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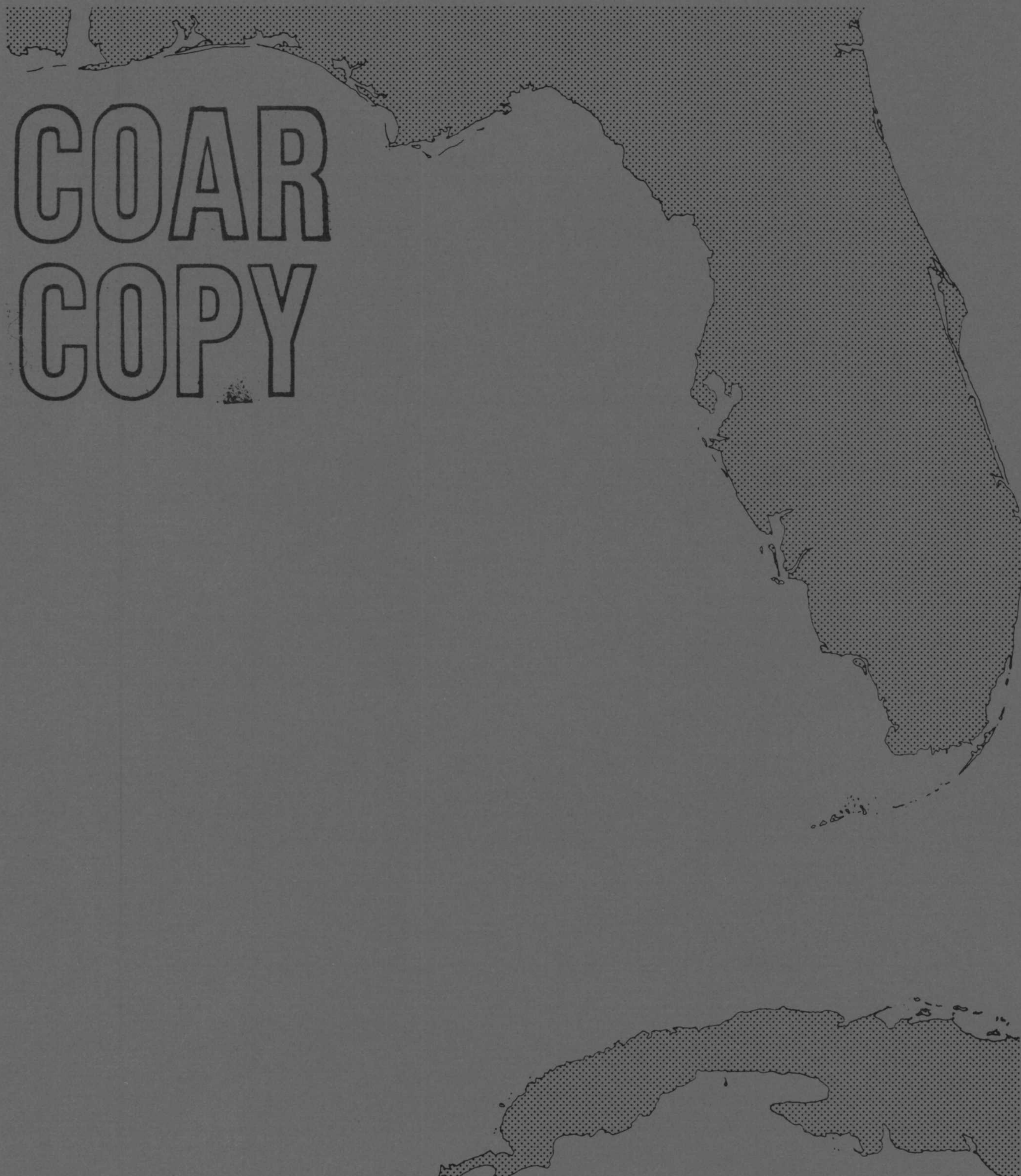

Prepared for:
U.S. Department of the Interior, Minerals Management Service
Gulf of Mexico OCS Region, Metairie, Louisiana
Contract 14-12-0001-29142
April 15, 1983

FINAL REPORT

SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY - YEAR 1

Prepared for
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
Metairie, Louisiana

Contract 14-12-0001-29142

April 15, 1983

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

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Continental Shelf Associates, Inc.
CSA
"Applied Marine Science and Technology"

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1.0 INTRODUCTION

1.1 Introduction

Expeditious development of oil and gas deposits beneath the Outer Continental Shelf (OCS) is essential to meet the present and future energy requirements of the United States. The Secretary of the Department of the Interior has been designated by the Outer Continental Shelf Lands Act of 1953 (43 U.S.C. 1331-1343), as amended by the Outer Continental Shelf Lands Act Amendments of 1978, to manage and regulate many of the activities that relate to the leasing, exploration, development and production of OCS mineral resources outside the territorial boundaries of individual states. Many of the Secretary's responsibilities were originally delegated to the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS). More recently, to streamline increasingly complex OCS management activities and speed up the leasing process, OCS responsibilities dispersed among different government programs and branches have been consolidated within the newly created (January 19, 1982) Minerals Management Service (MMS). This new agency now carries prime responsibility for all aspects of OCS leasing and resource management.

The National Environmental Policy Act (NEPA) of 1969 requires all federal agencies to consider environmental effects of proposed activities, and calls for the protection of marine and coastal environments. In response to NEPA and subsequent federal regulations, BLM initiated the Environmental Studies Program, beginning in the Gulf of Mexico in 1973. The principal objective of this studies program is to:

> "...establish information needed for prediction, assessment, and management of impacts on the human, marine, and coastal environments of the OCS and nearshore areas which may be affected by oil and gas activities in such area or region" (Federal Register 43:3893, January 27, 1978; 43 CFR part 3301.7).

More specific objectives of the MMS Environmental Studies Program, for all OCS areas, are as follows:

- To provide information about the OCS environment that will enable the Department of the Interior and MMS to make sound management decisions regarding the development of mineral resources on the federal OCS.

- To gather information that will enable MMS to identify elements of the environment likely to be affected by oil and gas exploration and development.

- To establish a basis for predicting the effects on the environment of OCS oil and gas activities.

- To measure the effects of oil and gas exploration and development on the OCS environment. These data may result in modification of leasing and operation regulations to permit efficient recovery of resources with maximum environmental protection.

The coastal area and continental shelf off southwest Florida have been less thoroughly studied than most other areas around the Gulf of Mexico and marine environmental information is scarce. The possible existence of oil beneath the shelf, the demand for new domestic energy sources, and the recognition of the lack of basic environmental information accented the need for the Southwest Florida Shelf Ecosystems Program, the initial phase of which is described in this report.

1.1.1 Relevance

Under the U.S. Department of the Interior's accelerated 5-year leasing program approved by the President and the Congress in July, 1982, the MMS is proposing to offer for lease certain tracts in the eastern Gulf of Mexico. Proposed lease offerings are presently scheduled for November 1983 and November 1985.

The southwest Florida continental shelf includes sandy seafloor substrates, "live bottom" and other areas which may favor the development and concentration of marine biota. The distribution of these bottom types and their significance in relation to the regional marine benthic and water column ecosystem is not well known. The BLM (now MMS) therefore determined that a study should be conducted to describe the ecology of the southwest Florida shelf with emphasis on mapping the benthic environment (including such features as sand bottom, "live bottom", debris, gas seeps, karst, surface faults or other seafloor anomalies). For the purpose of this proposed study, BLM defined the term live bottom as:

"...an area which contains biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans and hard corals living upon or attached to naturally occurring hard or rocky formations with rough, broken or smooth topography; and whose lithotope favors the accumulation of vulnerable species -- e.g., turtles and certain pelagic or demersal fishes" (BLM Solicitation No. AA851-RPO-21, April 1, 1980 and USDI, 1981.).

Some additional explanation of the terms live bottom, hard bottom and soft bottom, as applied throughout this report, is presented in Section 1.4. While live bottoms were to be investigated as part of the study proposed by BLM, other seafloor substrates (mud, sand, etc.) were to be equally thoroughly investigated and not considered any less important.

1.1.2 Overall Program Objectives

The overall objectives defined by BLM for the Southwest Florida Shelf Ecosystems Study are as follows:

(1) To determine the potential impact of OCS oil and gas offshore activities on live bottom habitats and communities, which are integral components of the southwest Florida shelf ecosystem.

(2) To produce habitat maps that show the location and distribution of various bottom substrates. This was to be done by exploring several widely spaced transects across the southwest Florida shelf.

(3) To broadly classify the biological zonation across and along the shelf, projecting the percent of the area covered by live/reef bottoms and the amount covered by each type of live/reef bottom.

1.2 Program Scope

Since the Southwest Florida Shelf Ecosystems Study is a multi-year, multi-disciplinary program, the following paragraphs are included to provide the reader with a general perspective on first, second and third year activities within the Study. Publication of this Final Report will conclude the Year One program; the second and third year programs are both scheduled for completion in 1983.

A listing of all research cruises completed through September, 1982, is presented in Table 1-1. The principal purpose of each cruise, along with its

Table 1-1. Southwest Florida shelf ecosystems study: Cruises completed through September 1982.

Cruise Number (Departure and Return Date)	Principal Cruise Purpose	Cruise Designation In WCC Reports
YEAR ONE (AA851-CT0-50)		
Cruise I (9-10-80 to 10-8-80)	Bathymetric, Seismic and Side Scan Sonar Surveys	Geophysics Cruise
Cruise II (10-10-80 to 10-21-80)	Underwater Television and Still Camera Photography	Television Cruise
Cruise III (10-25-80 to 11-23-80)	Biological and Hydrographic Sampling	Fall Cruise
Cruise IV* (4-22-81 to 5-5-81)	Biological and Hydrographic Sampling	Spring Cruise
YEAR TWO (AA851-CT1-45)		
Cruise I (7-8-81 to 7-15-81)	Underwater Television, Still Camera Photography and Geophysical Profiling	Year Two Television/ Geophysics Cruise
Cruise II (7-16-81 to 8-5-81)	Biological and Hydrographic Sampling	Summer Cruise
Cruise III (1-28-82 to 2-15-82)	Biological and Hydrographic Sampling	Winter Cruise
YEAR TWO - MODIFICATION		
Cruise I (4-1-82 to 4-7-82)	Hydrography and Primary Production	--
Cruise II (9-12-82 to 9-19-82)	Hydrography and Primary Production	--

* Deferred by BLM from January, 1981.

designation in subsequent Woodward-Clyde reports, is also included. A listing of all reports generated from the Southwest Florida Shelf Ecosystems Study and previously submitted to BLM/MMS is presented at the end of this section.

1.2.1 Year One

During the first year of the program, a variety of geophysical, hydrographic, and biological parameters were studied along five east-west transects (Transects A-E) across the southwest Florida shelf. Final study transect locations are shown in Figure 1-1. Geophysical data -- bathymetric, seismic and side scan sonar surveys -- were collected along each transect from about 40-m water depth out to 200-m water depth. Visual data -- combining black and white underwater television and 35-mm, still color photography -- were collected in depths between 20 and 200 m. Finally, a broad range of hydrographic measurements, water column samples, bottom sediment and benthic biological samples (e.g., triangle dredge, otter trawl and box cores) were collected from 30 stations located along the various cross-shelf study transects.

Contract specifications called for the sampling station locations to be selected within three bathymetric zones along each transect: 20 to 45-m, 45 to 70-m, and 70 to 100-m depths. One live bottom/reef site and one sand/mud bottom site were to be sampled within each depth zone. This was not possible in all cases, due to the actual distributions of "live" and "soft" bottom types along each transect (see Section 3.3.4 for a discussion of station selection rationale). Final first year sampling locations are shown in Figure 1-2. Each of these sampling stations was occupied twice during the first year, once during a Fall Cruise (October-November 1980) and again during a Spring Cruise (April-May 1981).

The geophysical and visual data were to be combined with results obtained from benthic sampling to refine the gross sea bottom/substrate type identifications into interpretations of specific community types, with emphasis on speciation, diversity, biomass, recreational and commercial value.

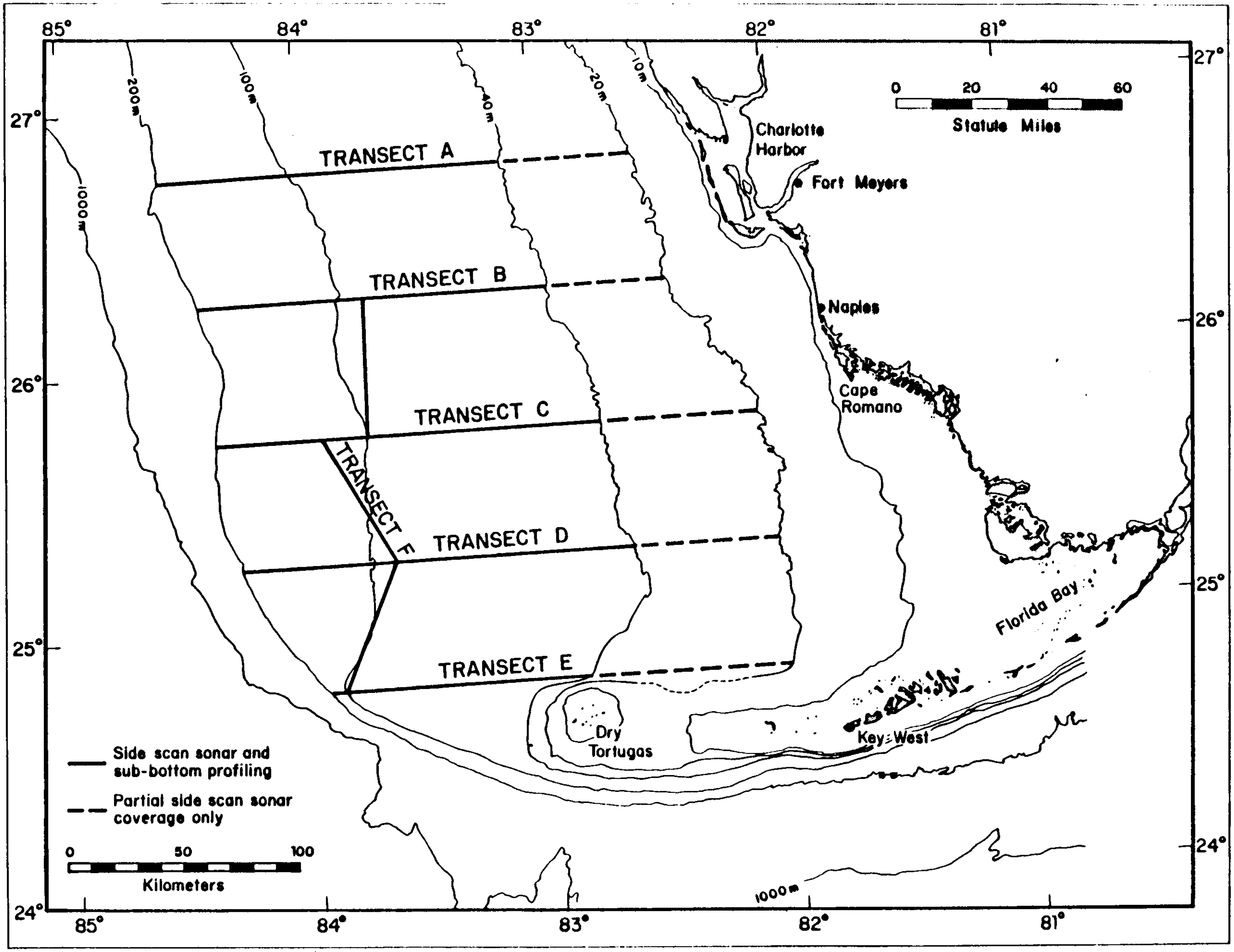

Figure 1-1. Geophysical survey transects.

