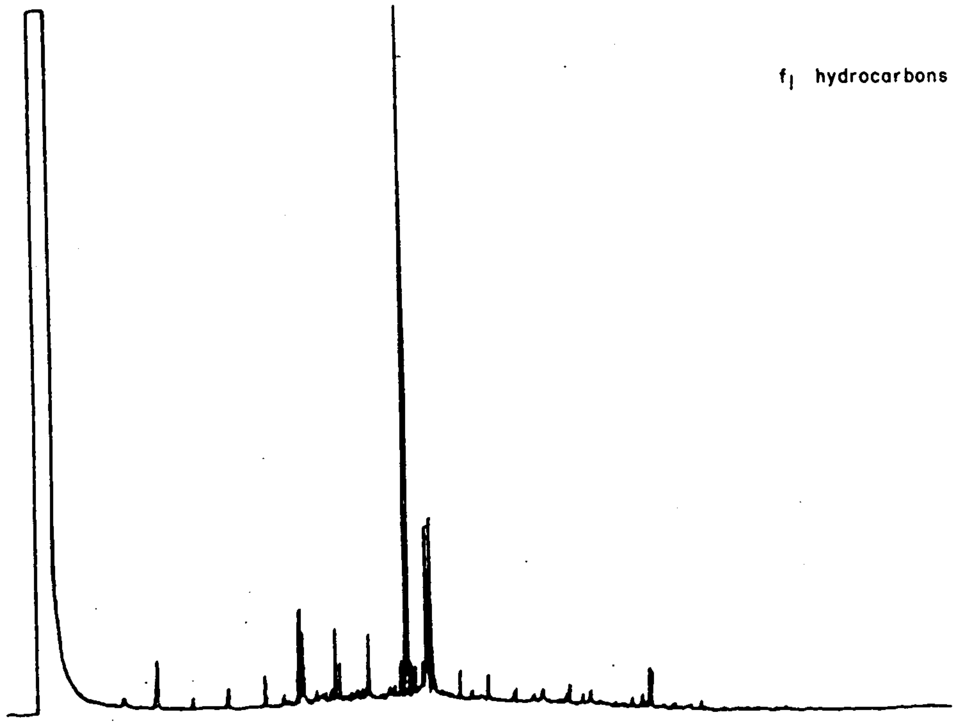
The unsaturated (f_2) hydrocarbon fractions from Stations 40, 42, 46, and 49 were also analyzed by GC/MS for select PNAH to estimate pyrogenic vs. petrogenic source. These data are summarized in Table 7.9, and a graphic depiction of the relative abundance of the PNAH alkyl homologues for Station 46 is presented in Figure 7.8. The graphs show a low concentration of PNAH of mixed pyrogenic, petrogenic material, indicating no substantial petroleum contamination. A comparison of Station 46 PNAH from Cruise II with that from Cruise III shows a shift in the most abundant naphthalene, phenanthrene, and pyrene homologues, whereas the benzanthracene consisted primarily of the parent compound during both sampling periods. The final interpretation indicating no petroleum contamination is consistent between sampling periods and is in accord with the GC-FID data.

One of the four samples from Cruise III that was analyzed by GC/MS exhibited PNAH content indicative of petrogenic material (Table 7.9). Although the PNAH from Station 49 were no more abundant than at other stations, only alkyl-substituted homologues were found in the Station 49 sample. This suggests the complete absence of pyrogenic material and the presence of a small amount of petrogenic PNAH. The latter was not present in amounts sufficient to signify petroleum contamination.

7.4 DISCUSSION

Characterization of the hydrocarbon content in surface sediment from stations inshore of the 20-m isobath on the southwest Florida shelf revealed low levels of predominantly marine biogenic hydrocarbons. Samples collected during May-June 1983 (Cruise III) contained higher total hydrocarbon content (1.3 to 4.5 μg g^{-1}) than did samples collected during December 1982 (Cruise II) (0.3 to 4.3 μg g^{-1}).

Some petroleum-like characteristics were observed from the GC-FID fingerprints of some Cruise III samples. The presence of small amounts



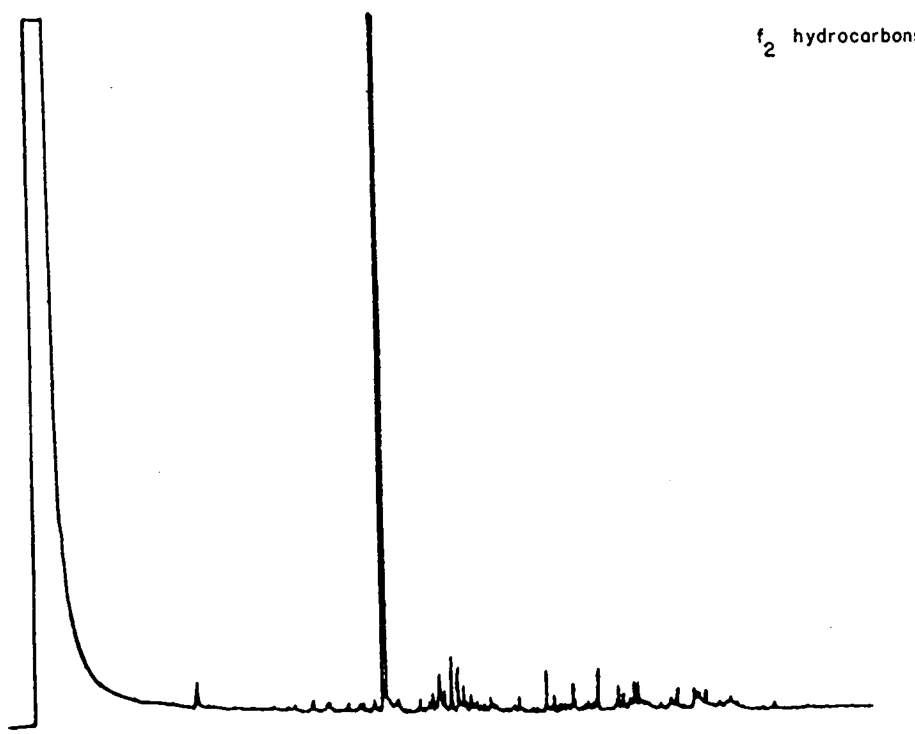


FIGURE 7.7. GC–FID CHROMATOGRAMS FOR f_1 AND f_2 HYDROCARBONS FROM STATION 46, CRUISE III.

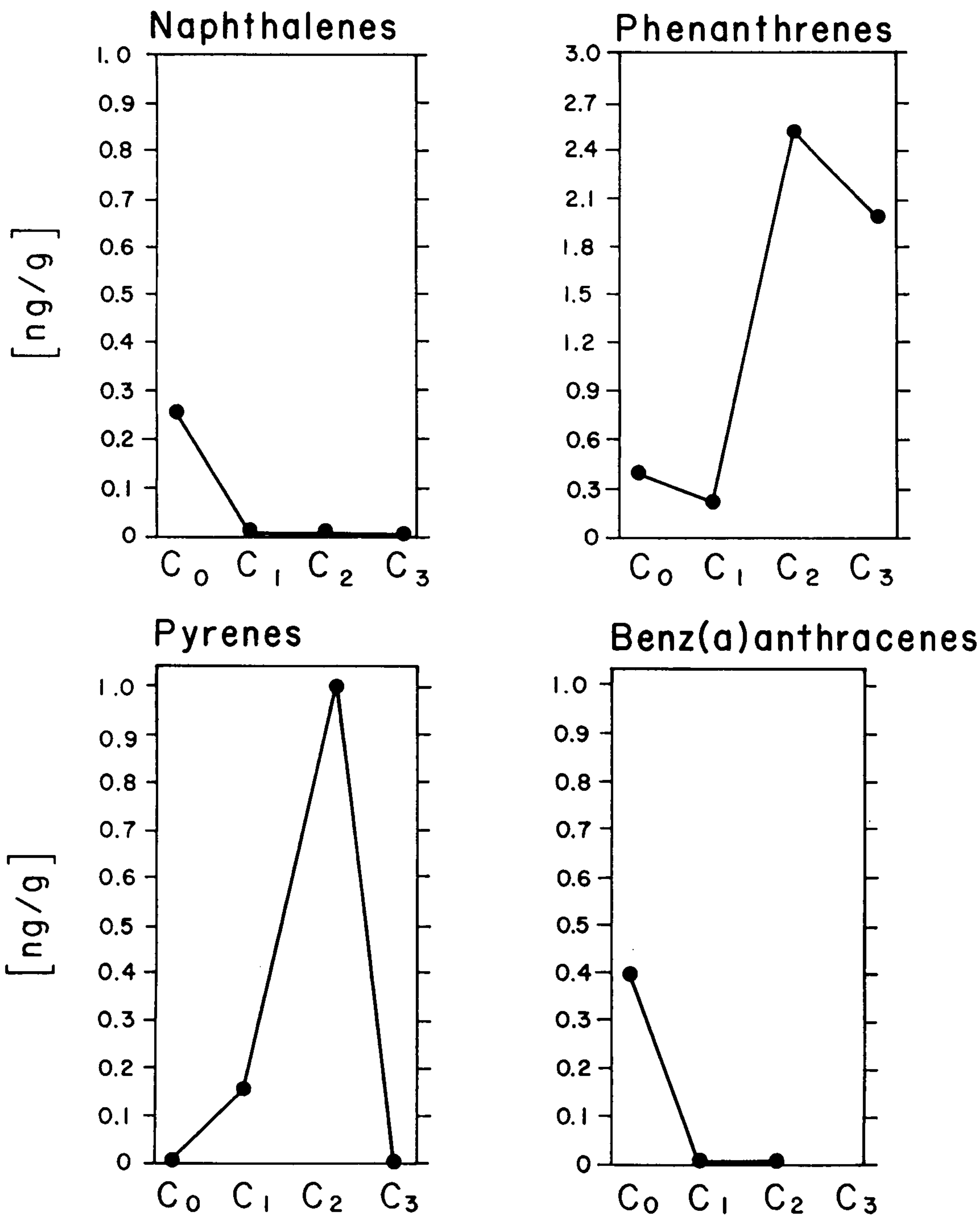


FIGURE 7.8. RELATIVE ABUNDANCE OF ALKYL HOMOLOGUES FROM SELECT PNAH, STATION 46, CRUISE III.

of petrogenic and pyrogenic PNAH also was observed by GC/MS analysis of the f_2 fraction from select stations. However, the very low concentrations of these saturated and unsaturated compounds are not indicative of petroleum contamination in the areas studied. Verification of the presence and identity of these petroleum-like compounds prior to the onset of extensive drilling activities in this area, however, is essential for accurate interpretation of the effects of future oil and gas exploration activities. As some drilling did occur about 6 km off of the Charlotte Harbor area in 1960 (M. Rinkel, 1983, personal communication, State of Florida Governor's Office), the potential for some prior petrogenic contamination exists.

Total hydrocarbon levels in soft-bottom sediments analyzed during the two previous years of the Southwest Florida Shelf Ecosystems Study were in the range of 0.1 to 1.0 $\mu g\ g^{-1}$ dry wt sediment (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1985). Station depths ranged from about 25 to 150 m, and the hydrocarbons were determined to be of predominantly marine biogenic origin with some evidence for biogenic terrigenous inputs (presumably from the Mississippi River) at some middle and outer shelf locations. Only one station (Station 12; 90 m depth) exhibited the presence of some petroleum-like hydrocarbons. Total hydrocarbon levels in noncontaminated estuarine sediments in the Charlotte Harbor Area, as reported by Pierce et al. (1983), ranged from 0.8 to 27.3 $\mu g\ g^{-1}$ dry wt sediment, with evidence for localized areas of petroleum contamination.

Additional research is needed to ascertain the distribution and concentrations of recently biosynthesized aliphatic hydrocarbons and of PNAH alkyl homologues normally observed in marine sediment relative to those levels that indicate potentially harmful petroleum contamination. These data should be collected prior to extensive oil drilling operations in any new lease area so that impacts of future drilling activities can be determined.

CHAPTER 8
POTENTIAL IMPACTS OF OIL AND GAS RELATED ACTIVITIES

8.1 OIL AND GAS LEASING ON THE SOUTHWEST FLORIDA CONTINENTAL SHELF

The continental shelf off southwest Florida is a frontier area for offshore petroleum exploration. Although 90% of the offshore oil and gas production in Federal waters of the United States occurs in the Gulf of Mexico (Lynch and Rudolph, 1984), most of the drilling has taken place offshore Texas and Louisiana. The eastern Gulf recently has become a focus of renewed industry interest, although the overall hydrocarbon potential of the area is not believed to be great (Lynch and Rudolph, 1984).

Blocks in Federal waters of the southwest Florida shelf have been offered in OCS Lease Sales 32 (1973), 41 (1976), 65 (1978), 66 (1981), 67 (1982), 69 (1982), 79 (1984), and 94 (1985). Figure 8.1 shows all active leases as of February 1986--32 leases in the Charlotte Harbor Area, 3 in the Howell Hook Area, and 65 in the Pulley Ridge Area. During Sales 79 and 94, most of the industry interest in the eastern Gulf centered on the Pulley Ridge Area (all of the leased Pulley Ridge blocks were obtained during Sale 79 or Sale 94).

In November 1983, Congress passed restrictions on Federal leasing off Florida's west coast in connection with the then upcoming (January 1984) Lease Sale 79. Two restrictions pertained to the southwest Florida shelf. First, a buffer zone was established within which no blocks would be leased. The zone included all blocks within 56 km (30 NM) of the Florida three-league line (the boundary between Federal and State waters) as far south as Block 524 in the Pulley Ridge Area and all blocks within the 20-m isobath south of 26°N latitude (Figure 8.2). Blocks south of 26°N and seaward of the 20-m isobath were subject to the following lease stipulations:

1) The MMS would not approve exploratory drilling operations in this area until three study years of physical oceanographic and biological resource data had been accumulated.

2) Lessees would be required to conduct biological photo-documentation surveys prior to initiation of exploratory

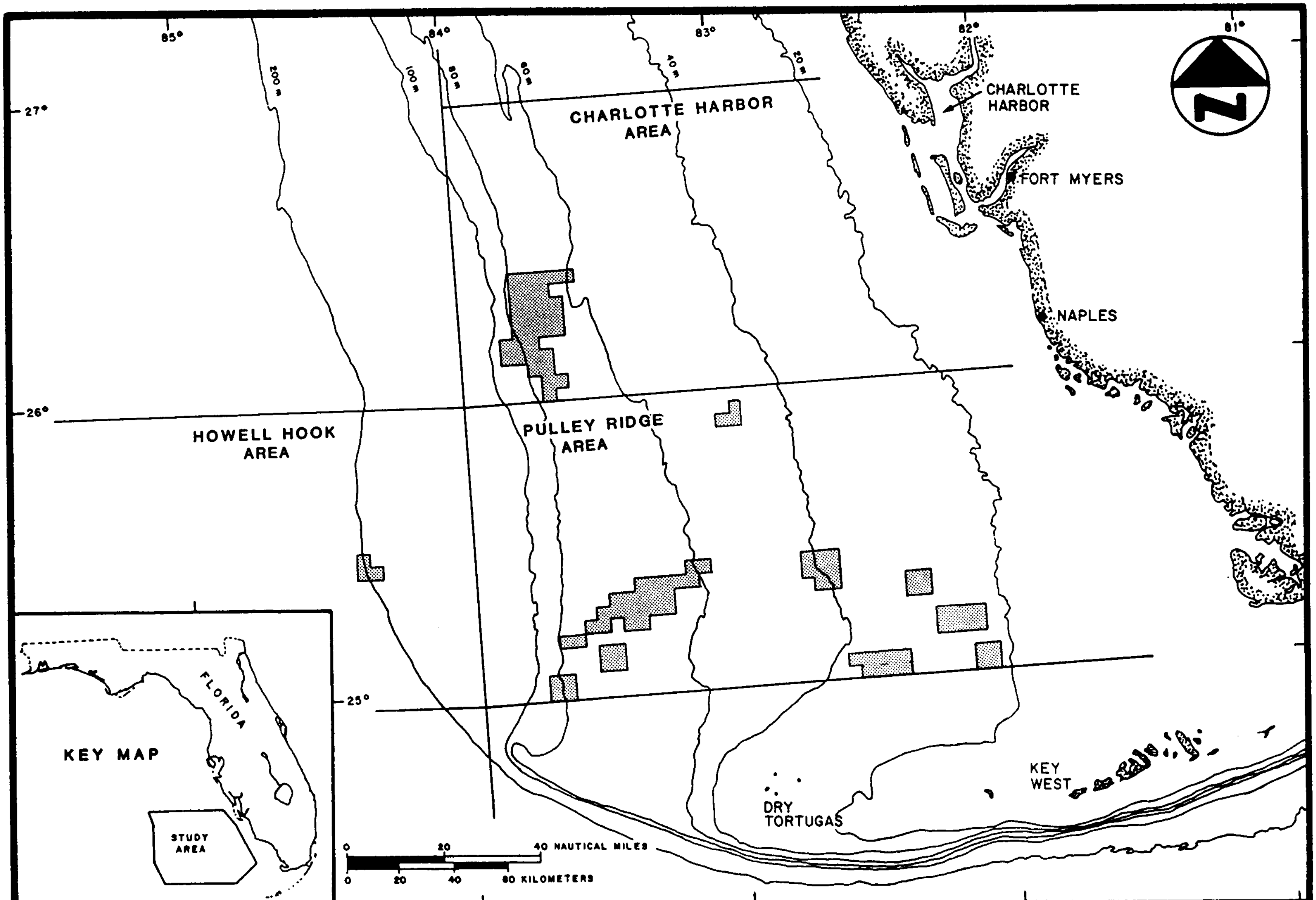


FIGURE 8.1. CURRENTLY ACTIVE LEASES ON THE SOUTHWEST FLORIDA SHELF (AS OF FEBRUARY 1986).