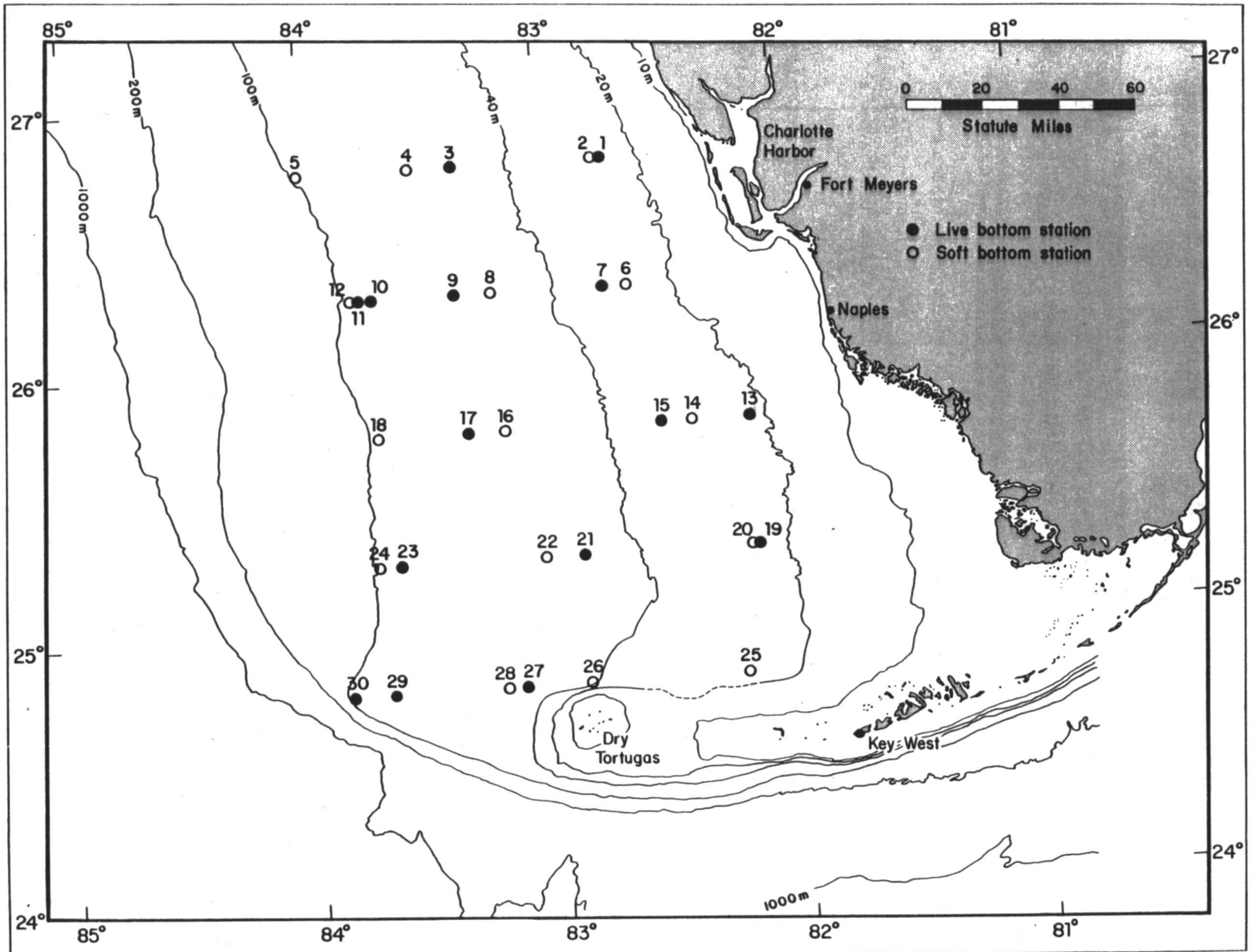

Figure 1-2. Sampling station locations for biological/hydrographic studies.

1.2.2 Year Two

During the second year, geophysical information was collected along a new north-south transect (Transect F), at about 100-m water depth, that tied together several of the previously surveyed east-west transects (Transects B-E). Visuals data, again including underwater television and still camera photography, was extended along each east-west transect from 100 to 200-m water depths, as well as along Transect F.

Twenty-one of the 30 hydrographic and benthic biological sampling stations occupied during Year One, were resampled twice more. Once during a Summer Cruise (July-August, 1981) and again during a Winter Cruise (January-February, 1982). For this set of stations hydrographic and biological data are now available on a seasonal (quarterly) basis. In addition, nine new hydrographic and benthic biological stations were established on Transects A through E, in water depths ranging from 100 to 200 m. Each of these stations was sampled during both the Summer and Winter Cruises.

Overall program objectives for Year Two are the same as for Year One; however, the volume of data available for analysis has been greatly increased. A more complete understanding of possible seasonal changes should also be forthcoming.

1.2.3 Year Two - Modification

This contract, essentially a third year program, is significantly different from the first two years. Two seasonal hydrographic cruises (April and September 1982; Table 1-1) will provide data that can be synthesized with Year One and Two results to yield a hydrographic analysis and atlas of water quality parameters (temperature, salinity, transmissivity, chlorophyll _a_, phosphates, nitrates, nitrites and dissolved silica). Primary productivity measurements taken during both cruises will allow meaningful interpretations to be placed on nutrient and other physio-chemical data. A simultaneous overflight by the NASA Ocean Color Scanner during the April cruise will allow chlorophyll and productivity to be estimated throughout the region during the spring bloom, a period of great importance. Additionally, optical oceanographic measurements taken during the April cruise will allow reduction of the Color Scanner data, and yield data concerning the apparent unusual depth of significant photosynthetic activity in the area, and the occurrence of turbidity "fronts" encountered during previous cruises.

The overall goal of the Year Two Contract Modification is to synthesize existing and newly obtained hydrographic and primary productivity data into an overview of the driving energetic forces within the southwest Florida shelf regional ecosystem.

1.3 Specific Study Objectives

In addition to the overall program objectives and program scope outlined above, more specific study objectives were identified under BLM Year One contract requirements for data interpretation and synthesis:

(1) Characterization of individual study sites:

- bottom type per unit area, topographic relief, habitat complexity, etc., at each study site.
- percentage of epibenthic growth on each substrate, at each study site, for each sampling period.
- community structure, including ranked species abundances, apparent or actual biomass, faunal affinities among live bottom study sites, and species diversities of benthic fauna and macroalgae.

(2) General characterizations of bottom areas and inter-site comparisons:

- gross characterization of broad seafloor areas not selected as "study sites".
- assessment of live bottom areas supporting greatest standing crop or appearing most productive. Possible controlling factors.
- relationship between live bottom community characteristics and seafloor relief; comparison with artificial reefs.
- intercomparison of shelf benthic communities (within and between bathymetric zones; spatial and temporal variability).
- observed relationships between live bottom areas, fish spawning, and juvenile fish distributions.

- development of conceptual models (i.e., qualitative portrayals of energy flows) for each benthic ecosystem identified, with major emphasis on identifying potential impacts on fisheries resources.

- apparent health of benthic communities considering prevalence of "red tide" kills on the west Florida shelf.

(3) Assessment of impact/enhancement potential:

- identify features of bottom types that make them "sensitive" to offshore oil and gas activities. (Sensitive, as used here, means a potential for reduction of relative abundance or standing stock of various fishes or benthic organisms.)

- potential for enhancement by emplacement of offshore structures (artificial reefs; oil and gas platforms).

- prediction of short (ca. 1 year) and long (ca. 5-10 years) term impacts, both detrimental and beneficial, that might occur if an exploratory drilling rig or production platform was emplaced immediately adjacent to each study site.

(4) Methodology evaluation:

- evaluation of, and recommendations for, methods of sampling, surveying and observation at similar future study sites.

- recommendations for study methods to monitor the effects, if any, of exploratory drilling activities.

(5) Watermass characterization:

- possible sources and flux of inorganic nutrients.

- possible forcing factors in primary production (based upon chlorophyll a, nutrients, and light penetration).

- possible interaction between marine shelf water and freshwater outflow from the Florida Everglades (based upon salinity and yellow substance).

(6) Recommendations for future studies.

Some of the specific study objectives listed above have not yet been fully accomplished, nor are all thoroughly covered in this Final Report. Interruption of the Fall Cruise by a hurricane and BLM's rescheduling of Cruise IV from January to April-May, 1981, slowed progress. Far more significantly, the biological sampling program yielded double the volume of material and nearly twice the number of taxa, that had been predicted from an analysis of previously available Florida shelf studies. This substantially added to laboratory and data analysis tasks (and costs), consequently restricting the level of detail that could be accomplished for this report. Woodward-Clyde anticipates that these omissions will be more completely covered in the Year Two and Year Two - Modification Final Reports, following a more intensive data analysis effort.

1.4 Explanation of Terminology

1.4.1 Live Bottom, Hard Bottom, and Soft Bottom

The first known reference to live bottom areas in the scientific literature was made by Struhsaker (1969). He defined the live-bottom habitat as small areas of broken relief with a rich assemblage of sessile invertebrate fauna and fishes. This definition is similar to the expanded definition used by the BLM/MMS and already cited above (Section 1.1.1); this definition has been used throughout this program and is used herein.

Hard bottom may either outcrop on the seafloor and be of high, medium or low relief, or be covered by a veneer of sand of variable thickness. Rocky outcrops are probably always covered with epifauna and have associated fish populations (i.e., live bottoms), though the density and composition may be quite variable. The hard bottoms that are covered by a veneer of sand may also support a variable biomass and number of species depending on the thickness and mobility of the sand layer. If the sand layer is too thick the area would not support an attached epifauna (i.e., barren sandy bottom), but if the layer is thin, a relatively large number of attached biota (anchored to the buried hard bottom) and fish may be present (i.e., live sandy bottom). The term hard bottom or hard ground has been used extensively in the literature (Continental Shelf Associates, Inc., 1980), while live bottom has been used infrequently. When the term live bottom has occurred it has often been used synonymously with hard bottom (Marine Resources Research Institute, 1981) or has been discarded in favor of the term hard bottom (Continental Shelf Associates, Inc., 1979). Since the BLM definition of live bottom contains reference to hard bottom (i.e., "... hard or rocky formations...") it encompasses both a geological and biological description. In the content of this report, hard bottom will refer only to the seafloor substrate.

Soft bottom is defined as that substrate which will support macroinfauna (worms, crustaceans, bivalves, etc.) and epifauna (such as starfish), but not attached epifauna (sea whips, sponges, etc.). Soft bottom areas, in this report, are defined as those areas that do not support an attached macroepifauna density of more than approximately one individual per square metre. This definition is necessitated by the extreme variability of the apparent thickness of the sand veneer over large areas of low-relief hard bottom and the subsequent patchiness of sparsely distributed attached epifauna.

1.4.2 Inner, Middle, and Outer Shelf

The following subdivisions of the southwest Florida shelf have been used throughout this report:

Inner Shelf:	0 to 40-m water depths
Middle Shelf:	40 to 100-m water depths
Outer Shelf:	100 to 200-m water depths

These designations were originally established to reflect differences between the first and second year contract scope, as well as preliminary geophysical interpretations.

First year geophysical surveys were conducted, across the shelf in 40 to 200-m water depths as contracted, while visual data, hydrographic and biological samples were to be collected from 20 to 100-m water depths. (In fact, Woodward-Clyde was able to "bootleg" some additional geophysical data from 20 to 40-m water depths concurrently with the visuals observations during the Year One Television Cruise.) The second year contract extended the visuals data, hydrographic and biological sampling out to 200-m water depths. This difference in the timing and availability of various data sets during the first year contributed to an arbitrary subdivision of the shelf as noted above. (Inner shelf -- visuals data only; middle shelf -- geophysical and visuals data both available; outer shelf -- geophysical data only.) As the geophysical results (Section 2.0) were worked up, the division of the shelf, as noted, was supported by more objective criteria. The benthic biological data were found to support the three-fold subdivision of the shelf in a general manner, however, exceptions to the arbitrary depth limits were evident. The biological results favored a further subdivision of the Middle Shelf into Inshore and Offshore regions (Section 11.0, Figure 11-20), but this is less apparent from the geophysical and visuals observations.

1.5 Base Maps and Lease Blocks

To facilitate comparisons among different data sets many of the first year results have been presented visually in this report on standard lease area base maps (e.g., Figures 1-1,2,3). The map used is an exact half-scale reduction of the "Visuals" base map (1:1,200,000) included in the Draft Regional Environmental Impact Statement for the Gulf of Mexico (USDI/MMS, August 1982). The base map utilizes the Universal Transverse Mercator (UTM) system.

The southwest Florida shelf study region is shown in Figure 1-3, superimposed with the MMS lease block grid. This grid system divides OCS areas into large rectangular sections known as "sheets". Each sheet has been assigned a unique name (e.g., Charlotte Harbor, Pulley Ridge, NG 16-16, etc.). Sheets are further subdivided into lease blocks or squares, 4,828 m on each side and containing 2,331 hectares, which have been identified by MMS for possible sale and development. For purposes of identification and sale, lease blocks are numbered within each sheet.

1.6 Prior Leasing History

Between 1947 and 1963, all territorial waters of Florida in the Gulf of Mexico were leased for petroleum exploration. Industry has relinquished most of the leases with the exception of several located between Apalachicola Bay and Naples. From 1947 to 1968, eight wells were drilled, and a few in the Florida Bay area yielded 50-100 barrels/day (b/d). Commercial production was deemed unfeasible at that time. Since then federal lease sales have been conducted

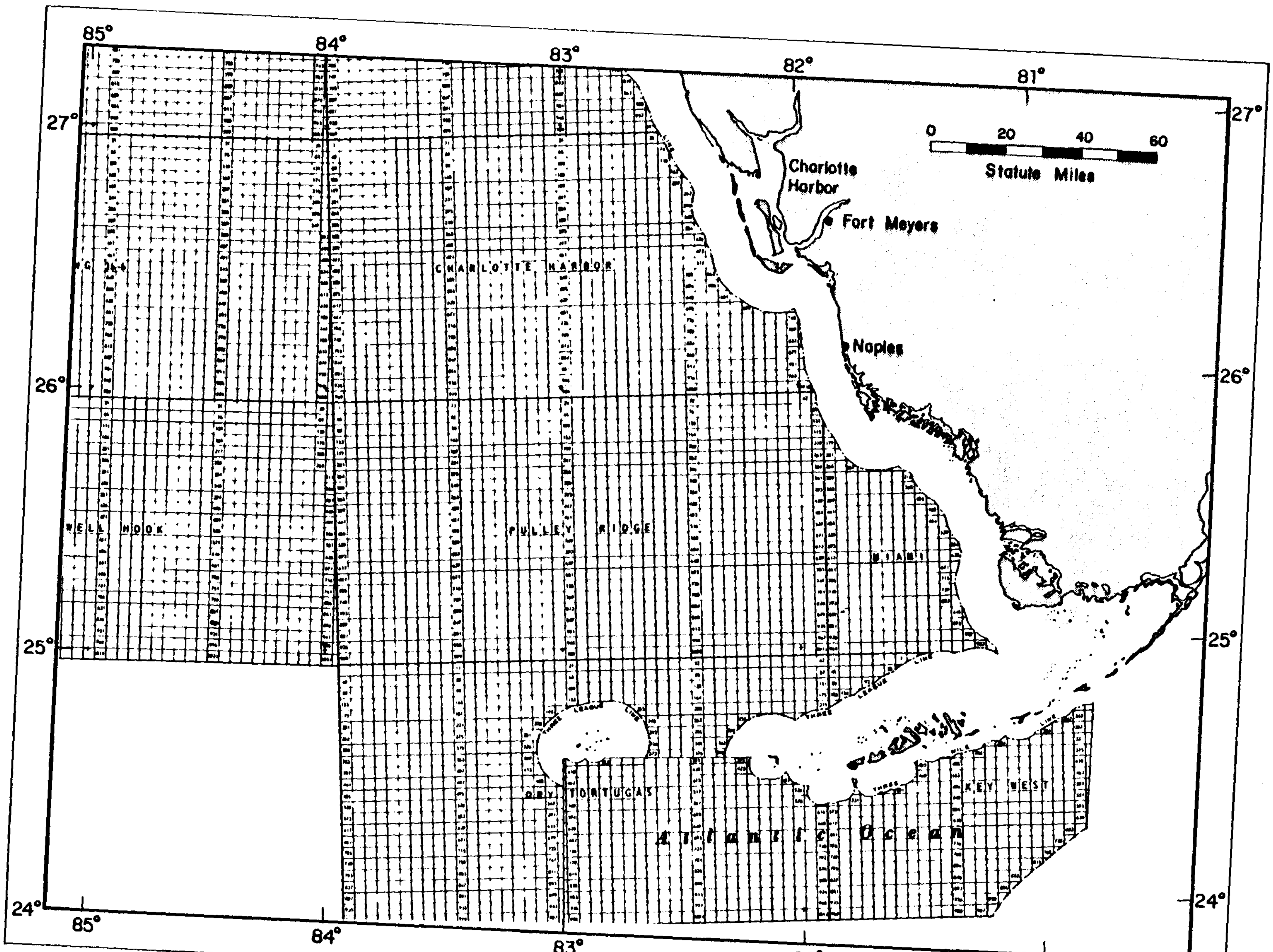

Figure 1-3. Southwest Florida shelf lease block grid.

for tracts in the southwest Florida region in 1973 (Sale 32), 1976 (Sale 41), 1978 (Sale 65), 1981 (Sale 66), 1982 (Sale 67 and Sale 69, Part I), and 1983 (Sale 69, Part II). Additional lease offerings are presently scheduled for November 1983 and November 1985 (USDI Final 5-Year OCS Oil and Gas Leasing Schedule. July 1982). The locations of active, recently offered (Sale 69, Part II) and expired leases within the study region are shown in Figure 1-4. In the eastern Gulf of Mexico off the Florida coast, 853 lease blocks have been offered for sale to date, 226 have been leased, and 36 exploratory wells have been drilled. To date, no wells have produced commercial quantities of hydrocarbons (Rinkel, 1982).