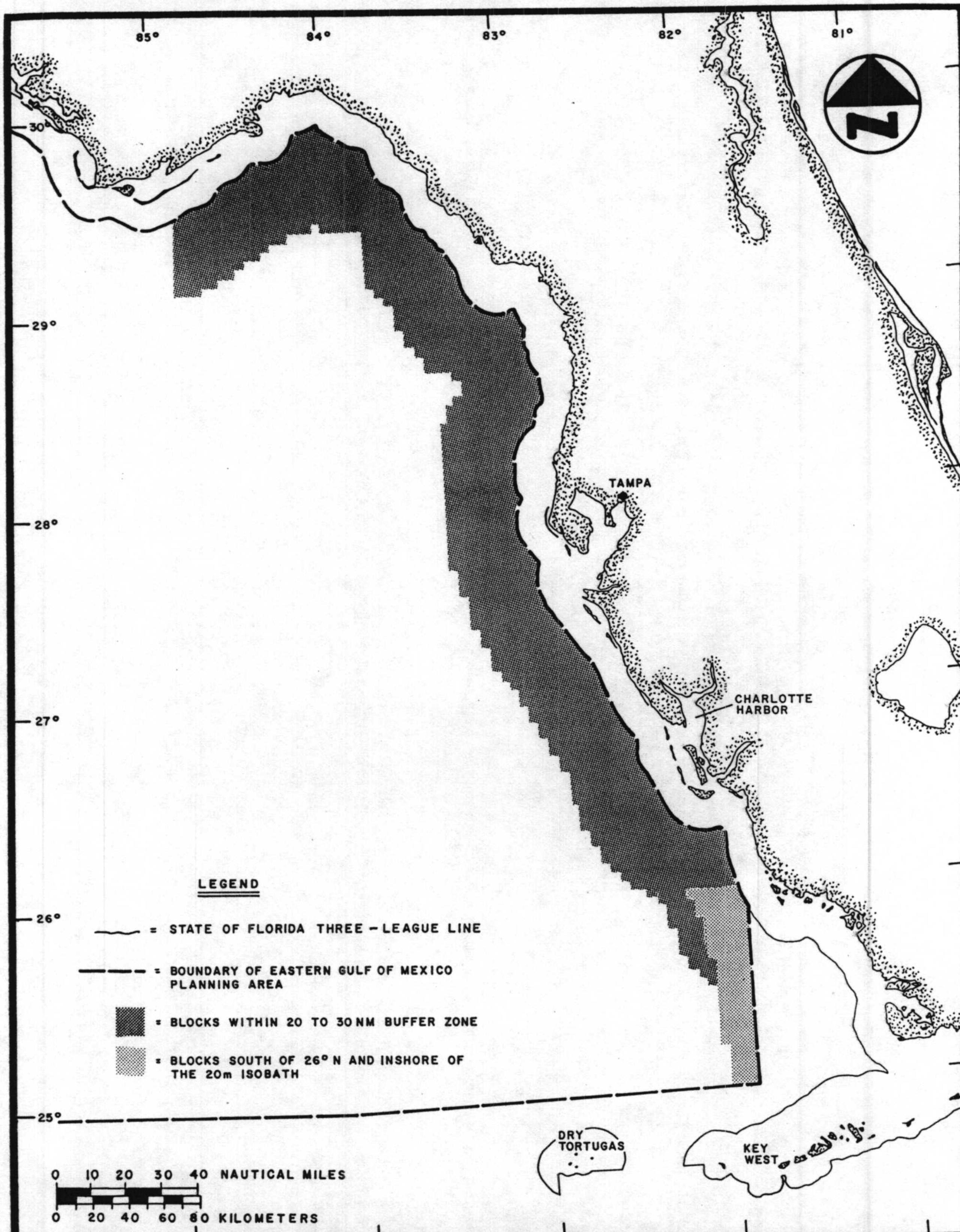


FIGURE 8.2. THE NO-LEASING BUFFER ZONE ESTABLISHED OFF FLORIDA'S WEST COAST PRIOR TO LEASE SALE 79 (JANUARY 1984).

drilling operations and to work with the MMS to develop monitoring plans for subsequent drilling activities.

This report contains the third year of biological resource data cited in the first stipulation. The same restrictions and stipulations developed for Sale 79 were incorporated in the terms of the recent lease offering (Sale 94).

Offshore areas also have been leased within Florida territorial waters. At one time, all of the State's west coast offshore lands were under lease, but most have since reverted to the State. Three offshore leases remain, encompassing the outer third of Florida's territorial waters from Pensacola to Naples. A total of 19 exploratory wells have been drilled--the most recent in 1983 off Santa Rosa County--but no production has yet occurred (Lynch and Rudolph, 1984).

8.2 DESCRIPTION OF OFFSHORE OIL AND GAS RELATED ACTIVITIES

Offshore oil drilling involves numerous activities that may impact benthic communities of the southwest Florida shelf. These activities include some associated with exploration and others associated with development and production. The extent of development and production operations in an area depends on the success of exploratory drilling.

The exploration phase involves several operations. Suitable drillsite locations are identified in a lease block, and a geophysical survey is conducted to identify potential structural hazards on the seafloor. In the eastern Gulf of Mexico, depending on location and lease stipulations, a photographic documentation survey ("live-bottom survey") may also be conducted. Then, a mobile drilling unit is brought in to drill one or more exploratory wells.

When exploratory drilling identifies producible quantities of oil or gas, development and production operations follow. Activities include installation of platforms, drilling of multiple wells, and possibly, installation of pipeline(s) to transport the oil or gas to shore.

8.3 GENERAL IMPACT ASSESSMENT

Because this study has focused on characterizing benthic habitats and biota, our discussion concentrates on benthic impacts. We omit in-depth discussions of development scenarios, oil spill probabilities and spill trajectory analyses, and onshore facility impacts. The Environmental Impact Statement prepared by the MMS for Sales 94, 98, and 102 (USDOI, MMS, 1984) discusses these aspects of oil and gas related impacts. Additional impact evaluations are to be produced in the near future as part of ongoing MMS-sponsored southwest Florida shelf studies. The reader is also referred to recent reviews of drilling mud impacts [National Research Council (NRC), 1983], oil in the sea (NRC, 1985), and long-term effects of oil and gas development activities (Boesch and Rabalais, 1985).

8.3.1 Benthic Impacts

We discuss four categories of potential impacts associated with exploration and/or development and production. Impacts may result from seafloor disturbance, presence of offshore structures (artificial reef effects), drilling mud and cuttings discharges, and accidental oil spills.

Seafloor Disturbance. Both exploration and development activities involve the use of offshore structures whose emplacement and removal inevitably disturb the underlying seafloor.

During exploratory drilling, a mobile drilling unit is used; Figure 8.3 shows several types. In most water depths on the west Florida continental shelf, either a jack-up or semisubmersible drilling unit probably would be used. A jack-up rig is supported by legs that are extended to rest on the seafloor. The supporting legs compress surface sediments and crush underlying benthic organisms near the drillsite. In contrast, a semisubmersible (floating) drilling unit is held in place by large (several-ton) anchors deployed in a radial pattern around the drillsite. Deployment and retrieval of the anchors disturbs the seafloor and may crush and/or bury benthic organisms. The attached anchor chains also can disturb the seafloor. The severity of impact would depend on the distance the anchors were dragged along the bottom during emplacement and removal.

During development and production drilling, platforms and other structures are installed. The offshore structures range in size from flare stacks to small, single well platforms, to large, multi-well platforms, the latter often accompanied by adjacent quarters structures for platform personnel. Platforms typically are fabricated at onshore facilities and barged to a site for installation. Platform emplacement