Five potential gas and oil-producing basins are thought to occur off the west coast of Florida. The region from Fort Myers south to the Keys and the continental slope and basin are the two provinces that are currently being investigated most intensely by the oil industry. The State of Florida recently analyzed drilling patterns in OCS frontier areas in Florida and concluded that about five or six exploratory wells will be drilled in each new lease tract area. Once drilling is initiated in each of the potentially producing areas, further drilling will be limited to one or two wells, unless a significant find is discovered. Several platforms may be installed during the development phase in each lease area (Rinkel, 1982). These findings based on an analysis of drilling trends are much more conservative than those presented in the Final Environmental Impact Statement for Proposed Lease Sales 67/69 and in a recent document prepared by the Florida Office of Planning and Budgeting (Hodecker, 1981), but they may be more in line with the oil industry's intentions to develop the area. Exploration efforts are undoubtedly going to increase in southwest Florida and offshore. The extent of development depends on whether a successful set of wells are drilled and when.

1.7 Final Report Organization

The entire Year One Final Report consists of four separate volumes: this Final Report technical volume, two appendix volumes (Appendix A Methodology and Appendix B Supporting Data), and an Executive Summary.

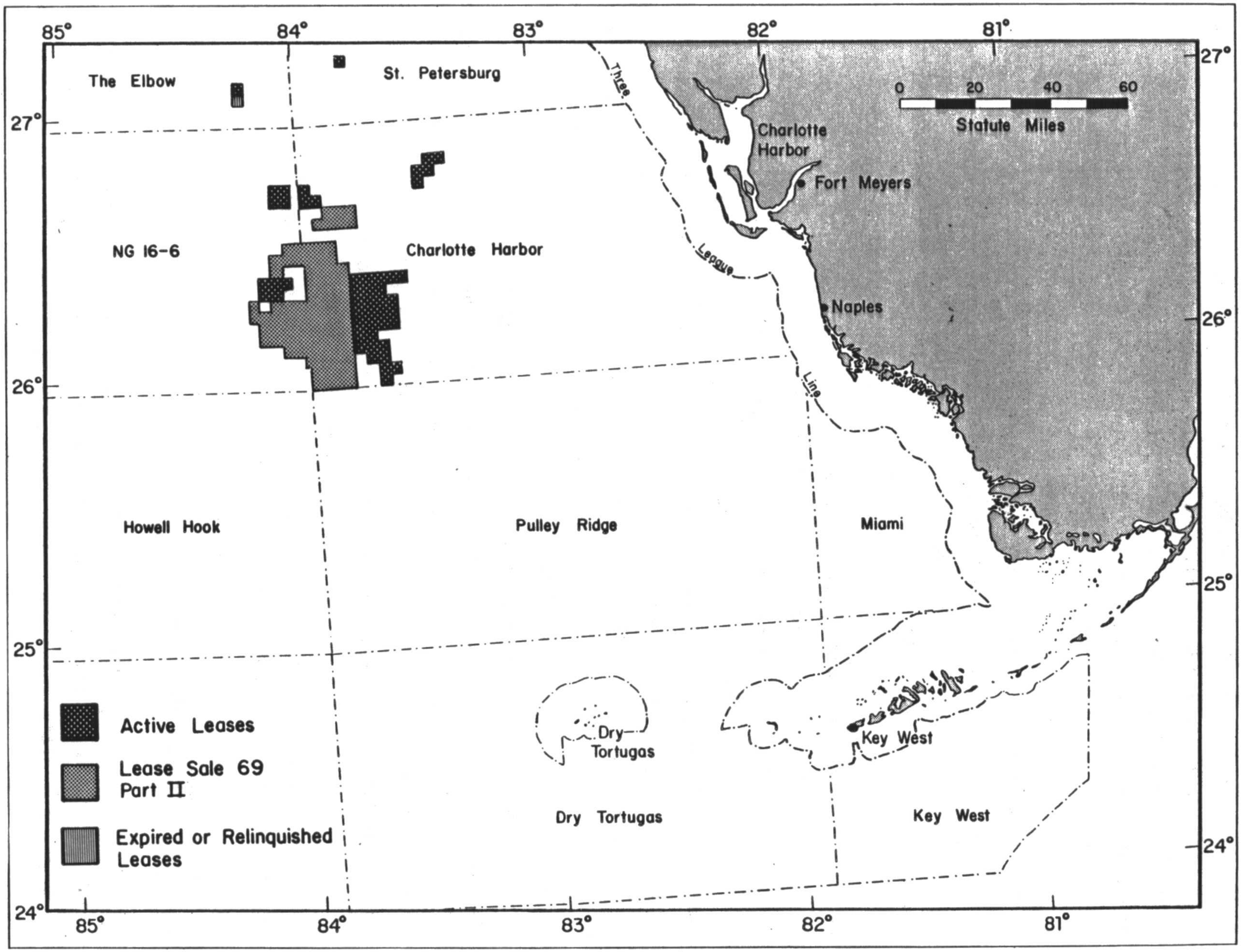

Figure 1-4. Southwest Florida shelf active, recently offered, and expired lease tract areas.

1.8 Southwest Florida Shelf Study Reports Previously Submitted to BLM/MMS

Woodward-Clyde Consultants. 1981. Southwest Florida shelf ecosystems study. Summary cruise report. Cruise I - Geophysics. Prepared for Bureau of Land Management (2-10-1981). 128 pp.

Woodward-Clyde Consultants. 1982. First ternary eastern Gulf of Mexico studies meeting, October 15-16, 1981, Tallahassee, Florida. Proceedings. Prepared for Bureau of Land Management (2-26-1982). 75 pp.

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Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1981. Southwest Florida shelf ecosystems study. Summary cruise report. Cruise II - Underwater television and still camera photography. Prepared for Bureau of Land Management (2-11-1981). 36 pp.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1981. Southwest Florida shelf ecosystems study. Summary cruise report. Cruise III - Biological and hydrographic sampling. Prepared for Bureau of Land Management (3-25-1981). 75 pp.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1981. Southwest Florida shelf ecosystems study. Summary cruise report. Cruise IV - Biological and hydrographic sampling. Prepared for Bureau of Land Management (7-20-1981). 42 pp.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1981. Southwest Florida shelf ecosystems study - Year 2. Summary cruise report. Cruise I - Underwater television, still camera photography and geophysical profiling. Prepared for Bureau of Land Management (8-12-1981). 77 pp.

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Hodecker, E.A. 1981. A Florida scenario of oil and gas development in the eastern Gulf of Mexico. Executive Office of the Governor, Office of Planning and Budgeting, Tallahassee, Florida. 25 pp.

Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department and Coastal Resources Division Georgia Department of Natural Resources. 1981. South Atlantic OCS area living marine resources study. A report for the U.S. Dept. of Interior, Bureau of Land Management OCS Office. Washington, D.C. Contract No. AA551-CT9-27.

Rinkel, M.O. 1982. Statement to the subcommittee on oversight and investigations, committee on interior and insular affairs. U.S. House of Representatives on the July 1981 5-year offshore oil and gas leasing program and other related OCS proposals. 14 June 1982. Presented on behalf of the State of Florida. 14 pp.

Struhsaker, P. 1969. Demersal fish resources: composition, distribution, and commercial potential of the continental shelf stocks off southeastern United States. Fish Ind. Res. 4(7):261-300.

United States Department of the Interior, Bureau of Land Management. 1981. Final environmental impact statement, proposed OCS oil and gas sales 67 and 69. 300 pp.

United States Department of the Interior, Minerals Management Service. 1982. Draft regional environmental impact statement, Gulf of Mexico (Proposed OCS oil and gas sales 72, 74, and 79). 735 pp.

2.0 MARINE GEOPHYSICAL INVESTIGATIONS

2.1 Introduction

The marine geophysical investigation was designed as a reconnaissance survey of the southwest Florida continental shelf. The survey area extends from Port Charlotte to the north to the Dry Tortugas on the south. The eastern boundary is the 40-m isobath and western boundary is the 200-m isobath. This is an area where the present knowledge of the marine habitat and subbottom geology is very limited or generally unknown.

The specific objectives of the marine geophysical investigation were:

- To provide reconnaissance information on the surficial and subbottom sediment and rock distributions that, when analyzed in conjunction with "ground-truth" data (underwater television, still camera photography, and bottom sediment and biological samples), would permit the identification and mapping of marine habitat types across the southwest Florida shelf.

- To identify categories of bottom and subbottom features that could represent potential geologic hazards or geologic design constraints to sea floor oil and gas operations.

2.2 Geophysical Surveys

2.2.1 Survey Plan

The geophysical survey plan was designed by the Minerals Management Service. Five east-west transects and one north-south transect (Figure 2-1) were surveyed with a multi-system, high-resolution geophysical survey. The east-west transects consisted of three parallel survey lines spaced at approximately 800 m (0.5 mi)[1]. The survey lines were designed to run through

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[1] Throughout this report "mi" denotes statute mile and "nmi", nautical mile (1 mi = 0.869 nmi = 1.609 km).

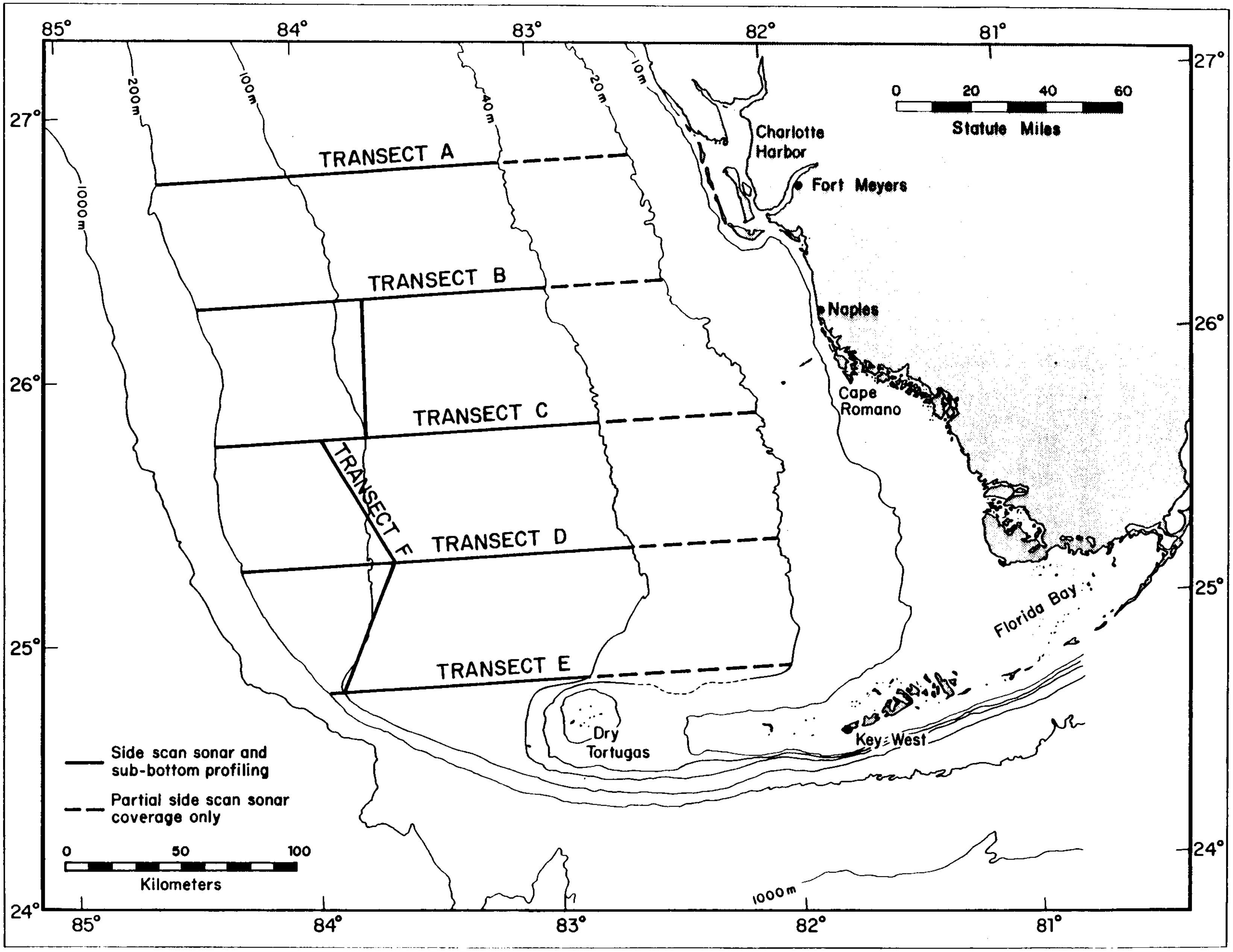


Figure 2-1. Geophysical survey transects.

the central area of the lease blocks as shown in Figure 2-2. Each survey line extended from the 40-m isobath, offshore to a water depth of approximately 200 m. Data along these transects were collected during Year 1 Cruise I which lasted from 8 September to 8 October 1980. Bathymetric and side scan sonar data were also collected over selected portions of the center line of each transect between 20-m to 40-m water depths during the subsequent underwater television and still camera photography cruise (Year 1, Cruise II).

Transect F (Figure 2-1) was surveyed as part of Year 2, Cruise I, during July 1981. It consists of a single line trending approximately north-south between Transects B and E in the approximate water depth range of 80 m to 120 m. Additional geophysical data were also collected on Transects A through E over the 100 to 200-m water depth range during this cruise.

The geophysical surveys consisted of simultaneous data collection from the following systems:

Navigation	Decca Hi-Fix and Loran C.
Depth Sounders:	Raytheon DFS-600 or Raytheon DE-719B.
Side Scan Sonar:	EG&G SMS 960 sea floor mapping system, or Klein Model 400 hydroscan system.
Subbottom Profiler:	EG&G UNIBOOM and Teac 4-channel tape recorder.

A brief description of the instrumentation is given in the following sections. The layout of the equipment aboard the survey vessel is shown in Figure 2-3 and specifications of the instrumentation are given in Appendix A-7.

2.2.2 Navigation

Offshore positioning for the Geophysical Survey (Year 1, Cruise I) and Underwater Television and Still Camera Survey (Year 1, Cruise II) of Transects A to E was subcontracted to Racal/Decca of Houston, Texas. The primary navigation system consisted of a Decca Hi-Fix radio-positioning system and a

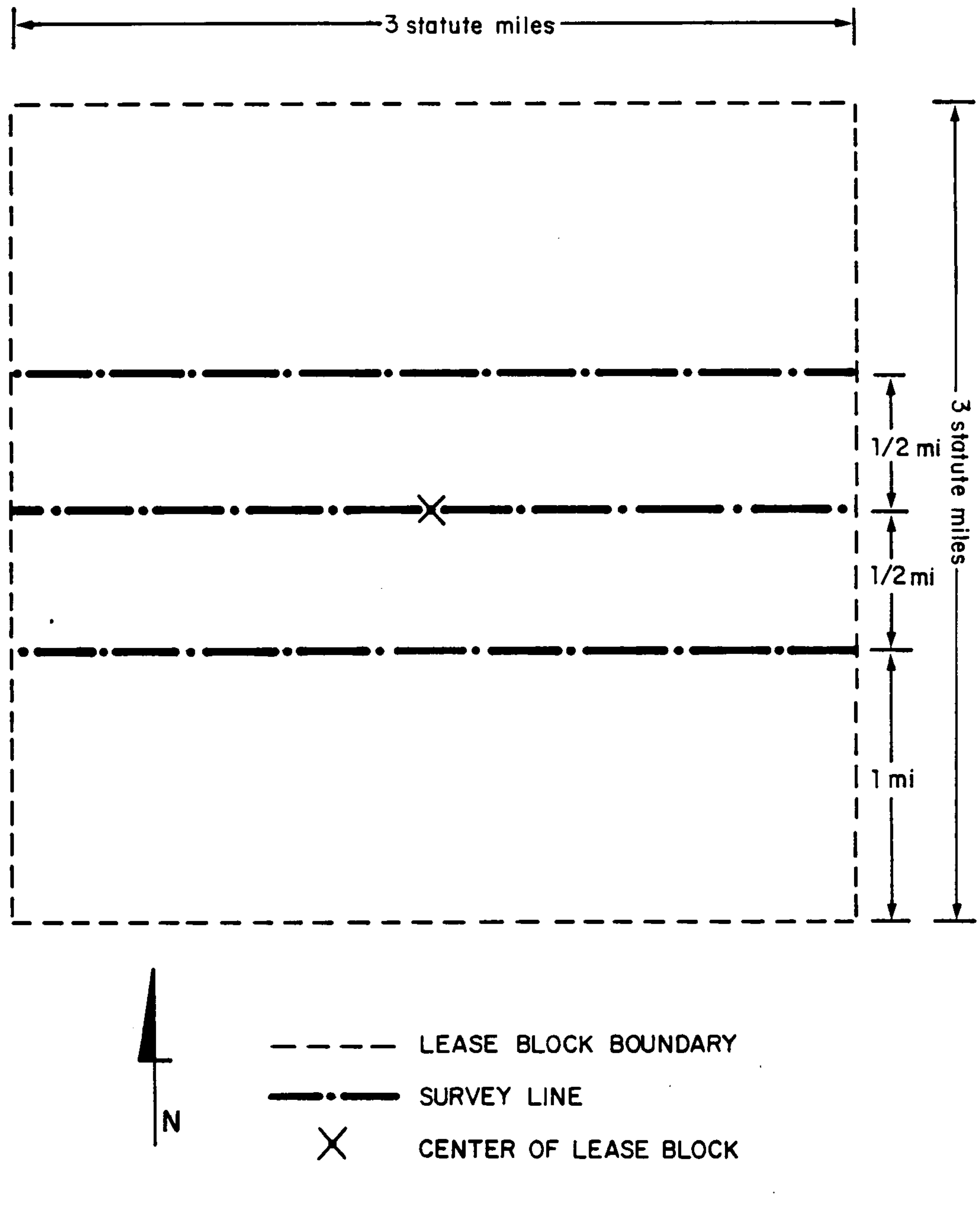


Figure 2-2. Geophysical survey pattern within lease blocks.

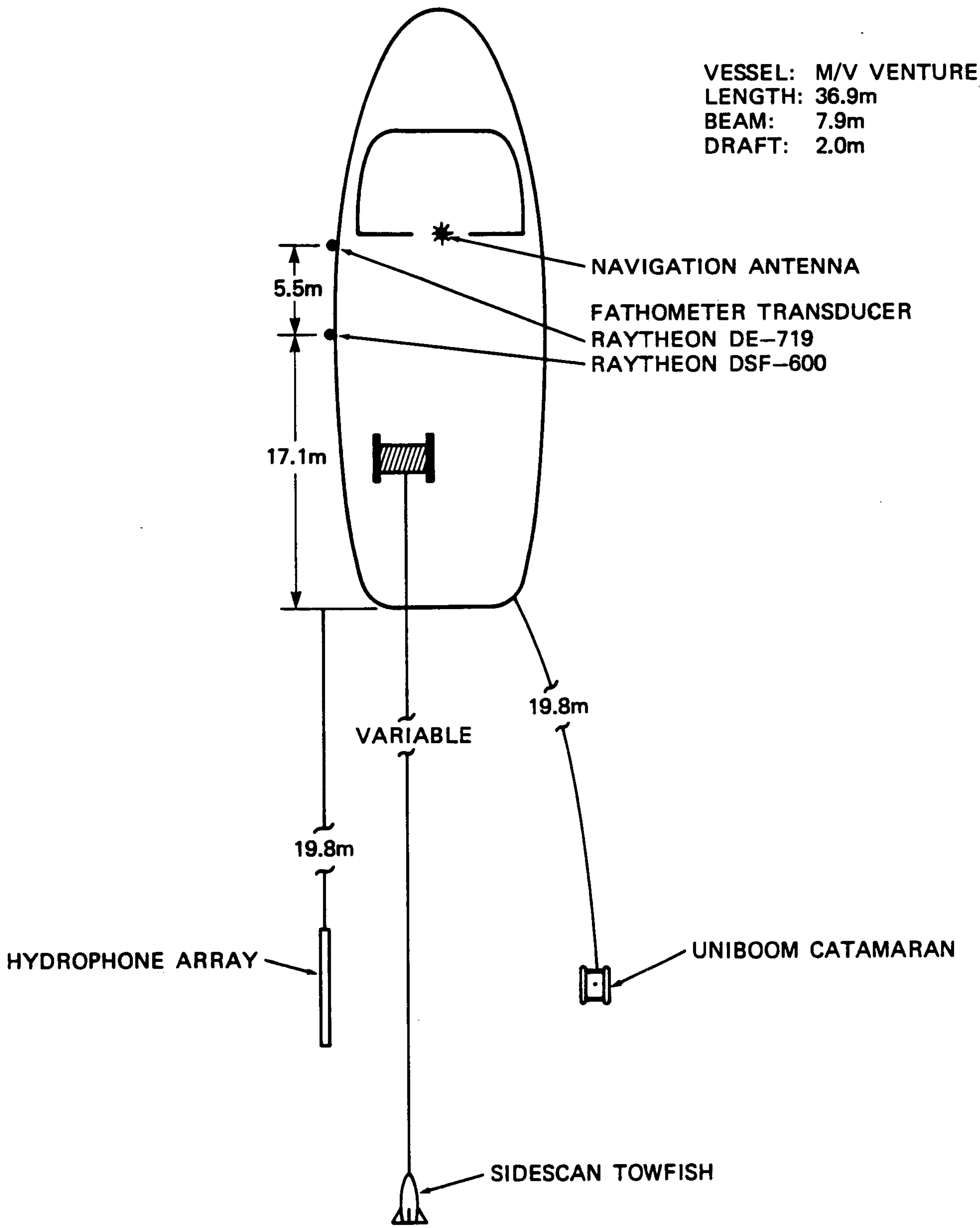


Figure 2-3. Geophysical survey vessel equipment layout.

Decca Autocarta onboard plotting system. A Decca Pulse-8 Loran C medium-range positioning system was also provided as a backup navigation system.

The Decca Hi-Fix radio navigation system is a phase-comparison hyperbolic or range-range electronic positioning system, capable of operating out to a range of approximately 200 km, with an accuracy of about ± 3 m. The system consists of a master transmitting station, two slave transmitting stations, and a shipboard receiving system.

The Decca Autocarta system was used in conjunction with the basic navigation system. It is an onboard real-time navigational data recording and plotting system. In addition to recording all navigation data on magnetic tape and plotting a real-time ship track map, it provides navigational guidance along predetermined survey tracks in the form of a helmsman's left/right display. At the completion of the survey, the system was used off-line to provide final field post-plot maps at the desired mapping scale.

The Decca Pulse-8 navigation system is a hyperbolic electronic positioning system which utilizes the Loran C navigation net established and maintained by the U.S. Coast Guard. The system is capable of operating at ranges in excess of 800 km, with an established accuracy of approximately ± 50 m at 500 km. The Loran C system was less prone to operational difficulties arising from sky wave or thunderstorm interference than was the Hi-Fix system and was utilized for primary positioning whenever the Hi-Fix system was inoperable.

Primary calibration of the onboard navigation systems was accomplished by tying into presurveyed onshore control points. Calibration was then carried to the work areas where secondary control points (Lane-count buoys) were established. In the event of a navigation system failure, the equipment was recalibrated without returning to shore. The location of the secondary control points was established using both the Hi-Fix and Pulse-8 system values.

Offshore positioning for the Geophysical/Underwater Television and Still Camera Survey of Transect F (Year 2, Cruise I) was conducted by Continental Shelf Associates, Inc. Data for these cruises were collected with an Epsco

C-Nav XL Loran C system. The operational characteristics are similar to the previously described Loran C system. Throughout all of the surveys navigation data were recorded at an interval of approximately 150 m. Further details regarding the navigation systems can be found in Appendix A-7.

2.2.3 Instrumentation

2.2.3.1 Depth Sounders

Two depth sounder systems were utilized on this survey to record water depth. The primary system was a Raytheon DSF-600 digital survey fathometer. A Raytheon DE 719-B precision survey fathometer was onboard as a backup. The operating principle for both instruments is the same. They emit a high-frequency (200 kHz) signal from a transducer mounted on the side of the ship's hull. The return signal is graphically displayed on a continuous chart. Both instruments incorporate calibration adjustments to account for the depth of the transducer beneath the water surface and, since the fathometer converts travel time of the acoustic signal to water depths using a calibrated velocity, a provision for setting the observed velocity of sound in sea water. This value is established by conducting bar checks and from observed temperature profiles. Throughout this survey the calibration velocity was set for a speed of sound in sea water of 1,524 m s^{-1}.

A fix mark was placed on the depth sounder records each time a navigation fix was recorded so that the measured water depth could be correlated with the positioning data. Specifications of the depth sounders are presented in Appendix A-7.

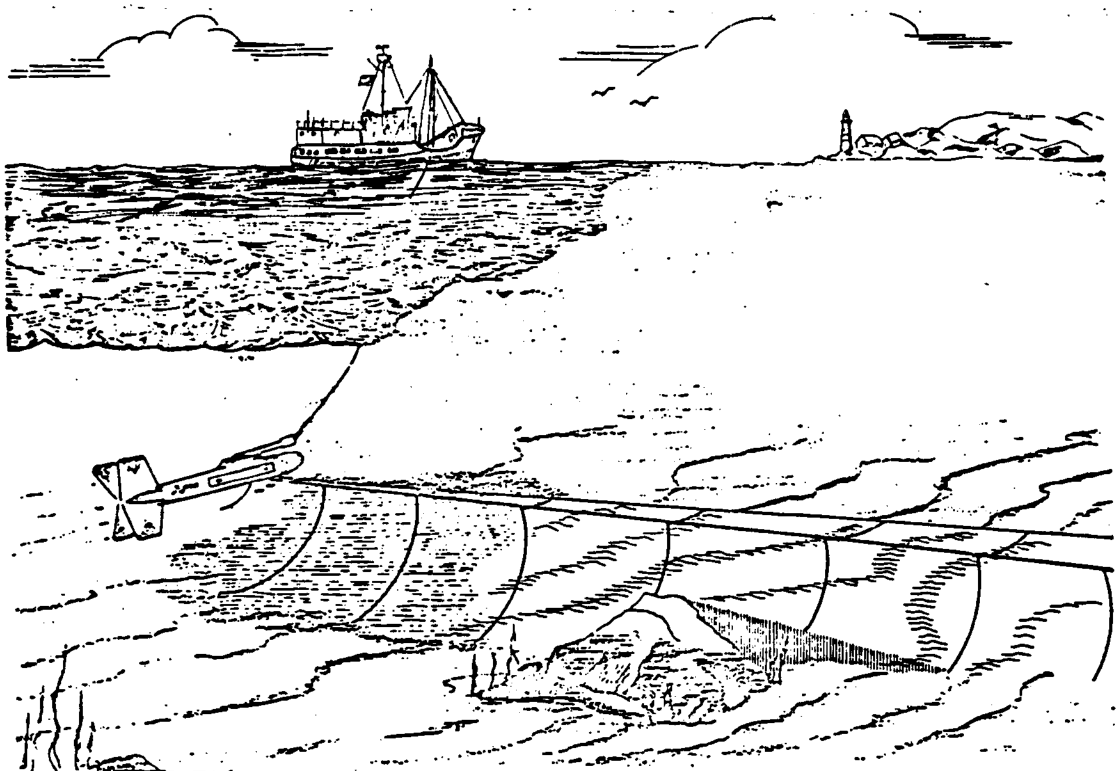
2.2.3.2 Side Scan Sonar

Two side scan sonar systems were utilized on this survey to continuously record sea floor features along the transect lines. The primary system for Transects A through E was an EG&G SMS 960 sea floor mapping system. A Klein Model 400 hydroscan system was onboard as a backup for Transects A through E and was used as the primary system on Transect F. The side scan sonar records a continuous acoustic reflection of the sea floor and may be used for identifying changes in bottom sediment characteristics, or for locating and identifying natural and man-made objects lying on the seabed. The system consists of a towed, dual-beam transducer, a dual-channel recorder, and associated cables. The side scan sonar emits a narrow acoustic beam perpendicular to the direction of travel of the towfish along the survey line. The acoustic beam's primary concentration of energy is directed slightly below the horizontal plane. Echoes are obtained from the bottom directly beneath the transducers to several hundred metres to the side, depending on the range setting. The range setting is adjusted to maintain the desired target resolution and bottom coverage consistent with survey objectives. A range setting of 150 m (to port and to starboard of ship's path) was used throughout this survey. Specifications of the side scan sonar systems are presented in Appendix A-7.

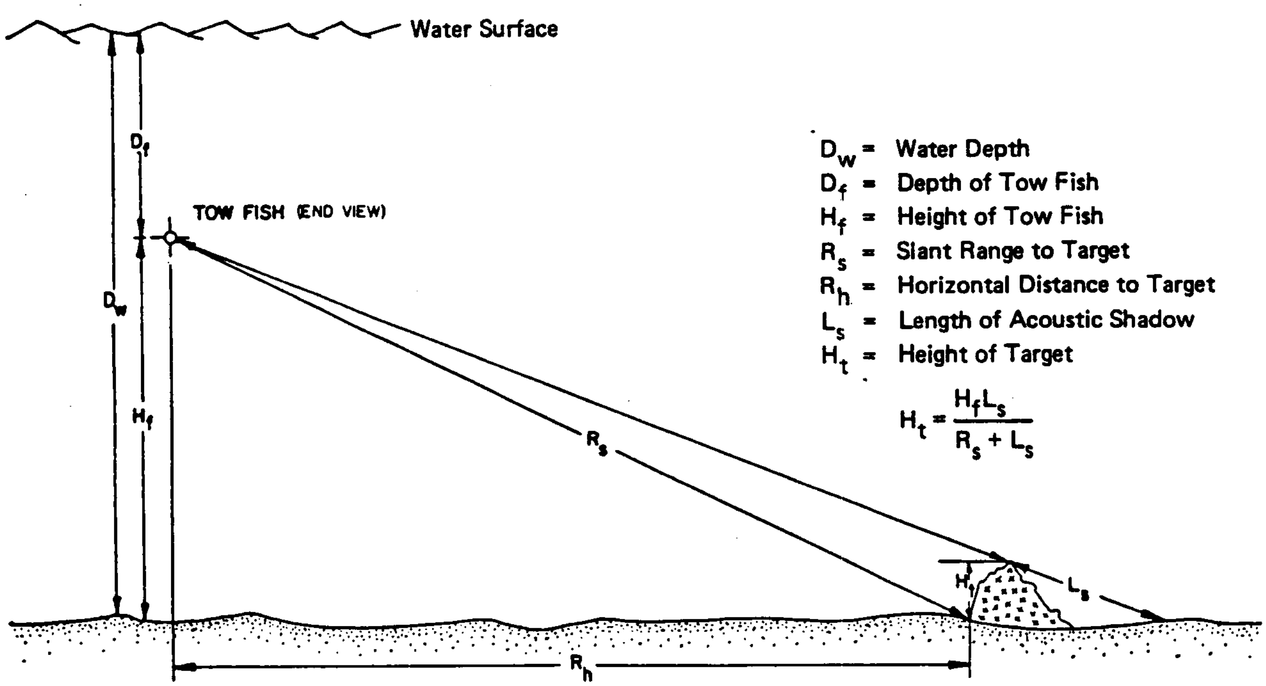
The side scan sonar technique is illustrated in Figure 2-4. The combination of beam shape and short-wavelength, high frequency (100 kHz) acoustic pulse gives the side scan the ability to resolve small topographic irregularities and man-made objects on the sea floor. As a transducer is towed behind the ship, the reflected echoes are graphically recorded in a form which appears like a continuous photograph of a strip of sea floor. The SMS 960 system automatically removes the water column data from the plan view presentation and corrects for slant range, producing a single record of corrected data. Speed data input from the positioning system automatically corrects the data along the track line to give equal dimensional scales in both directions. This eliminates the distortion of observed objects and allows the size and range of targets to be measured directly from the side scan sonar records. Automatic water column and speed corrections are found on the SMS-960 records only. These corrections were made manually during the mapping process on records obtained from the Klein Model 400 system.