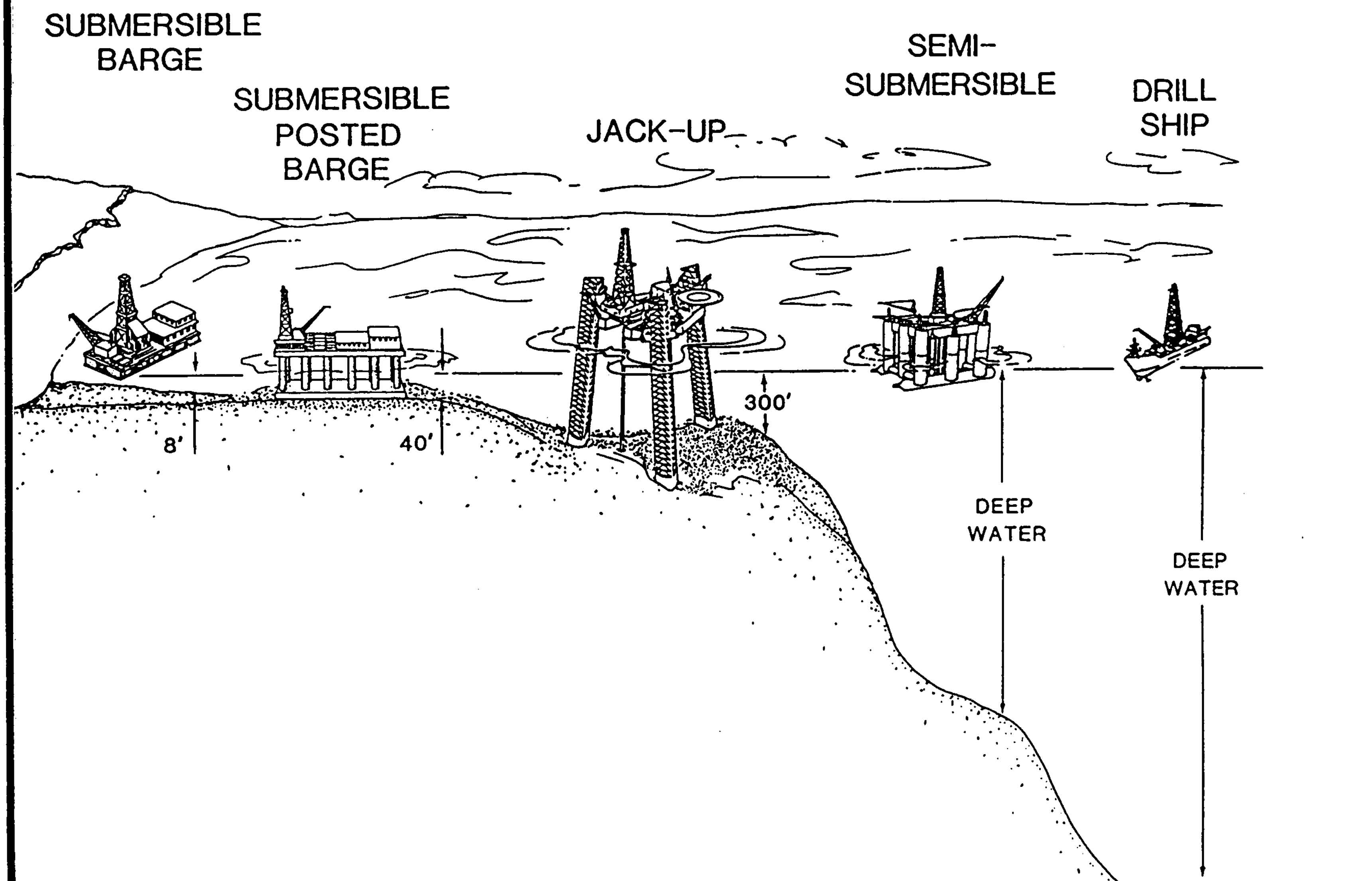


FIGURE 8.3 TYPES OF OFFSHORE DRILLING RIGS (FROM: LYNCH AND RUDOLPH,1984).

involves considerable disturbance of the seafloor in the immediate vicinity of the drilling location, with the severity depending largely on platform size. Anchoring of support and supply vessels in the vicinity of a platform both during emplacement and routine production operations is an additional source of bottom disturbance.

Pipeline installation also physically disturbs the seafloor. Approximately six acres of seafloor are disturbed per mile of pipeline laid (USDOI, MMS, 1984). The damage is due to pipe emplacement (i.e., trenching and burial) as well as anchoring by pipelaying barges (USDOI, MMS, 1984).

Seafloor disturbances such as those cited above could impact benthos in various ways. Some organisms could be affected directly--e.g., killed or damaged by anchors or jack-up legs. In addition, altered bottom topography could mediate indirect impacts on the benthic community. In soft-bottom areas, some fishes and epifauna may be attracted to the increased microrelief afforded by anchor scars, for example. In live-bottom areas, destruction or fragmentation of low-relief rock outcrops could reduce habitat for cryptic fishes and invertebrates. Sediments stirred up during placement of a drilling unit, platform, or pipeline could stress organisms that are intolerant to sedimentation (e.g., some corals); however, this impact is unlikely to occur on the southwest Florida shelf because sediments are predominantly sandy.

Seafloor disturbance is an impact associated with a discrete event such as anchor removal or pipeline laying. Once a disturbance occurs, the habitat and the benthic community may eventually recover if not damaged irreparably. In soft-bottom areas, irregular seafloor features such as anchor scars eventually would be eroded and levelled by near-bottom currents and/or infaunal bioturbation. The ambient current regime would be an important factor influencing recovery rate. At a drillsite located in a low-current environment off the mid-Atlantic coast, EG&G Environmental Consultants (1982) noted the persistence of anchor scars for at least a year after exploratory drilling ceased. In hard-bottom areas, destruction of low-relief outcrops would permanently alter the local habitat. However, on the southwest Florida shelf, most reef epibiota are associated with thinly covered hard bottom or surface rubble layers rather than rock outcrops, so this impact would be less severe than at a reef.

Offshore Structures as Artificial Reefs. Once a drilling rig or platform is in place, it provides exposed hard substratum that typically attracts reef-dwelling fishes. Well developed and characteristic fish assemblages have been described for production platforms in the northern Gulf of Mexico (Continental Shelf Associates, Inc., 1982; Gallaway and Lewbel, 1982; Boland et al., 1983). This "artificial reef effect" is attributable to the increased availability of habitat (exposed hard substratum) and food (sessile "fouling" epibiota that colonize the structure). In the case of exploratory drilling units, the effect would be short-lived (weeks to months), whereas production platforms would provide habitat over a much longer term (years).

Studies of fish populations associated with a newly installed platform near the East Flower Garden Bank (Boland et al., 1983) and artificial reefs of different ages in the South Atlantic Bight (Marine Resources Research Institute, 1984) suggest that fish assemblages similar to those associated with nearby hard-bottom areas would rapidly colonize drilling-related structures installed on the southwest Florida shelf.

Drilling Mud and Cuttings Impacts. Rotary drilling operations necessitate the use of specially formulated mixtures referred to as drilling fluids or muds. Drilling muds serve primarily to cool and lubricate the drill bit, seal and control pressure in the well, and carry bits of formation solids (drill cuttings) to the surface during drilling. The discharge of these drilling muds and cuttings to the ocean is a potential source of impacts to marine organisms.

Drill cuttings are generated and discharged continuously while drilling is in progress. In contrast, drilling muds are recirculated through the system and, with the exception of small amounts adhering to cuttings, released intermittently. Bulk mud discharges occur when the mud pits are cleaned, when the mud mixture is changed to penetrate a particular formation, or when the mud has become too viscous for use. A large bulk discharge typically occurs at the end of drilling.

All drilling muds used for offshore wells are water-based mixtures. Barite, clay, lignosulfonate, and lignite are the major solid constituents (Table 8.1); various special-purpose additives may also be used. The U.S. Environmental Protection Agency, which regulates ocean discharge of potential pollutants, has designated eight generic mud formulations. Under the National Pollutant Discharge Elimination System

TABLE 8.1. REPRESENTATIVE COMPOSITION OF DRILLING MUDS USED ON THE OUTER CONTINENTAL SHELF (FROM: NRC, 1983).

Component	Concentration (wt %)	
	Low Density Mud ($1.19\ g\ cm^{-3}$)	High Density Mud ($2.09\ g\ cm^{-3}$)
Barite	15.0	62.0
Low-gravity solids	6.5	5.9
Lignosulfonate	1.0	0.9
Lignite	1.0	0.9
Inorganic salts	0.7	0.5
Water	75.8	29.8

(NPDES), the EPA issues permits that allow ocean discharge of generic drilling muds and approved additives.

In a review of drilling mud discharge fate and effects, the NRC (1983) cited two environmental concerns about drilling muds: (1) that the muds may kill marine organisms, produce harmful sublethal responses in them, or alter ecosystems; and (2) that some muds may contain metals and/or organic compounds that accumulate to harmful concentrations in tissues of consumers, including humans. There are two additional concerns in relation to southwest Florida shelf benthos: (3) that turbidity due drilling mud discharges may hamper photosynthesis by benthic algae and seagrasses; and (4) that deposition of drilling mud particles may stress epifauna that are intolerant to sedimentation. The major environmental concern about drill cuttings discharges is that they may suffocate benthic organisms near drillsites.

Issues associated with ocean discharge of drilling muds recently have been discussed by Neff (1982, 1985), the NRC (1983), Petrazzuolo (1983), and Duke and Parrish (1984). An in-depth review of the topic is beyond the scope of this report. Some general conclusions regarding the environmental concerns stated above are summarized below.

(1) <u>Toxicity</u>. Most water-based drilling muds are of a low order of "acute" toxicity to most marine organisms when tested in 96-hour laboratory exposures (Neff, 1982; NRC, 1983). Greater toxicity of some used drilling muds can usually be attributed to contaminants such as diesel oil (NRC, 1983; Duke and Parrish, 1984) (which ordinarily may not be discharged under NPDES permit terms). Sublethal physiological effects have been detected at concentrations one to two orders of magnitude lower than the concentration producing mortality over a given exposure interval (Petrazzuolo, 1983).

One should use caution in applying these data to hazard assessment in the real world. Most data concerning mud toxicity have come from laboratory bioassay experiments. Appropriate uses of these data are to assess the relative toxicity of different mud formulations and to evaluate the relative sensitivities of various organisms and life stages under a fixed set of environmental conditions. The use of bioassay data to estimate lethal or stressful concentrations in the field is of doubtful validity because field environmental conditions (ambient environmental conditions and exposure conditions) differ from those used in the bioassays. Specifically, bioassays rarely duplicate the modes and duration of exposure that marine organisms would likely experience in the vicinity of drilling discharges. Moreover, a concentration that produces a particular response (or lack of response) under a fixed set of laboratory environmental conditions may not induce the same response under a different (and rarely fixed) set of field environmental conditions.

These qualifications notwithstanding, most data collected to date (and independent reviews of the data) indicate that drilling muds have little potential for direct toxicity to marine organisms. Dispersion of drilling muds typically is rapid enough that potentially lethal concentrations occur only very near the discharge point; therefore, water column organisms are unlikely to experience prolonged exposures to hazardous concentrations. The potential for toxic effects on benthic organisms is greater because they may be exposed over much longer intervals if deposited drilling muds from one or many drilling operations were to persist in an area. Resuspension and transport of deposited drilling mud particles is determined largely by the near-bottom current regime and (in shallow water) surface waves.

(2) Contaminant Bioaccumulation and Biocentration. Drilling muds contain detectable concentrations of several metals. Barium and chromium are present as constituents of drilling mud components. Barium is the most abundant metal; it is the primary constituent of barite, which in turn is one of the main solid components of drilling muds. Chromium is the second most concentrated metal in muds containing chrome or ferrochrome lignosulfonates. Other metals such as cadmium, copper, lead, mercury, and zinc typically are present at trace concentrations as contaminants of barite (Neff, 1982). The potential for bioaccumulation (accumulation in tissues of organisms exposed to drilling muds) and bioconcentration (increasing tissue concentrations in successive trophic levels) of metals from drilling muds apparently is low (Petrazzuolo, 1983; Neff et al., 1985a). Moreover, elevated tissue concentrations of barium (the metal marine organisms are most likely to bioaccumulate from drilling muds) have not been linked to adverse physiological effects at concentrations that are possible in seawater (Petrazzuolo, 1983).

(3) Turbidity. Drilling mud discharges produce increased turbidity in the vicinity of a drillsite. Turbidity could affect primary production of benthic algae and seagrasses through shading. In most instances, this impact would be minor because drilling mud discharges are intermittent and of short duration.

During bulk drilling mud discharges, two distinct plumes are produced (Figure 8.4). The lower plume containing >90% of the solids descends rapidly as a convective jet until it encounters the seafloor or a layer of dense seawater that has a similar retarding effect on the plume's downward momentum (Brandsma and Sauer, 1983). Just downstream of the discharge point, turbulence causes some fine drilling mud particles to separate from the main plume as a highly visible upper plume. Field dispersion studies of this upper plume have shown elevated concentrations of suspended solids and reductions in transmissivity (water clarity) within a range of a few hundred meters to over 2,000 m downstream from the discharge point (Ayers et al., 1980a,b; Ray and Meek, 1980; Trocine and Trefry, 1983). The time interval over which these alterations in water clarity would persist depends on the duration of the drilling mud discharges and the ambient current regime. In general, one would expect detectable reductions in water clarity to persist for a few minutes to a few hours following a bulk discharge.

The importance of light as a factor influencing primary production by benthic macroalgae (Lapointe and Tenore, 1981; Vooren, 1981; Rosenberg and Ramus, 1982) and seagrasses (Wiginton and McMillan, 1979; Williams and McRoy, 1982) is well established. Some benthic epifauna containing symbiotic microalgae (zooxanthellae) also can be affected by variations in environmental light levels. For example, decreasing light levels with increasing depth may be responsible for the general restriction of symbiont-containing gorgonians to relatively shallow water depths (Goldberg, 1973). However, the overall relationship of light to distribution patterns of zooxanthellate corals is complex and not well understood (Sheppard, 1982).

To the extent that drilling discharges reduce ambient water clarity near a drillsite, benthic algae and seagrasses that are sensitive to reductions in light levels may be affected. Because bulk drilling mud discharges typically are intermittent and short-lived, any impacts would probably be temporary. However, if significant quantities of drilling muds were released with cuttings (i.e., adhering to the cuttings particles) or if the cuttings themselves were to include a significant proportion of fine particles, resulting turbidity impacts could be more serious.

(4) Sedimentation. Drilling mud and cuttings discharges may bury some benthic organisms and stress certain others that are sensitive to sedimentation. In addition, deposition of these particles on the

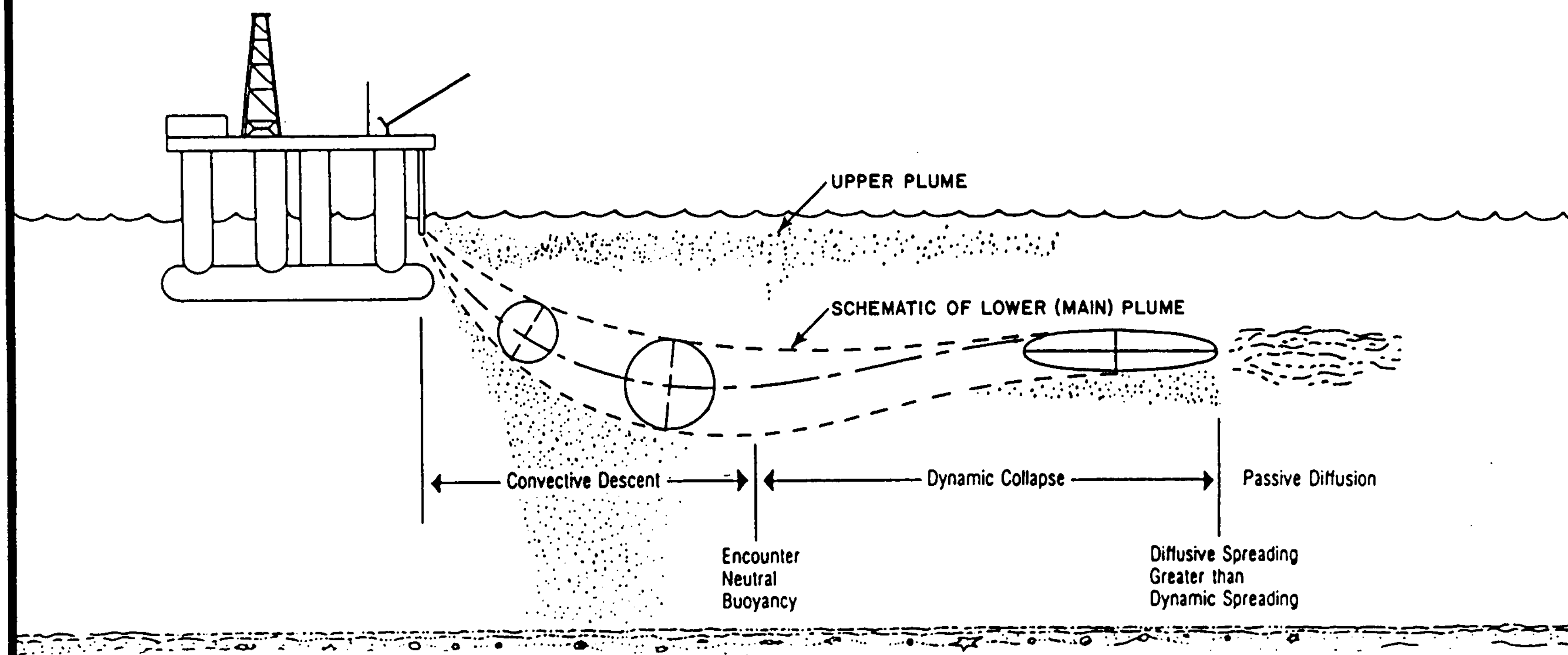


FIGURE 8.4. IDEALIZED DRILLING MUD DISCHARGE SHOWING THE UPPER AND LOWER PLUMES (FROM: BRANDSMA ET AL., 1980).

seafloor could alter the ambient substrate composition, with possible consequences for both infauna and epifauna.

Direct burial by cuttings or (less likely) drilling muds is one potential impact. Discharged cuttings typically are coarse and settle to the seafloor very near the discharge point, forming a distinct pile that may be up to several meters in height (Zingula and Larson, 1977). Some benthic organisms can recover from burial (Maurer, 1983), but most probably would not if the pile were more than a few centimeters deep.

Sedimentation per se may also adversely affect benthos, particularly epibiota such as hard corals or suspension-feeding sponges and bivalves. Various corals exhibit different degrees of tolerance to sedimentation (Hubbard and Pocock, 1972). Sediment particles can be cleared from coral surfaces by passive and active mechanisms. Passive sediment removal by gravity and currents is facilitated by tall, erect polyp structures with convex upper surfaces (Lasker, 1981). There are several removal processes: (1) distension via stomodeal water uptake; (2) ciliary action; (3) tentacular removal of individual (especially coarse) sediment grains; and (4) production and sloughing of mucus, which traps sediment particles (Hubbard and Pocock, 1972; Fisk, 1981). Sediment clearance capabilities of a particular coral species may be related to the degree of exposure to natural sedimentation (Hubbard and Pocock, 1972; Lasker, 1980). Thus, for example, effective sediment removers (e.g., Isophyllia sinuosa, Manicina areolata, Meandrina meandrites) typically predominate in areas exposed to high natural sedimentation (Loya, 1976). Less effective sediment removers, including plate corals such as Agaricia spp., typically are found in sheltered positions in Caribbean reefs--for example, the underside of ledges (Hubbard and Pocock, 1972).

On most of the southwest Florida shelf, emergent hard substratum is rare; small hard coral heads occur primarily on hard substrate overlain by a thin sand veneer. We presume these corals tolerate some degree of sediment movement as part of their normal environment. In contrast, corals occurring on the algal pavement area along Transect E (Agaricia spp.) probably are not exposed to sedimentation under normal conditions and would likely be sensitive to drilling mud and cuttings deposition. Year 4 and 5 studies may provide data to indicate the frequency of naturally-occurring sediment movement and burial/exposure at live-bottom areas.

Oil Spills. Offshore oil extraction and transportation involve oil spill risks. Southwest Florida shelf benthos already are exposed to some risk due to tanker traffic in the eastern Gulf of Mexico. Exploration and development on the continental shelf would bring additional site-specific risks (e.g., a blowout at a particular platform; chronic leakage from a pipeline, etc.). In addition, large-scale development probably would increase the overall risk of a spill from transfer and transport operations.