2.2.3.3 Subbottom Profiler

An EG&G UNIBOOM high-resolution seismic reflection profiling system was used to provide shallow-to-moderate penetration high-resolution subbottom data. The EG&G UNIBOOM system consists of an EG&G 231/232 power source, a UNIBOOM



Idealized Sketch of Side Scan Sonar in Operation



Side Scan Sonar Geometry

Figure 2-4. Side scan sonar technique.

plate mounted on a towed catamaran, a receiving hydrophone and an EPC Model 3200 or 4100 seismic recorder. The UNIBOOM sound source is an electromechanical boomer plate which generates a broadband acoustic pressure pulse with a frequency spectrum from 400 Hz to 8 kHz. Specifications of the UNIBOOM system are in Appendix A-7.

The resulting seismic records generated by the subbottom profiling system are similar to a geologic cross section except that the vertical axis represents the two-way travel time of the reflected seismic signal rather than a true depth. Reflection times are converted to depths of the sedimentary layers using an assumed or measured value for the velocity of sound in the sediments. The system is towed behind the ship and mapping of the data requires a correction for the layback of the system from the positioning antenna. A fix mark is placed on the seismic records each time a navigation fix is recorded (approximately every 150 m) so that the data can be correlated with the positioning information.

2.2.4 Data Collected

Over 2,438 km (1,515 mi) of geophysical data were collected during the two geophysical survey cruises. In addition to the analog records from the primary systems, a tape recording was made of all of the subbottom profile records. All analog records were subsequently microfilmed and will be available through NOAA/NGDC at the conclusion of this project. The amount of survey data is summarized below.

Transect	Survey Lines	Total Lease Blocks Covered	Total Survey Distance km	(mi)
A	3	30	435	(270)
B	3	32	463	(288)
C	3	34	492	(306)
D	3	34	492	(306)
E	3	26	377	(234)
F	1	37	179	(111)
		Total	2,438	(1,515)

2.3 Data Reduction and Mapping

2.3.1 Introduction

The data reduction and mapping procedures used for the navigational and geophysical data are discussed in the following paragraphs. These data were integrated with the results of the underwater television and still camera surveys (Section 3) and presented as a Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1982). The Marine Habitat Atlas and the data integration procedures are described in Section 4.

2.3.2 Navigational Data

Navigational post-plot data for the shiptrack lines on Transects A through E were provided by Racal/Decca. Post-plot data for Transect F and the biological sampling stations were provided by Continental Shelf Associates, Inc. In all cases navigational data were recorded at an interval of approximately 150 m and converted to appropriate Universal Transverse Mercator coordinates.

2.3.3 Bathymetric Mapping

Bathymetric data were recorded with Raytheon DSF-600 and DE-719B fathometers. Both systems contain provisions for automatic correction of the transducer draft and a calibrated velocity correction. The calibration velocity was set for a speed of sound in sea water of 1,524 $m\ s^{-1}$ based on bar checks (instrument calibration based on fathometer readings obtained from a metal bar or reflector which has been lowered from the ship to a measured depth) and temperature profiles. The data were referenced to the Gulf Coast Low Water Datum. Tidal corrections were minimal and were made only where they exceeded 0.5 m in the shallow water areas.

In the Marine Habitat Atlas, the corrected bathymetric data were plotted at every fifth navigation fix point or whenever the sea floor elevation changed by one metre. The data were contoured at a one-metre interval except in a few areas of steep gradient where a five-metre interval was used. A generalized contour map of the bathymetry of the southwest Florida shelf is given in Figure 2-5.

2.3.4 Side Scan Sonar Patterns

A preliminary map of the sea floor was prepared for each Transect (A through E) onboard the geophysical survey vessel during the initial geophysical cruise. This map was used for selection of the survey lines for the subsequent ground-truth survey.

During the initial stages of the investigation, prior to the ground-truth surveys, several types of side scan sonar record patterns were recognized and mapped throughout the shelf. These patterns are briefly described in the following paragraphs and their generalized distribution on the survey transects is shown in Figure 2-6.

2.3.4.1 Sediment Bottom

Extensive areas of relatively featureless bottom occur throughout the southwest Florida shelf. The side scan sonar signatures range from white to dark grey and occasional bedforms such as sand waves can be recognized on the records. Although isolated targets (strong reflections) are seen in these areas, they are very sparsely distributed. This pattern was interpreted to represent a sand or silt bottom generally devoid of rock outcrops or large attached epifauna communities. Subbottom profile records indicated the sediment cover was generally less than one metre thick although local patches five metres or more in thickness were noted (Figure 2-7).

2.3.4.2 Striped Mottling

Figure 2-8 illustrates one of the more common patterns found in the survey area. This mottled pattern generally occurs in water depths of 20 m to 60 m and was seen on all of the east-west transects. On long range records (150-m scale) taken by the sea floor mapping system, the dark and light areas are quite distinct. However, short range records (50-m scale) from the Klein

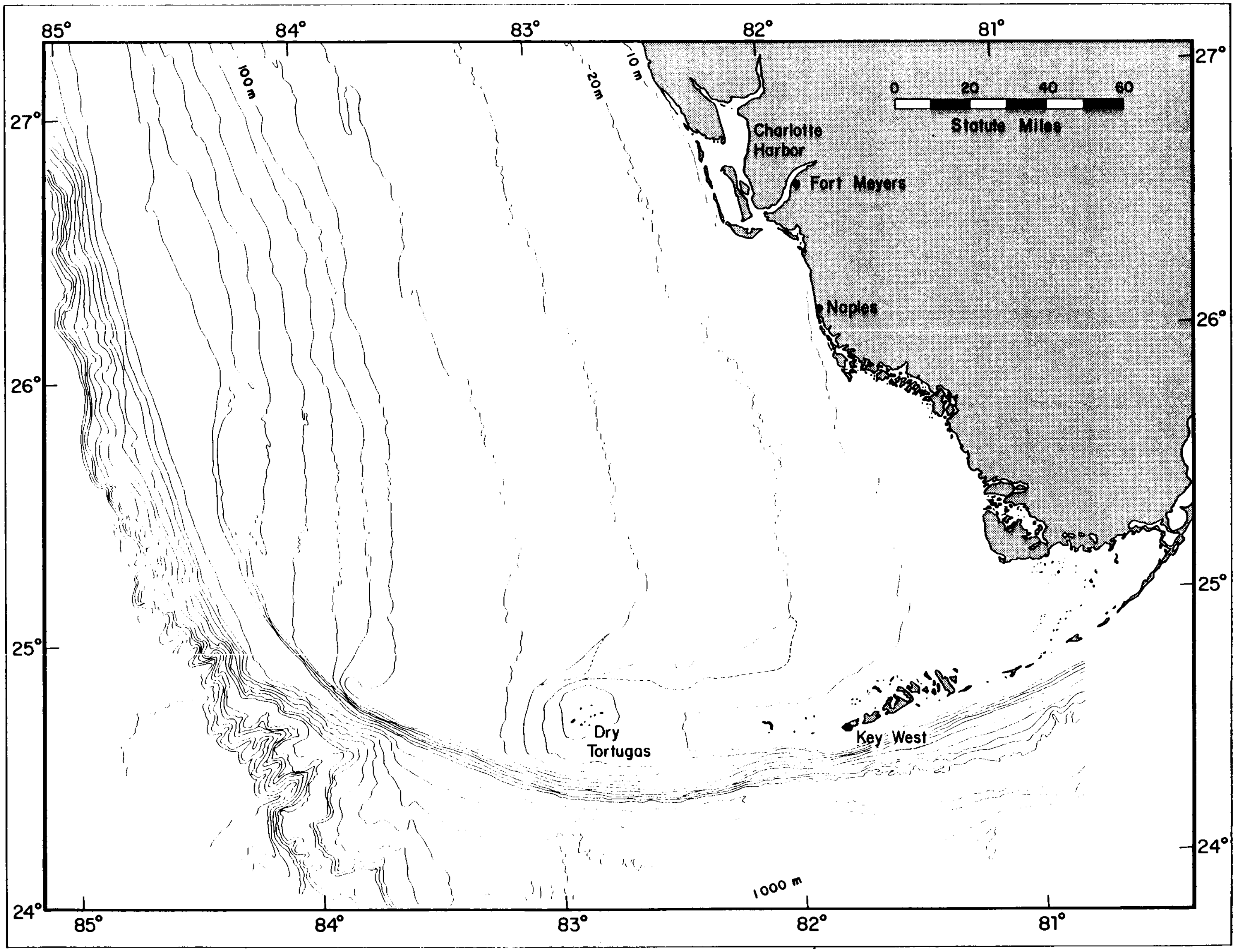


Figure 2-5. Generalized bathymetry. [after U.S. Dept. Interior, 1982 and WCC-corrected bathymetry (dashed lines)].

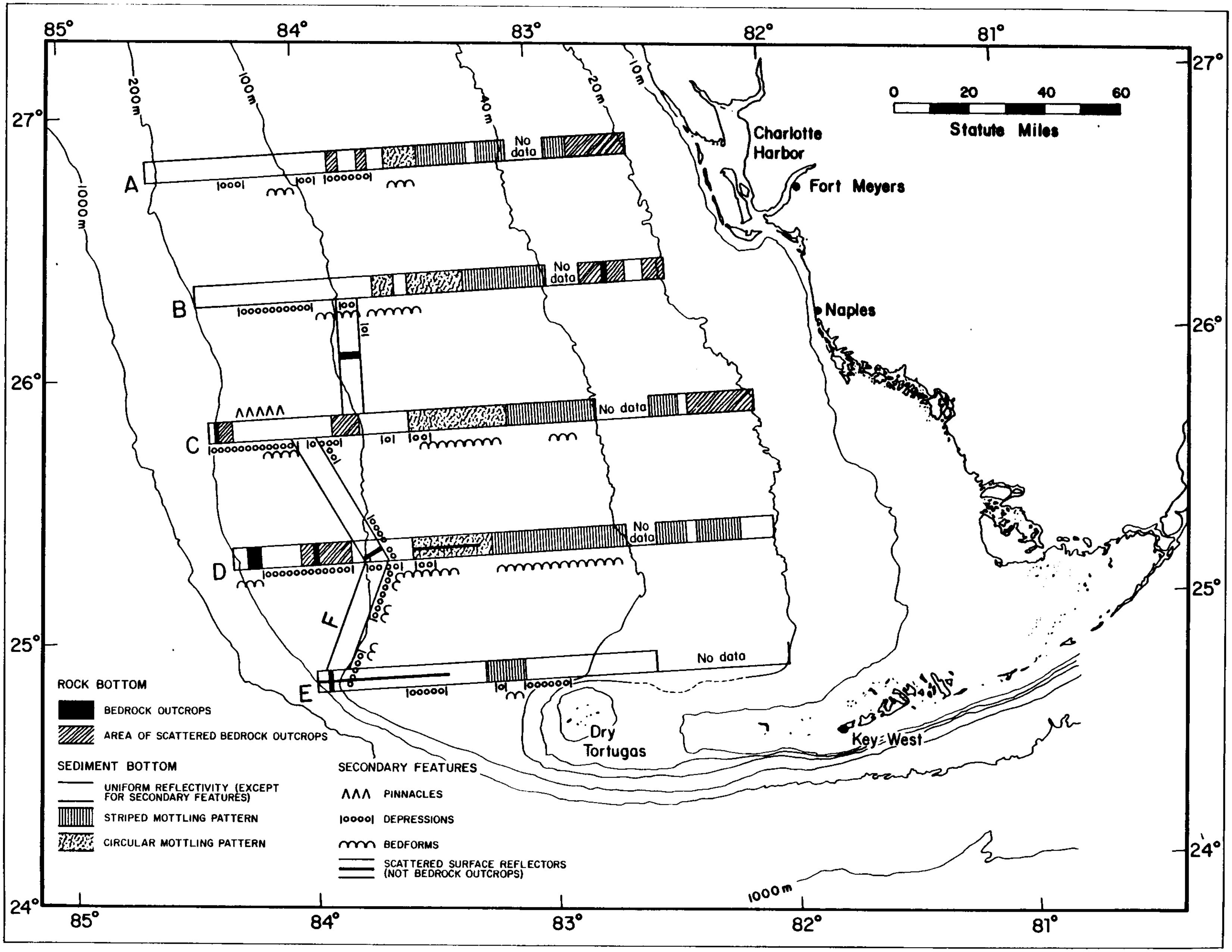
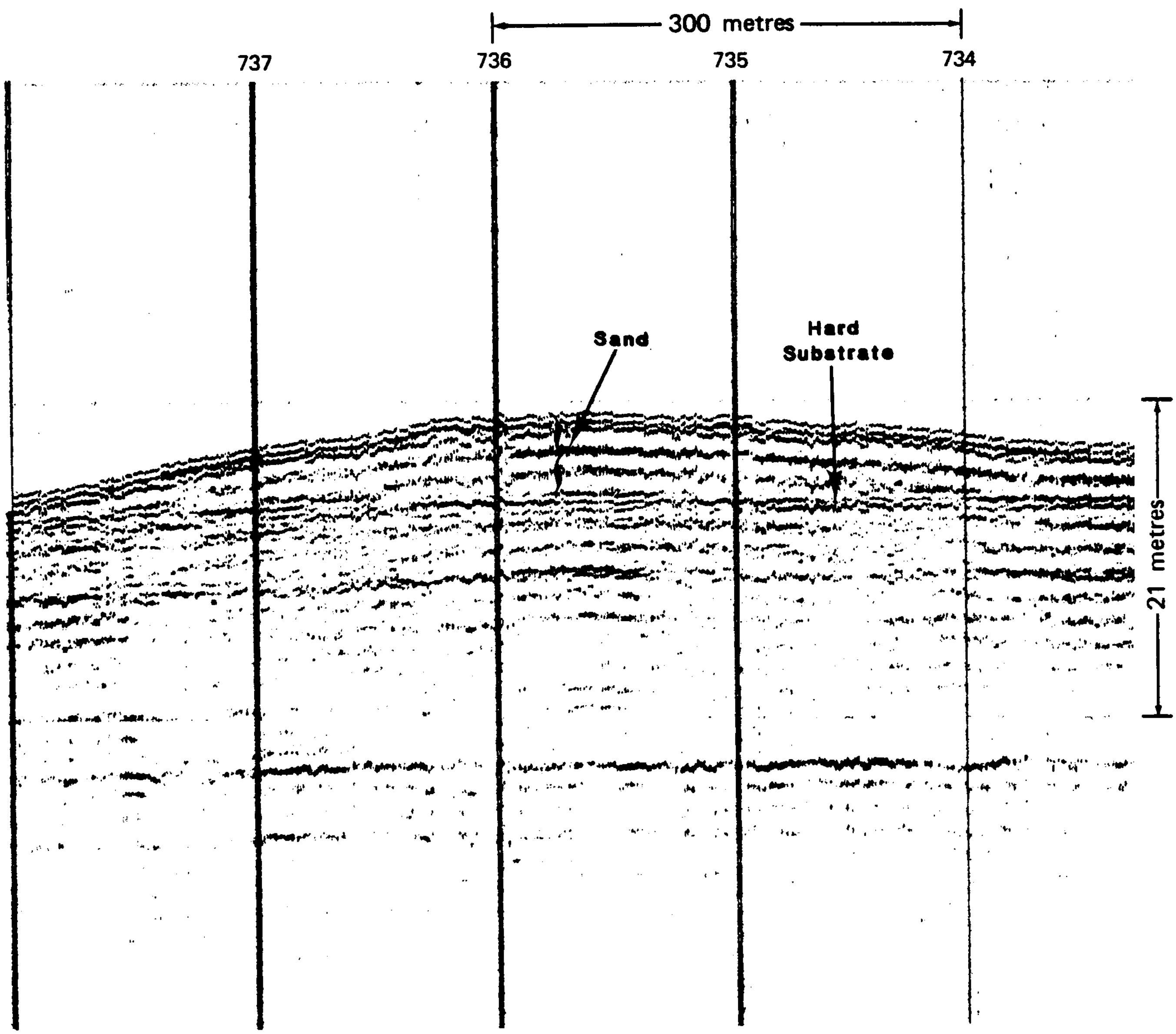
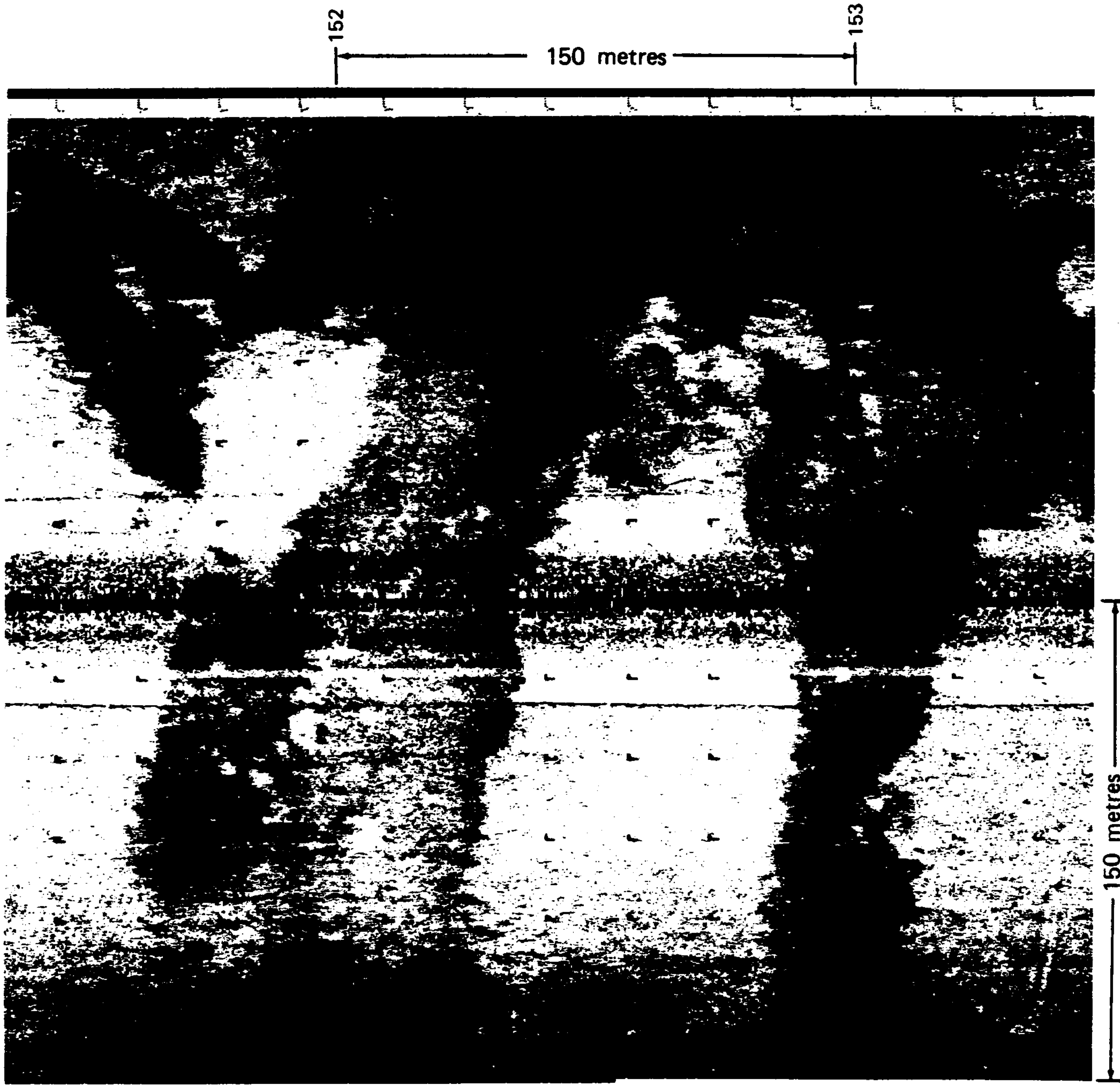


Figure 2-6. Generalized distribution of side scan sonar patterns.



Thick Sand Deposit over Hard Substrate

Figure 2-7. **Subbottom profile record showing thick sand deposits over hard substrate. Sand layers have an angular unconformity with relatively horizontal substrate. Sand is approximately five metres thick in the center of the bathymetric high. Location: Transect C, water depth 118 m.**



Thin Sand over Hard Substrate

Figure 2-8. Side scan sonar record showing the mottled pattern typical of areas on the inner and middle shelf where there is a thin sand cover over a hard substrate. On short-range records the dark areas appear as a large number of individual targets representing reflections from exposed substrate, coarse rubble, and epibiota. Location: Transect C, water depth 51 m. Instrumentation: EG&G SMS 960.

system indicate the dark patterns are composed of a large number of closely spaced small targets.

A typical subbottom profile record from an area with a striped mottling pattern is shown in Figure 2-9. The light and dark patterns on the side scan record can often be correlated with the minor topographic highs and lows respectively, possibly reflecting the thickness of the sediment cover. Possible sources of the mottling include sediment textural changes, zones of coarse rubble or exposed bedrock, attached epifaunal communities or areas of dense algal growth.

2.3.4.3 Circular Mottling

As the water depth increases beyond the 50-m isobath, the striped patterns seen in the shallower waters become more subdued (low contrast) and have a circular rather than a striped pattern. This pattern was seen on Transects A to D in the water depth ranges of 60 m to 75 m. Ground truth data did not identify any specific features or organisms to provide an explanation for this pattern.

2.3.4.4 Bedrock Outcrop and Scattered Bedrock Outcrop Areas

Bedrock outcrop areas generally appear as strong (dark) reflectors with numerous small shadow zones indicating irregular low relief (<1 m) features of the outcrop zone. Only a few isolated areas of extended outcrop zones were mapped and these areas generally included patches of sediment cover. In many areas the outcrops appeared as low relief ledges covered by a thin sediment cover. Where the exposed rock outcrops were significantly less than 50% of the area, they were mapped as scattered bedrock areas. Subbottom profile records (Figure 2-10) were useful in correlating the exposed rock areas with bedrock outcrops or shallow-buried bioherms.

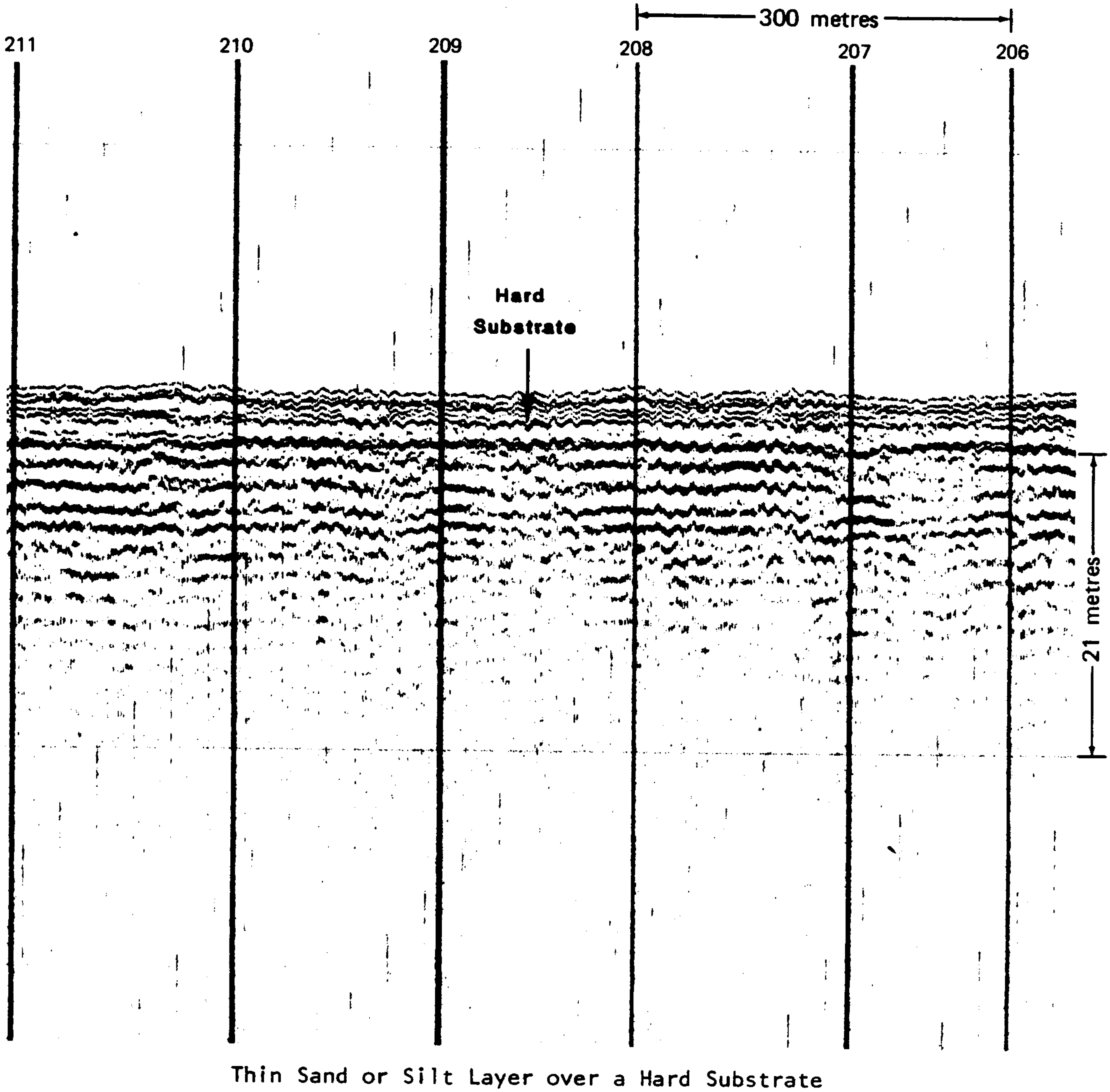
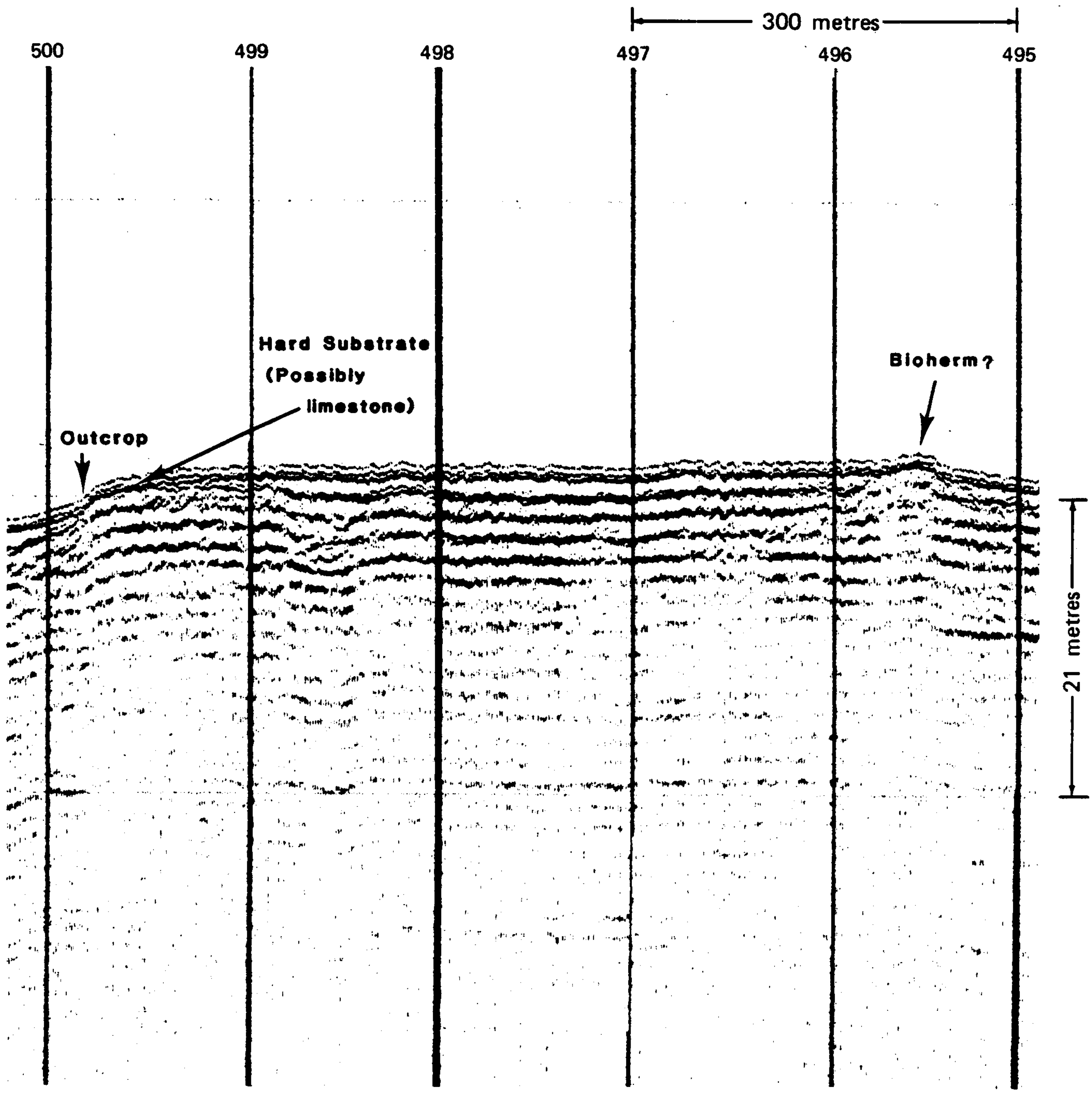


Figure 2-9. Typical subbottom profile record showing thin sand or silt over a hard bottom. (Side scan record would show striped mottling pattern). Location: Transect B, water depth 54 m.



Exposed Hard Substrate and Algal Nodule Surface

Figure 2-10. Subbottom profile record showing local areas of exposed hard substrate (arrows). Area to the right of scarp has a very thin sand layer covered with algal nodules. Location: Transect B, water depth 75 m.

2.3.4.5 Scattered Surface Reflectors

Figure 2-11 illustrates a side scan sonar pattern that is distinctly different from the bedrock outcrop areas. The signature is generally dark with associated white shadow zones resulting from a high density of small, low-relief, reflectors. The subbottom profile records from areas exhibiting such patterns generally show a strong sea floor reflector ("hard bottom"?) overlying a relatively thin transparent layer interpreted to be sand or silt (Figure 2-12). While the side scan sonar and subbottom profile records are indicative of a hard sea floor surface, the resulting patterns are different than those found in areas of scattered bedrock outcrops.

2.3.5 Secondary Sea Floor Features

The side scan sonar data also exhibited specific patterns of individual targets that were seen in association with one or more of the previously discussed patterns. These secondary patterns included pinnacles, depressions, and sediment bedforms. The general location of these secondary patterns is shown on Figure 2-6.

Figure 2-13 illustrates a side scan sonar record taken over a zone of pinnacles that extend one to five metres above the sea floor. The pinnacles were mapped only on Transect C in the water depth range of 137 to 167 m. In this area, the sea floor topography is irregular. The pinnacles appear to be coral heads that extend from a sequence of surficial and shallow buried bioherms[2] (Figure 2-14) that are covered with a thin layer of sediment.