Although the likelihood of a major spill on the southwest Florida shelf is very low, serious environmental impacts could result if one should occur. Estuarine wetlands and subtidal estuarine areas probably would be more susceptible to damage than benthic habitats in deeper waters of the continental shelf. Effects of chronic exposure to low level contamination from far more common minor spills are difficult to evaluate but could present localized hazards to benthos (e.g., those near a leaking pipeline or around a platform where minor spills occur).

Worldwide, the main sources of petroleum entering the marine environment are marine transportation (including tanker deballasting and bilge cleaning) and municipal and industrial waste and runoff (NRC, 1985). In the Gulf of Mexico, Mississippi River runoff is the largest petroleum input (USDOI, MMS, 1984) (Figure 8.5). The southwest Florida shelf is largely beyond the influence of Mississippi River hydrocarbons, although Year 1 sampling revealed evidence of petrogenic hydrocarbons of probable Mississippi River origin at one outer shelf station (Station 12, 90 m water depth). Offshore oil operations per se contribute a minor fraction of total inputs (Figure 8.5).

Potential oil spill sources on the southwest Florida shelf include blowouts, pipeline ruptures or leaks, and transport/transfer operations. Blowouts and pipeline ruptures could introduce oil near the seafloor, whereas spills occurring during transport or transfer operations would most likely introduce oil at or near the sea surface. Large oil spills are uncommon; no spills larger than 1,000 bbl have occurred off the U.S. coast since 1981 (Neff et al., 1985b). The spill rate from tankers and platforms has declined since 1974 (Lanfear and Amstutz, 1983)--presumably a reflection of increased public and industry concern, greater governmental regulation, and improved technology.

Once oil is released into the ocean, it is subject to physical, chemical, and biological dispersive and degradative processes. Most

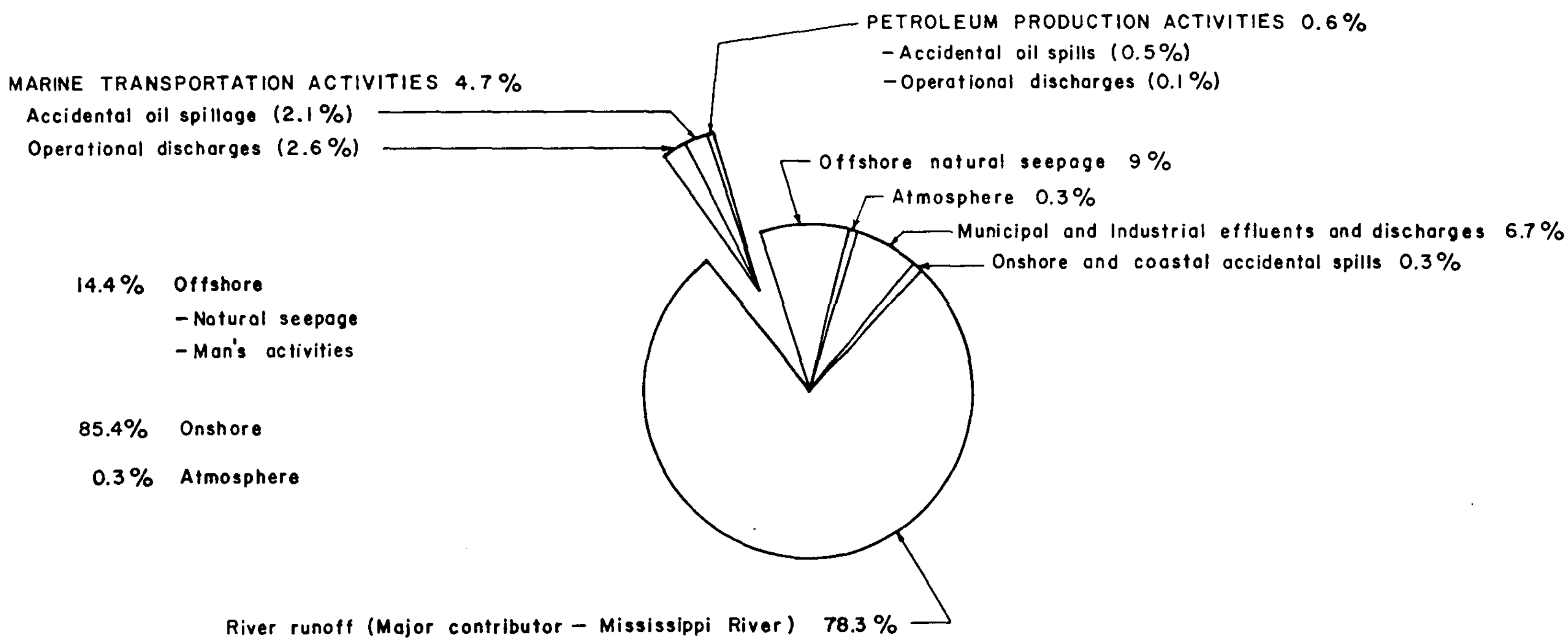


FIGURE 8.5. SOURCES OF PETROLEUM INPUTS INTO GULF OF MEXICO OUTER CONTINENTAL SHELF WATERS (ANNUAL PERCENTAGE) (FROM: USDOI, MMS, 1984).

crude oils float, but portions of the spilled oil enter the water column through dissolution, sinking, and sedimentation and could reach the seafloor in shallow, nearshore waters. In addition, oil from a subsurface spill (e.g., blowout or pipeline rupture) could contaminate the seafloor near a spill source. In general, dispersion and degradation of spilled oil are rapid in well oxygenated environments subject to water motion and wave action, whereas oil is likely to persist in quiescent environments, especially those where sediments are anaerobic (Boesch et al., 1985). Estuarine and wetlands areas are considered the most susceptible to persistent accumulations of hydrocarbons from oil spills (USDOI, MMS, 1984).

Spilled oil can have a wide range of effects on marine organisms. Physical fouling of seabirds and marine mammals is perhaps the most well-known impact. However, a variety of other impacts, some subtle and indirect, may also result (Table 8.2). The severity of biological effects depends in part on the bioavailability and persistence of petroleum components, the ability of organisms to accumulate and metabolize hydrocarbon components, and the degree to which accumulated hydrocarbons interfere with normal metabolism (Capuzzo, 1985). Oil toxicity varies with composition; refined oils are much more toxic than crude oils due to a higher concentration of aromatics in the former (Spies, 1985).

8.3.2 Benthic Recovery

We currently have no data concerning recolonization or recovery rates for defaunated or damaged benthic habitats in our study area. Studies of fouling plate colonization are being carried out as part of the ongoing Year 4 and Year 5 programs (Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc., 1985). The following discussion is necessarily speculative and general.

Smith (1975, 1979) described recolonization of patch reefs that were decimated by a "red tide" kill in summer 1971. The reefs are located in 13 to 30 m water depth near Sarasota, Florida. Over 77% of the resident fish species were eliminated immediately following the red tide, and populations of hard and soft corals, echinoderms, crustaceans, molluscs, and benthic algae sustained heavy mortalities. Blue green algae rapidly colonized decimated areas, followed by filamentous red and brown algae; although there was a second disturbance (Hurricane "Agnes") the following summer, most benthic algae present before the red tide had

TABLE 8.2. RESPONSE LEVELS OF MARINE ORGANISMS TO PETROLEUM HYDROCARBONS (FROM: CAPUZZO, 1985).

Level	Types of Responses	Effects at Next Level
Biochemical-Cellular	Impairment of metabolic pathways	Disruption in energetics Reduction in energy stores
	Detoxication	Adaptation of organism
Organismal	Metabolic changes Behavioral changes Increased incidence of disease Reduction in growth and reproduction	Reduction in performance of populations
	Adjustments in rate functions Disease defense	Regulation and adaptation of populations
Population	Changes in population dynamics	Effects on coexisting organisms and community
	Adaptions of populations to stress	No change at community level
Community	Changes in species composition Reduced energy flow	Deterioration of community Reduced secondary production
	Ecosystem adaption	No change in community stability

apparently recolonized within the first year. Irregular fish censuses during the five years following the red tide revealed that the number of fish species returned to approximately the pre-impact level within about 16 months. The species composition of the reef fish community approached that of the pre-impact community with one to two years. Recolonization by some epifaunal species was much slower, however, with several common and conspicuous reef species such as spiny lobster (Panulirus argus), Atlantic deer cowrie (Cypraea cervis), the gorgonians Muricea elongata and M. laxa, and two ophiuroids, Astrophytum muricatum and Ophiothrix suensoni, still absent nearly three years after the red tide.

Marine Resources Research Institute (1984) assessed the potential for colonization of newly submerged hard substratum (e.g., platform legs) and recovery of defaunated hard-bottom areas in the South Atlantic Bight in two ways: (1) by monitoring colonization of fouling plates over the course of one year; and (2) by comparing epibiotal community composition on artificial reefs that had been in place for 3.5 to 10 years. The fouling plates were rapidly colonized by sessile (barnacles and hydroids) and motile (amphipods) epibiota. There were some seasonal variations in colonization, and community composition on the plates did not converge to any "climax" state within the one-year interval. The artificial reef study showed that epibiotal community composition was more consistent on the artificial reefs than on the one-year colonization plates--suggesting that establishment of a fairly consistent epibiotal community on defaunated hard substratum may take several years. Even the 10-year artificial reef lacked large, sessile epibiota (certain sponges and hard corals) typical of natural hard-bottom areas in the same vicinity. Thus, recovery of live-bottom areas following a severe disturbance could take 10 years or more. A disturbed area might also recover in the sense of achieving a persistent community composition different from the one present before the impact occurred.