Sea floor depressions (pockmarks) are found throughout the study area, generally in the water depth ranges of 65 to 160 m. The depressions are up to 20 to 30 m across and 2 to 3 m in depth. The pockmarks are seen primarily on the side scan sonar records (Figure 2-15). Their origin is not known, but they may be related to sea floor springs and/or to subsurface karst features

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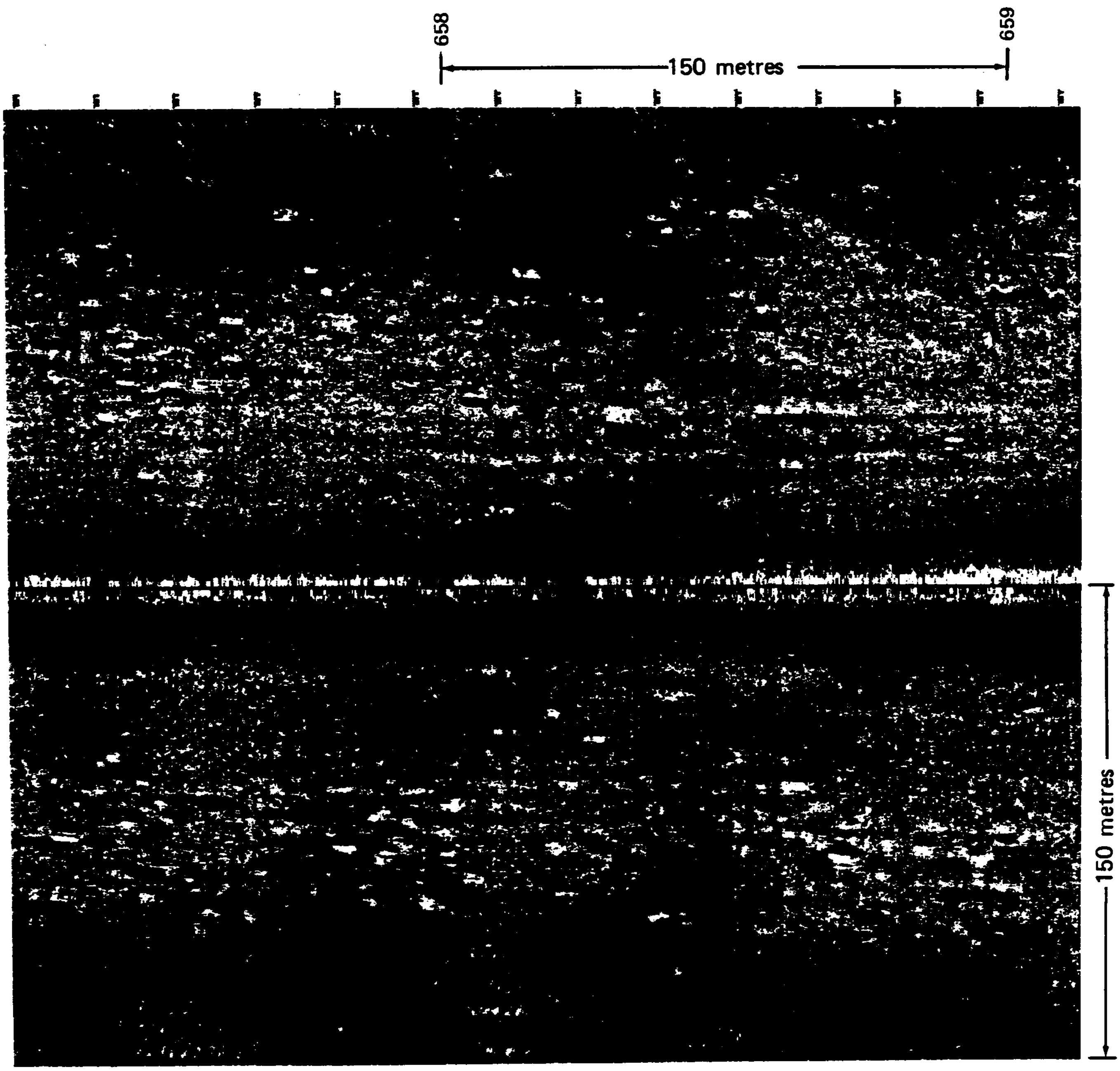
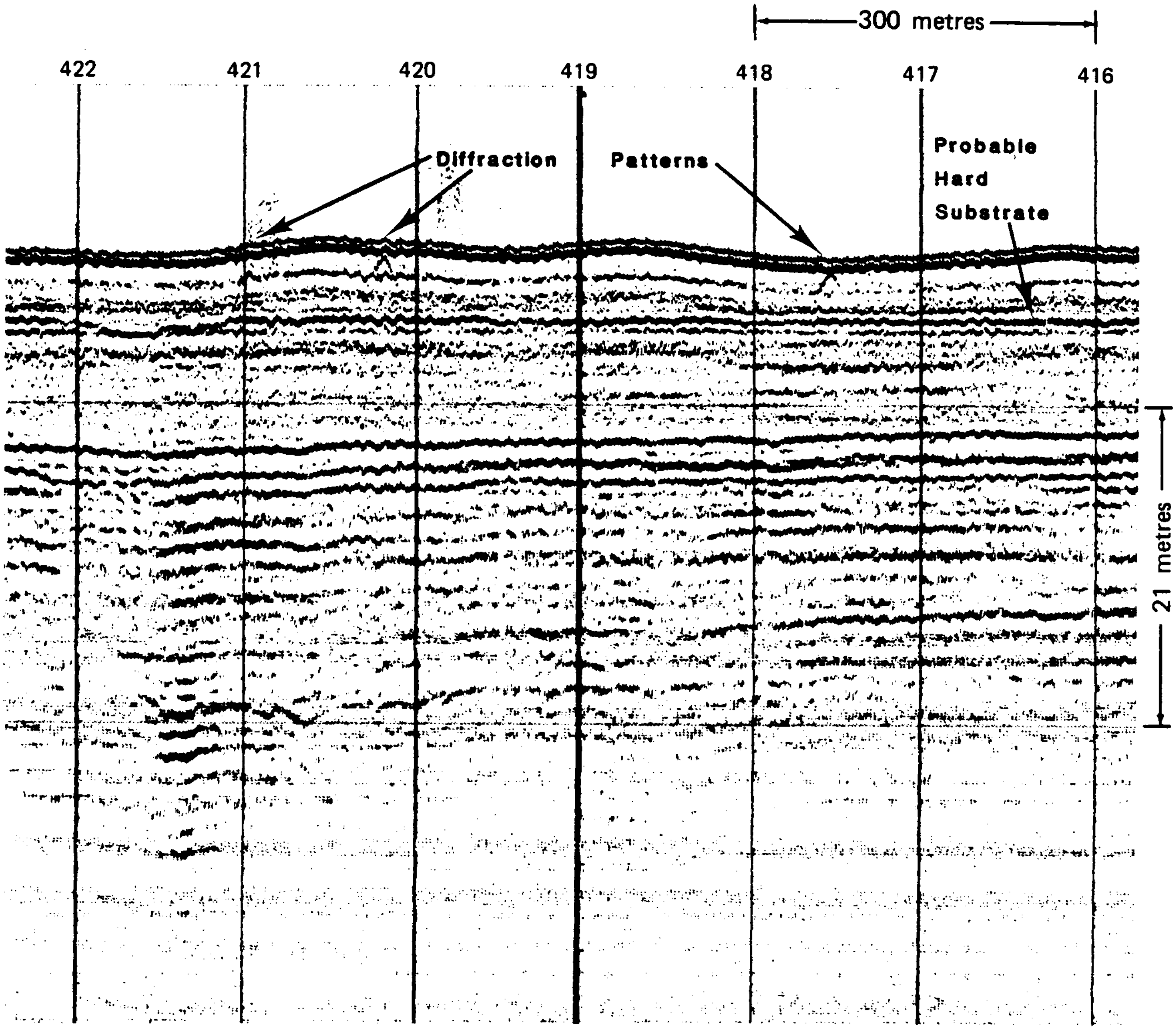
[2] Bioherm is defined as a moundlike or circumscribed mass built exclusively or mainly by sedentary organisms and enclosed in normal rock of different lithological character (American Geological Institute, 1976).



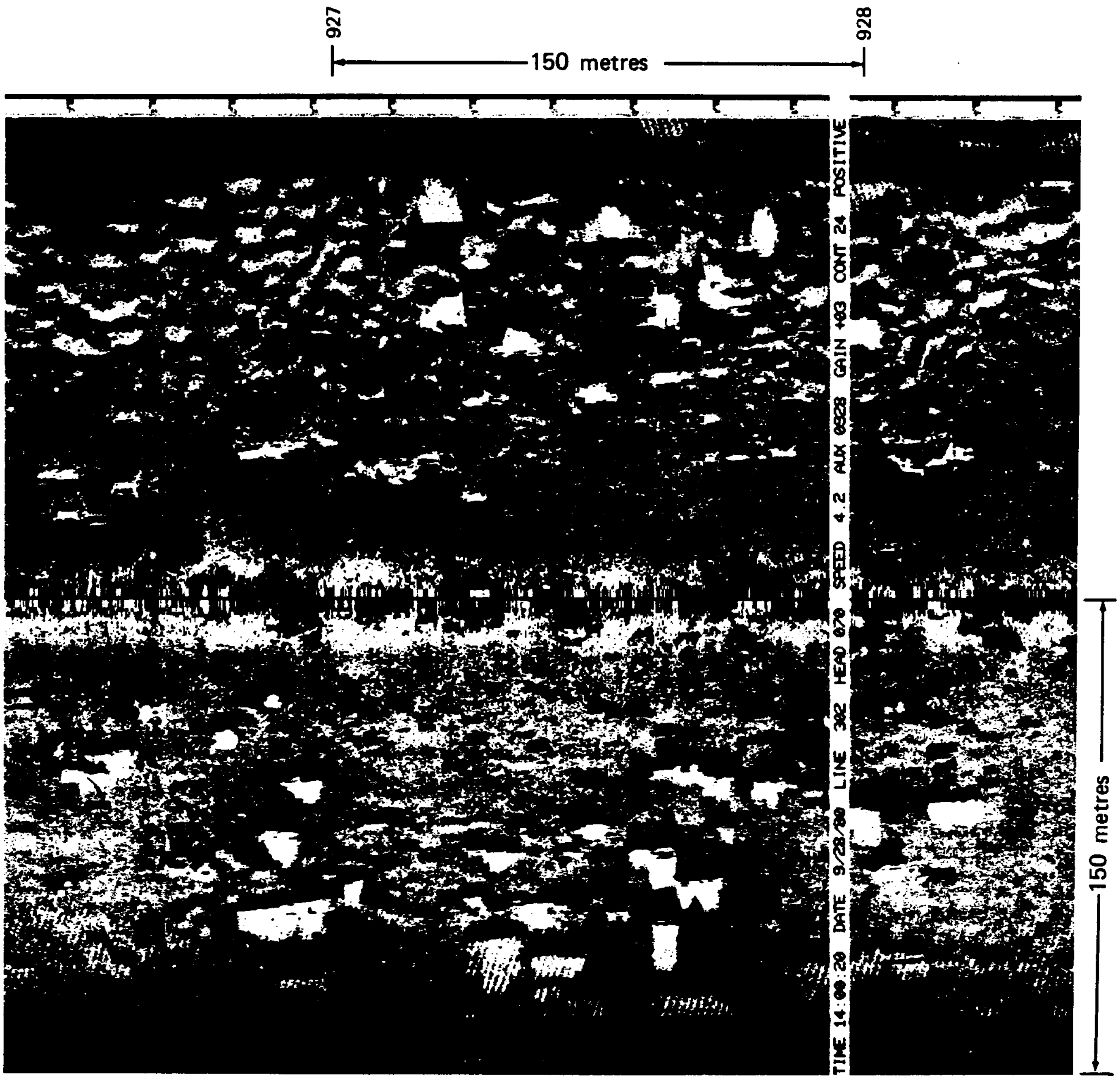
Algal Nodule Pavement

Figure 2-11. Side scan sonar record typical of the areas mapped as algal nodule pavement by the underwater television system. Linear reflections may represent the edges of pavement plates or epibiota communities. Location: Transect E, water depth 80 m. Instrumentation: EG&G SMS 960.



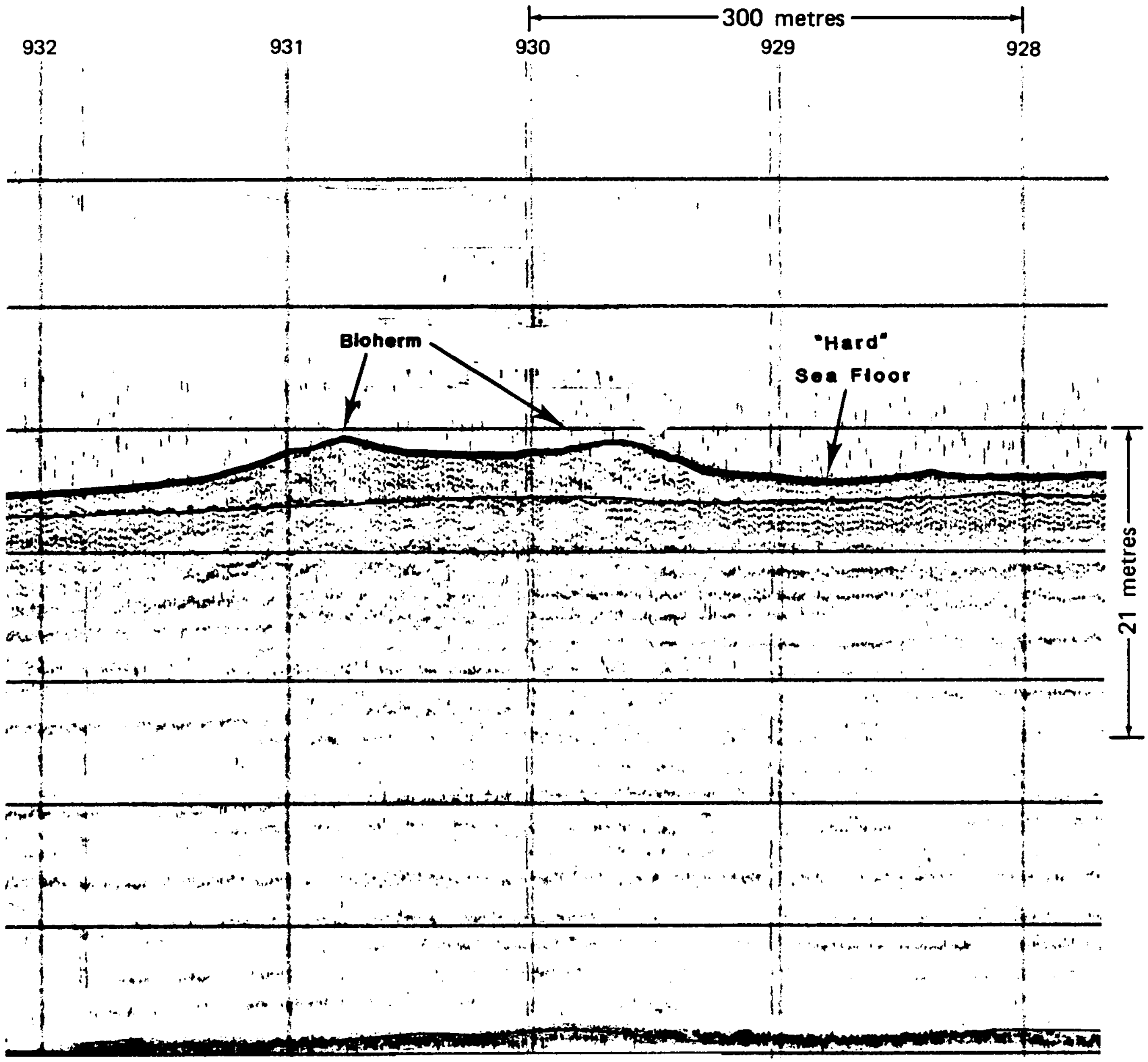
Algal Nodules over Sand

Figure 2-12. **Subbottom profile record of an area of algal nodules overlying sand. This substrate is characterized by a strong, sharp water bottom reflection with occasional diffraction patterns immediately beneath the sea floor reflector. Location: Transect E, water depth 66 m.**



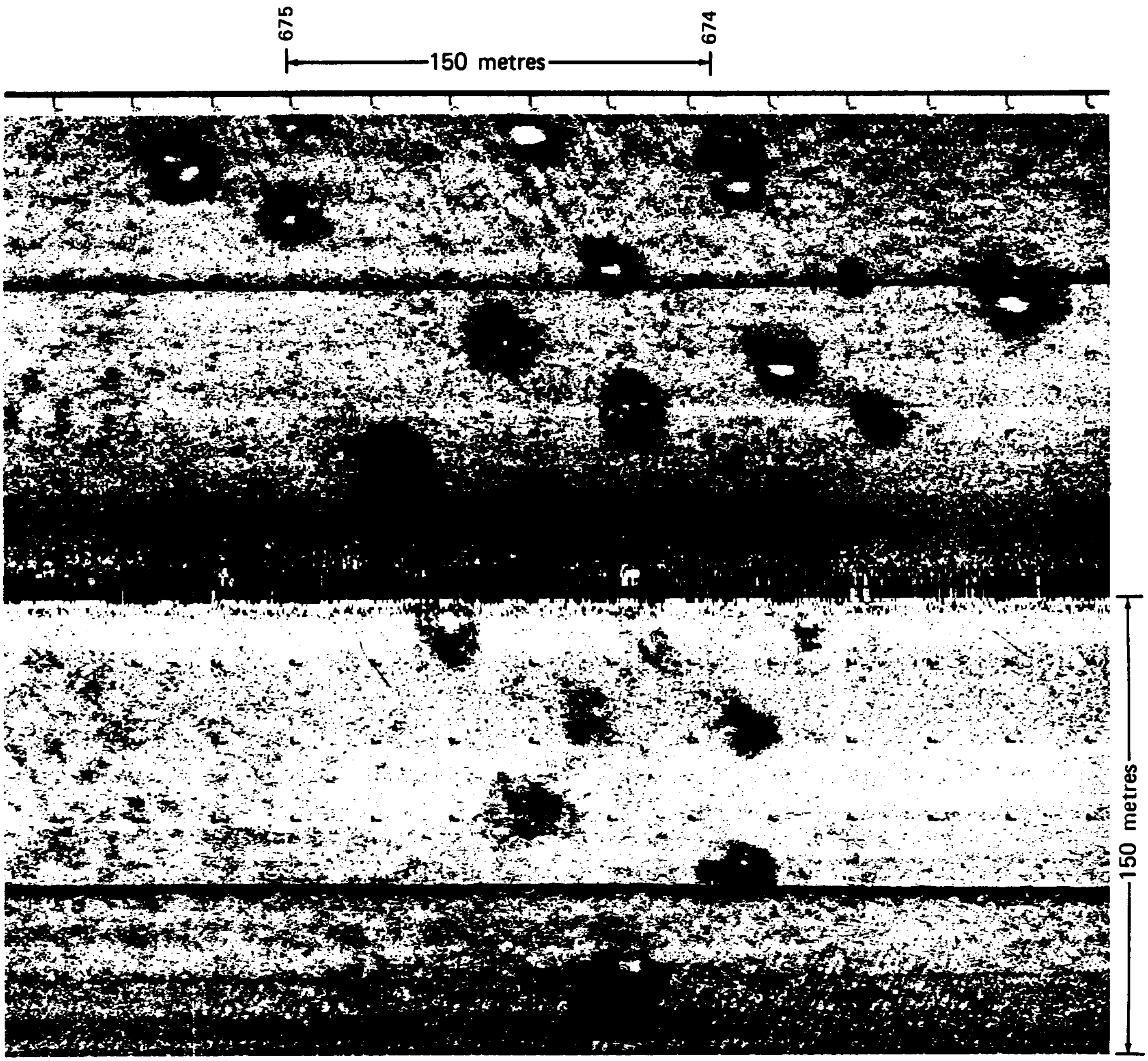
Sand Bottom with Pinnacles

Figure 2-13. Side scan sonar record showing exposed pinnacles extending above a sand covered bottom. The pinnacles represent dead coral heads and extend 0.5 to 3 m above the sea floor. Location: Transect C, water depth 158 m. Instrumentation: EG&G SMS 960.