These studies provide only a general indication of the time span that may be needed for recovery of live-bottom areas following a disturbance resulting from oil- and gas-related activities on the southwest Florida shelf. The conditions obtaining in the wake of such a disturbance would not necessarily be like those following a red tide kill or deployment of an artificial reef. In addition, fouling plate and artificial reef colonization are less than perfect models of live-bottom colonization, which may occur only infrequently when hard substratum is exposed. Differences in elevation, relief, size, shape, and texture of exposed hard surfaces also affect rates of colonization and types of colonizing biota. In the event that drilling is conducted on the southwest Florida shelf, the impacts on and recovery of nearby live-bottom areas could be determined directly through a monitoring program.

8.3.3 Fisheries Related Impacts

Fishes. This study did not involve major sampling efforts directed toward commercially important fishes, and none of the most frequently collected fish species in our study are of commercial importance in the area. However, many fishes typically associated with hard- or live-bottom habitats serve as prey for commercially valuable fishes such as groupers (*Mycteroperca* spp., *Epinephelus* spp.) and snappers (*Lutjanus* spp.), which were not frequently collected in our samples but which do occur in the area.

Several investigators have reported high fish abundance, biomass, and species richness associated with live-bottom areas (Marine Resources Research Institute, 1982, 1984; Darcy and Gutherz, 1984). During the three years of Southwest Florida Shelf Studies, the highest fish species richness (per trawl) was noted on the middle shelf at live-bottom stations and at soft-bottom stations that exhibited some live-bottom character. We did not specifically evaluate fish biomass or abundance because the trawl samples were unreplicated and the data were felt to be semi-quantitative at best.

Live bottom attracts fish species that use the habitat for feeding and/or shelter. Some species, such as sheepshead (*Archosargus probatocephalus*), graze directly on sessile live-bottom epibiota (Marine Resources Research Institute, 1984). Others, such as sand perch (*Diplectrum formosum*) and tomtate (*Haemulon aurolineatum*) forage for infaunal prey in surrounding sand-bottom areas. Still others, such as twospot cardinalfish (*Apogon pseudomaculatus*) and jackknife-fish (*Equetus lanceolatus*) may feed on water column animals, including nocturnally emerging benthic crustaceans (Marine Resources Research Institute, 1984). Of the two most frequently collected fish species at Year 1, 2, and 3 sampling stations, the fringed filefish (*Monacanthus ciliatus*) is considered a plant/detritus feeder (Randall, 1967), and the dusky flounder (*Syacium papillosum*) is considered a generalized benthic carnivore (Topp and Hoff, 1972).

Oil and gas drilling activities could affect fishes associated with live-bottom areas in several ways. Bottom disruption due to rig, platform, or pipeline emplacement, anchor deployment and retrieval, etc., may destroy or reduce habitat for those species that use an area for shelter. Bottom disruption and burial/sedimentation effects (e.g., due to deposition of discharged drilling muds and cuttings) on sessile epibiota could reduce food sources for species feeding on live-bottom epibiota. Infaunal abundance and species composition might be affected by deposition of drilling muds and cuttings, and this could affect feeding by live-bottom dwellers that feed on surrounding sand bottom. All of these effects should be local in scope and are not likely to have any overall effect on populations of commercially important fish species on the shelf.

Placement of drilling rigs and production platforms could also have beneficial effects in that additional habitat would be provided where there is currently little or no vertical relief. This artificial reef effect has been summarized in the Benthic Impacts section. In addition to the demersal, reef-dwelling fishes, schools of pelagic baitfishes (Sardinella, Decapterus punctatus) would be attracted to the structures. These species serve as prey for commercially and/or recreationally important pelagic fishes such as king mackerel, Spanish mackerel, greater amberjack, cobia, and little tunny.

Fish populations associated with offshore structures attract recreational fishermen. In the northern Gulf, there has been concern that the resulting recreational fishing pressure may deplete the stock of some sport fishes, such as red snapper (Gallaway, 1981). This question hinges on whether new offshore structures serve to funnel exploited populations to recreational fishermen or to tap "surplus" or currently unexploited stocks. In the case of red snapper populations off Texas and Louisiana, Gallaway and Lewbel (1982) suggest that the latter explanation is more likely.

Although fish populations in the vicinity of platforms are enhanced in comparison with those over nearby soft-bottom, trawling activities near platforms are limited due to the possibility of gear entanglement. A typical production platform is estimated to preempt three to five acres of trawling space (USDOI, MMS, 1984). Gear losses attributable to offshore petroleum structures are currently covered by a Fishermen's Contingency Fund administered by the National Marine Fisheries Service (USDOI, MMS, 1984).

A major oil spill contacting coastal estuarine habitats would present the most serious potential threat to fish populations, because many fishes use estuarine/nearshore areas as spawning or nursery grounds (USDOI, MMS, 1984).

Shellfish. Few commercially important shellfish species were frequently collected in our study. Some pink shrimp (Penaeus duorarum) were obtained in trawl samples from Year 3 Stations 44 and 51; during previous study years, pink shrimp were also obtained at soft-bottom Stations 6 (in the Sanibel grounds area) and 25 (in the Tortugas grounds area). Rock shrimp (Sicyonia brevirostris) were collected during Years 1 and 2, primarily at stations in 40 to 60 m depths. Spiny lobsters (Panulirus argus) were not collected in our samples; a few stone crabs (Menippe mercenaria) were collected at Year 3 Stations 44 and 45, and numerous stone crab pots were seen on the seafloor along the nearshore television transects. Major harvest areas for the latter three species are outside the immediate study area: most rock shrimp landings are from the northeastern Gulf of Mexico, whereas most spiny lobster and stone crab harvesting occurs in shallow nearshore waters off Monroe and Collier Counties (southwest Florida), respectively (USDOI, MMS, 1984).

Pink shrimp and most other common penaeids on the west Florida shelf are nocturnally active, generalized benthic carnivores that are preferentially associated with calcareous sand and shell rubble substrata (Huff and Cobb, 1979). Oil and gas exploration and development activities may adversely affect shrimp populations through localized habitat alteration due to placement of drilling rigs and platforms and deposition of drilling muds and cuttings. Such impacts would be localized in the vicinity of a rig or platform and would be unlikely to have any overall effect on shrimp populations. As noted for fishes, oil spills that contact estuarine bays and marshes present the most serious potential impact to these shellfish populations because these areas are used as spawning and/or nursery grounds.

8.4 SITE-SPECIFIC CONSIDERATIONS

Habitat characteristics will influence the likelihood and severity of the impacts described above.

Seafloor disturbance may have more serious and lasting consequences in live- than soft-bottom areas. Infauna are not as dependent on the macroscale seafloor topography as are live-bottom epibiota;

moreover, alterations in bottom configuration in soft-bottom areas eventually would be erased due to currents, surface waves (in shallow water), and infaunal bioturbation. In addition, infauna generally have high growth rates and short generation times in comparison with live-bottom epibiota such as scleractinian corals and large sponges. Thus, recovery would probably be more rapid in soft-bottom areas.

Recruitment of fishes to offshore structures might initially be more rapid in live-bottom areas than in soft-bottom areas due to the proximity of potential colonists. However, similar fish assemblages would likely develop eventually near structures in both live- and soft-bottom areas (Marine Resources Research Institute, 1984).

Drilling discharges are likely to have greater impacts at the shallow nearshore locations sampled during Year 3 than at middle and outer shelf locations sampled during previous study years. The greater the water depth, the greater the dispersion of a drilling mud plume before it reaches the seafloor; discharges in deep water result in thinner deposits than discharges in shallow water (Continental Shelf Associates, Inc., 1985c). (An accidental oil spill occurring at the sea surface also would be more likely to affect benthos in shallow, nearshore habitats because of similar dispersion considerations). On the other hand, water clarity impacts of drilling discharges may be less noticeable at some nearshore locations characterized by high ambient turbidity (e.g., Station 52).

Seagrasses and macroalgae associated with soft-bottom substrates may be especially sensitive to turbidity resulting from drilling discharges. During recent exploratory drilling on the continental shelf of the Florida Big Bend area, seagrasses (*Halophila* spp.) within 300 m of the drillsite apparently were decimated (Thompson, 1985). Chronic turbidity due to continuous discharge of fine drill cuttings may have been a contributing factor.

The location and leasing status of areas studied during Year 3 are also important considerations. Table 8.3 lists the lease block locations of all Year 3 sampling stations. None of the blocks are currently under lease. Moreover, under the restrictions likely to apply to upcoming lease sales, nearshore blocks containing the Year 3 stations sampled during this study could not be leased. Blocks containing Year 1 and 2 stations located on Transects C, D, and E (all south of 26°N latitude) would be subject to the lease stipulations cited in Section 8.1.

TABLE 8.3. LEASE BLOCK LOCATIONS OF SOUTHWEST FLORIDA SHELF REGIONAL BIOLOGICAL COMMUNITIES SURVEY (YEAR 3) STATIONS.

Station	Transect	Leasing Area and Block No.
LIVE-BOTTOM:		
44	B,G	Charlotte Harbor 697
45	G	Charlotte Harbor 962
47	C	Pulley Ridge 215
51	D	Miami 662
52	D	Miami 665
SOFT-BOTTOM:		
40	A	Charlotte Harbor 207
41	none	Charlotte Harbor 473
42	B	Charlotte Harbor 693
43	B	Charlotte Harbor 695
46	G	Charlotte Harbor 963
48	G	Pulley Ridge 217
49	none	Miami 355
50	none	Miami 617
52	D	Miami 665
53	none	Miami 888
54	E	Key West 133

8.5 IMPACT SUMMARY

Oil and gas related activities and general categories of potential impact on southwest Florida shelf benthos, as discussed in the preceding sections, are summarized in Table 8.4. Table 8.5 provides additional information concerning the timing and duration of impacts that might result from placement of an exploratory drilling rig or production platform in the vicinity of the Year 3 sampling stations.

TABLE 8.4. SUMMARY OF MAJOR OFFSHORE OIL-RELATED ACTIVITIES AND POTENTIAL BENTHIC IMPACTS.

Activity	Type of Impact			
	Seafloor Disturbance	Artificial Reef Effect	Drilling Mud and Cuttings Impacts	Oil Spill Impacts
Rig/platform emplacement	X	X		
Pipeline emplacement	X	X		
Routine drilling operations			X	X (blowout)
Transfer/transport of oil	X (anchoring)			X (spills, pipeline leaks)

TABLE 8.5. POTENTIAL IMPACTS OF EXPLORATORY DRILLING RIG OR PRODUCTION PLATFORM EMPLACEMENT IN THE VICINITY OF YEAR 3 SAMPLING STATIONS.

Impact	Timing/Duration	Habitat Considerations
Seafloor disturbance (crushing of benthos; resuspension of sediments; altered bottom topography)	Associated with discrete events such as rig emplacement, anchoring, etc.	Effects probably more severe and lasting in live-bottom areas.
Turbidity due to drilling mud discharges	Intermittent during drilling; short-lived impact during exploratory drilling but long-lived "chronic" impact during production drilling (e.g., multi-well platform)	Seagrasses, macroalgae, and zooxanthellate epifauna (some gorgonians, hard corals, and sponges) may be especially sensitive.
Sedimentation/burial by drilling muds and (primarily) cuttings	Cuttings deposition continuous during drilling; short-lived impact during exploratory drilling but long-lived "chronic" impact during production drilling. Drilling mud deposition intermittent and much lower in magnitude.	Some live-bottom epibiota probably sensitive to sedimentation. Soft-bottom infauna also sensitive to sediment composition. Deposition probably greater at shallow water depths.
Artificial reef effect	Continuous effect while a structure is present; short-term for exploratory rig, long-term for production platform.	Initial recruitment of fishes to offshore structures probably more rapid in live-bottom areas.
Oil spill impacts (various)	Could be associated with a discrete event (blowout) at exploratory rig or production platform. Chronic exposure to small leaks and spills also possible at production platform.	Greatest threat would be to wetlands and estuaries outside the immediate study area.

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Key participants in the study are listed below along with their roles and affiliations. Individuals with major responsibilities for project management or interpretation and synthesis are indicated by an asterisk (*).

<u>CONTINENTAL SHELF ASSOCIATES, INC.</u>

* Frederick B. Ayer, B.S. (Marine Biology, New College, 1974). Operations Manager.

Linda L. Balcer, B.A. (Journalism, Northern Illinois University, 1981). Report copy editor.

Robert W. Berry, B.S. (Oceanographic Technology, Florida Institute of Technology, 1980). Navigation and electronics technician.

Katharine End, A.S. (Oceanographic Technology, Florida Institute of Technology, 1981). Field sampling, Cruise III; sorting and identifications of live-bottom specimens.

Claudia G. Gettleson, B.A. (English, University of South Florida, 1971). Report copy editor.

* David A. Gettleson, Ph.D. (Biological Oceanography, Texas A&M University, 1976). Project Manager. Co-Chief Scientist, all cruises.

Bruce D. Graham, M.S. (Biological Science, Florida Institute of Technology, 1984). Field sampling, Cruises II and III. Sorting and identification of live-bottom specimens. Quantitative slide analysis of benthic still photographs.

* Alan D. Hart, Ph.D. (Oceanography, Texas A&M University, 1981). Data management and statistical analysis. Co-author of Chapter 2.

James P. Lamar, Jr., B.S. (Oceanographic Technology, Florida Institute of Technology, 1979). Navigation and electronics technician.

Robert Mulcahy, B.S. (Environmental Technology, Florida Institute of Technology, 1979). Field Operations Manager, Cruises I and III.

* Neal W. Phillips, Ph.D. (Ecology, University of Georgia, 1983). Final report editor. Author of Chapters 1, 2, 5, 8, and the Executive Summary. Co-author of Chapters 4 and 6.

Russell E. Putt, M.S. (Oceanography, Texas A&M University, 1982). Field sampling, Cruises II and III.

James D. Rosenbauer, B.S. (Biological Oceanography, Florida Institute of Technology, 1976). Field Operations Manager, all cruises.

Richard A. Shaul, Jr., M.S. (Biological Sciences, Florida Institute of Technology, 1981). Field sampling, Cruises II and III.

David B. Snyder, M.S. (Marine Biology/Ichthyology, Florida Atlantic University, 1984). Contributing author to Chapter 5.

* Keith D. Spring, M.S. (Biological Oceanography, Florida Institute of Technology, 1981). Assistant Project Manager. Co-Chief Scientist, all cruises. Laboratory manager for processing and identification of live-bottom station samples. Contributing author to Chapter 5.

* Robert C. Stevens, Jr., B.S. (Marine Science, U.S. Merchant Marine Academy, 1953). Contract administration and project management.

* M. John Thompson, M.S. (Marine Biology, Florida Atlantic University, 1974). Side-scan sonar and subbottom profiler operator, Cruise I. Analysis and interpretation of geophysical data. Co-author of Chapter 4.

Additional technicians involved in field and/or laboratory sample processing included Maryjon Large, Maryellen Lombardi, and Chris Olstad. The final report text was processed by Donna Baker, Kelly McDowell, Lynn

Powell, and Carole Owens. Figures were drafted by Lenny Albritton, Jim Barnes, and Carol Anderson.

MOTE MARINE LABORATORY

* Robert C. Brown, M.S. (Chemical Oceanography, Old Dominion University, 1981). Hydrocarbon analyses. Co-author of Chapter 8.

David A. Bruzek, M.S. (Marine Biology, Florida Institute of Technology, 1983). Field sampling, Cruise III; infaunal identifications.

* James K. Culter, M.A. (Zoology, University of South Florida, 1979). Infaunal sorting and identification; co-author of Chapter 6.

Susan Hofmann, B.S. (Southhampton College, 1980). Cruise II field sampling; infaunal sorting.

* Selvakumaran Mahadevan, Ph.D. (Biological Oceanography, Florida State University, 1977). Task Manager for soft-bottom station sampling and analyses.

Jay R. Leverone, B.S. (Biology, University of South Florida, 1976). Infaunal sorting and identification.

Nora V. Maddox, B.S. (Biology, University of Florida, 1976). Infaunal sorting and identification.

Jennifer Mapes, B.S. (Zoology, University of Florida, 1971). Infaunal sorting and identification (crustaceans).

* Richard H. Pierce, Jr., Ph.D. (Chemical Oceanography, University of Rhode Island, 1973). Principal investigator for hydrocarbon analyses. Co-author of Chapter 8.

Jay M. Sprinkel, B.A. (Zoology/Physiology, Miami University, 1971). Infaunal sorting and identification.

INDEPENDENT CONSULTANT

* Kenneth D. Haddad, M.S. (Marine Science, University of South Florida, 1980). Author of Chapter 3.

TAXONOMIC CONSULTANTS

A program such as this depends heavily on the availability of expert taxonomists to identify the large numbers of taxa collected. Taxonomists and their respective specialties are listed below. Their contribution to the program is greatly appreciated.

Taxonomists for Live-Bottom Epibiota

Mr. Steven M. Blair	Algae
Mr. R. Grant Gilmore	Ichthyofauna
Mr. Walter C. Jaap	Zoantharia
Mr. Rafael Lemaitre	Decapoda
Dr. Arthur J.J. Leuterman	Bryozoa
Ms. Jennifer Wheaton Lowry	Octocorallia
Dr. Patsy A. McLaughlin	Anomura, Cirripedia
Ms. Paula M. Mikkelsen	Bivalvia
Mr. John E. Miller, III.	Holothuroidea
Dr. Edward J. Petuch	Mollusca
Dr. Shirley A. Pomponi	Porifera
Dr. D. Keith Serafy	Echinoidea
Dr. Richard L. Turner	Ophiuroidea, Asteroidea
Dr. James A. Vallee	Ascidiacea
Dr. David L. West	Hydrozoa

Taxonomists for Soft-Bottom Infauna

Dr. Richard W. Heard, Jr.	Crustacea
Mr. Thomas H. Perkins	Polychaeta
Dr. Rosalie Maddocks	Podocopid Ostracoda
Dr. Louis Kornicker	Myodocopid Ostracoda

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.