Bioherm

Figure 2-14. Subbottom profile record over a bioherm. Side scan sonar shows this feature to have a thin sand cover with exposed pinnacles of coral extending several metres above the sea floor. Location: Transect C, water depth 159 m.



Sand Bottom with Depressions

Figure 2-15. Side scan sonar record showing depressions or "pock marks" on a sand bottom. The depressions range from 5 to 30 m across and 2 to 3 m deep. The depressions also occur on hard substrate and algal pavement bottoms. Location: Transect B, water depth 131 m. Instrumentation: EG&G SMS 960.

(Section 2.3.6). However, the karst features are generally buried 10 to 30 m and a one-to-one correspondence between a depression and a subsurface karst feature has not been established with the records from this survey.

2.3.6 Subbottom Profile Data

Geologic cross sections were prepared for each transect and are presented in the Marine Habitat Atlas. The cross sections were designed to illustrate the relationship between the shallow geology and the sea floor habitats and to identify potential geologic hazards or design constraints (e.g., shallow faulting, buried channels, karst features, anomalous bathymetric slopes, bedrock outcrops, coral heads) for sea floor oil and gas operations.

The cross sections were prepared for the centerline of each transect, except for Transect D where the northern line was used because of better data quality. The cross sections are based on interpretation of the UNIBOOM records. A velocity of 1,677 m s^{-1} (5,500 ft s^{-1}) was used to determine the depth to the subbottom reflecting horizons. In order that the cross sections could be compared directly with the bathymetry/marine habitat maps they were also prepared at a scale of 1:48,000. This is a relatively small scale for mapping shallow subsurface geology and many smaller features cannot be accurately illustrated at this scale. It was also necessary to use a 40X vertical exaggeration to emphasize the relatively gradual changes in sea floor gradients and subsurface geology.

The subbottom profile data indicate that the shelf is covered with a thin veneer of sediment (Figure 2-9) with only occasional areas of thick sediment cover (Figure 2-7). The shallow (upper 30 m) subbottom sediment and rock horizons are relatively horizontal and generally parallel the sea floor. Surficial and near surface features that were mapped from these records include bioherms (Figures 2-10 and 2-14), bedrock outcrops (Figure 2-10), buried karst features (Figure 2-16), buried channels (Figure 2-17), and shallow faulting.

The buried karst features (Figure 2-16) are evident from the subbottom profile records from the northern portion of the survey area (Transects A, B, C, and

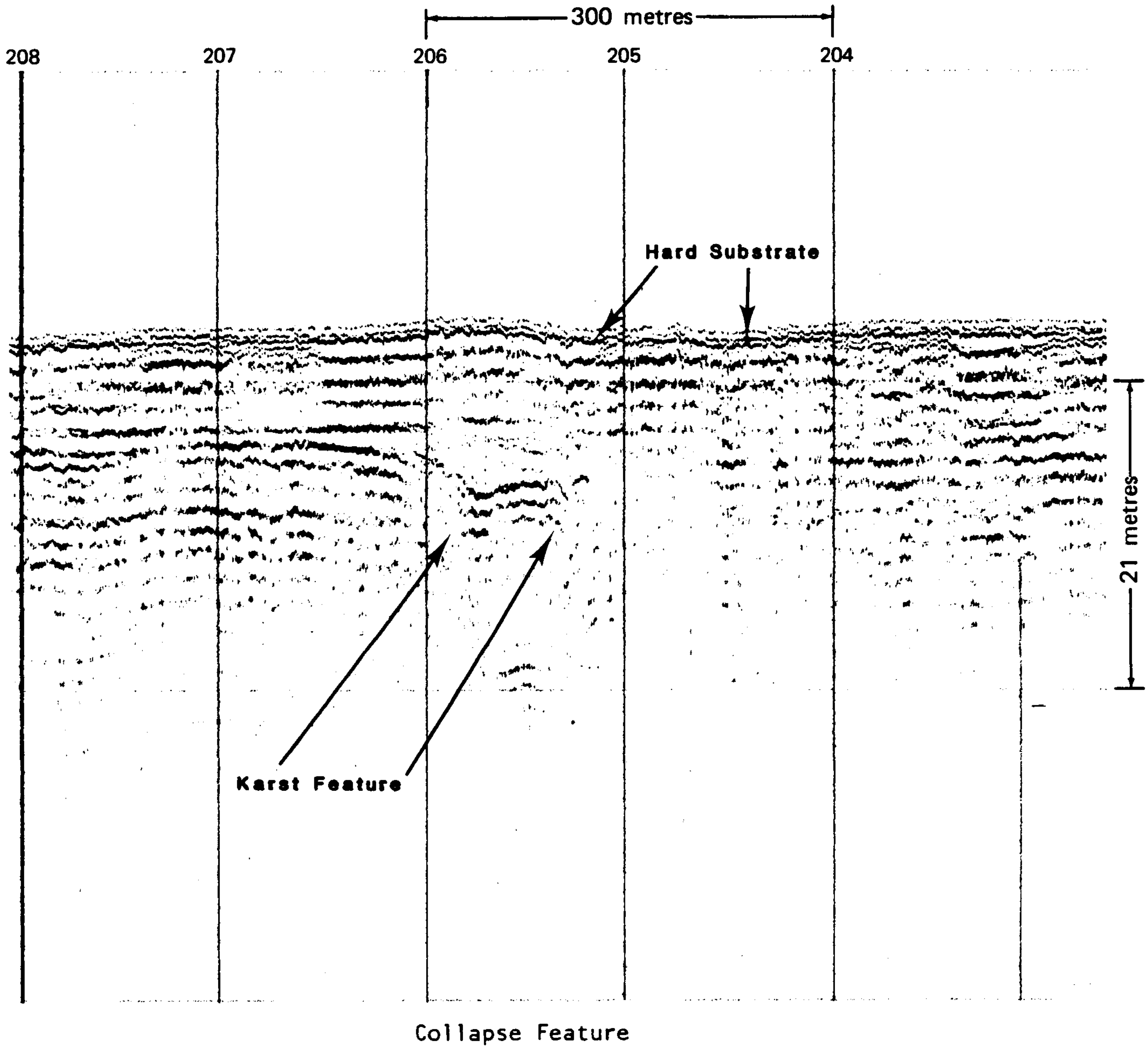
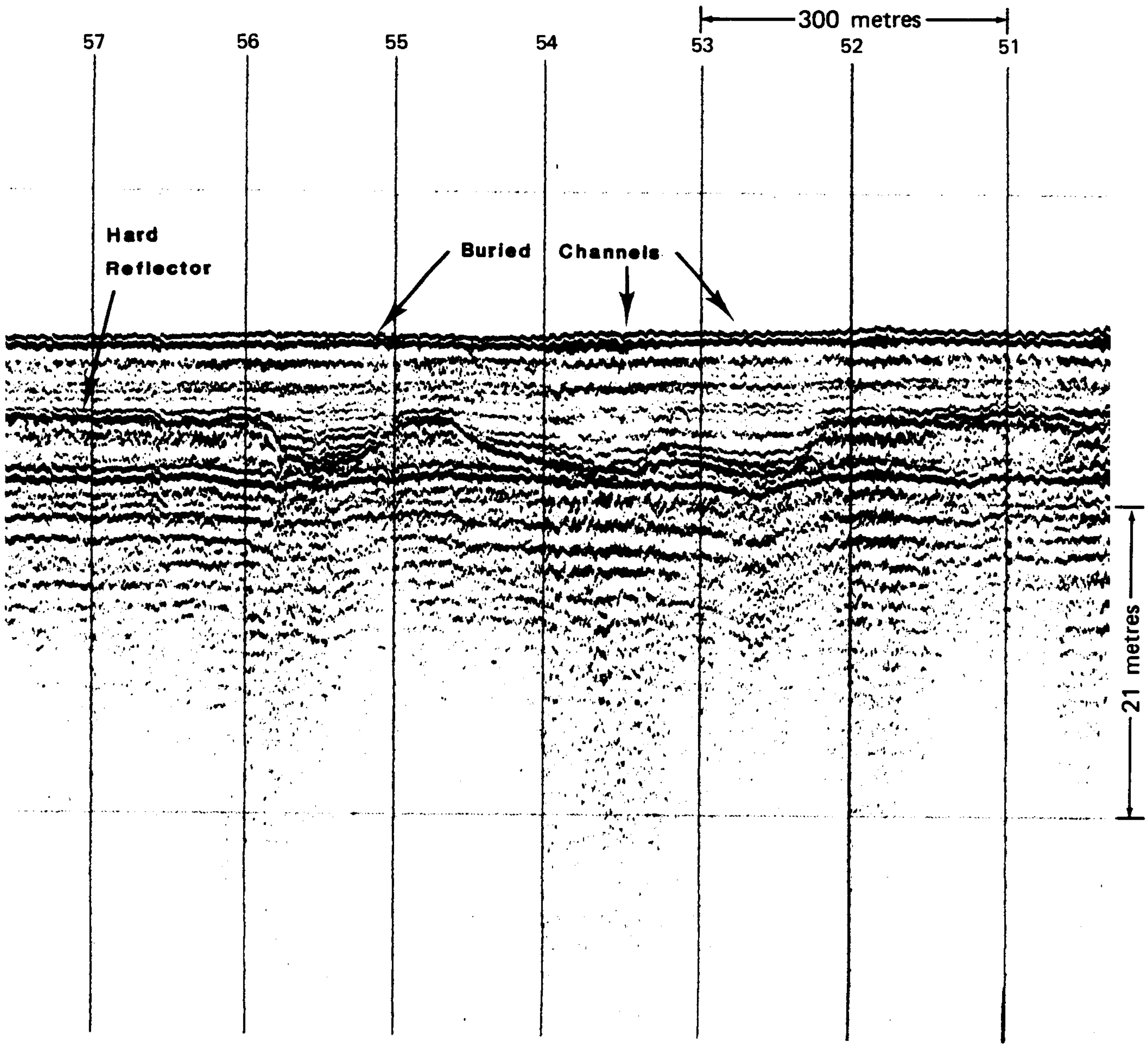


Figure 2-16. Subbottom profile record showing karst or collapse features. The collapse feature is approximately 150 m across and 8 to 10 m beneath the sea floor. Location: Transect A, water depth 54 m.



Sand or Silt over Buried Channels

Figure 2-17. Subbottom profile record showing buried channels with 5 to 10 m of sand or silt cover. These channels were found only on Transect E in water depths of 45 to 50 m.

the northern half of F). They occur in the water depth range of 55 to 200 m and are generally covered with 10 to 30 m of sediment.

Near-surface buried channels (Figure 2-17) were noted only on Transect E in the water depth range of 40 to 50 m. The base of the channels appears to be a strong reflecting horizon about 10 m beneath the sea floor.

2.4 Results

2.4.1 Bathymetry and Shallow Geologic Features

2.4.1.1 Introduction

The study plan for the 1980 (Year I) investigations called for the examination and sampling of continental shelf features within three water depth zones along five east-west trending transects (Transects A through E). The water depth zones and respective investigations are summarized below:

Zone	Survey
20 to 40 m	Underwater television and still camera survey and biological sampling.
40 to 100 m	Geophysical, underwater television, and still camera surveys and biological sampling
100 to 200 m	Geophysical survey only

Subsequently, the 1981 (Year II) study plan called for the collection of ground-truth data (underwater television and still camera survey) and biological sampling in the 100 to 200-m depth zone and additional geophysical and ground-truth data along a north-south trending transect (Transect F).

For the purposes of discussion throughout this report, these three arbitrary depth zones (see Section 1.4.2) have been designated the INNER (20-40 m), MIDDLE (40-100 m), and OUTER (100-200 m) SHELF, respectively.

2.4.1.2 Inner Shelf

The inner shelf is defined as the area from the coastline out to a water depth of approximately 40 m (Figure 2-5). In this portion of the study area, the investigations were limited to a single survey line along the centerline of the five east-west trending transects, between water depths of 20 to 40 m. Underwater television coverage was continuous along the survey lines. Although no geophysical data collection was programmed for these areas, side scan sonar data were collected periodically to establish local correlations with the ground-truth data.

Bathymetric profiles show the sea floor to be smooth and gently sloping to the west at less that 0.02° (0.3 m per km). Bathymetric maps published by the National Ocean Survey (Charlotte Harbor and Pulley Ridge sheets) indicate this area contains numerous circular or elongated depressions up to two kilometres in diameter. Holmes (1981) has noted the similarity between these features and active karst features and suggests the depressions were carved into the Miocene (?) bedrock during periods of lower sea level. He also indicates that some of these depressions may be undergoing modification by water flow from active subsea springs.

The side scan sonar data indicate that, on the four northern transects (A through D), the Miocene (?) bedrock is exposed or covered by a thin layer of mobile sand with local small scale outcrops of exposed bedrock (Figure 2-6). In the southern portion of the study area, Transect E, the surficial sediment appears to be finer grained, possibly a silt, overlying Holocene and Pleistocene sediments. No indications of bedrock outcrops were found along the inner shelf portion of Transect E.

No subbottom profiling was done on the inner shelf portions of the study transects. However, the only shallow structural features reported in this area by Holmes (1981) are the previously discussed near-surface karst features.

2.4.1.3 Middle Shelf

The middle shelf is designated as the area from the 40-m isobath out to the 90-m to 100-m isobath. Between water depths of 40 to 75 m, the sea floor is relatively smooth and dips to the west with slopes of 0.02 to 0.04° (0.3 to 0.7 m per km). Between the 70-m and 100-m water depths, the slope increases slightly to 0.08 to 0.1° (1.4 to 1.7 m per km). Local zones of irregular (rough) sea floor topography, areas of locally steeper slopes, and depressions have been mapped in this area (Figure 2-18).

Inshore from the 70-m depth contour, the sea floor has a thin sand veneer covering a wedge of late-Tertiary to Quaternary sediments (Holmes, 1981 and Figure 2-19). If the observed karst features (Figures 2-16 and 2-20) are assumed to occur near the top of the Miocene (?) bedrock, the estimated thickness of this wedge of younger sediments appears to increase from 5 m to approximately 20 m between the 40-m and 70-m isobaths. On Transect E the surficial sediment layer (silt?) is 10 m thick and fills occasional buried channels that occur in the 40-m to 50-m water depth range (Figures 2-17 and 2-20). Generally this layer of unconsolidated sediment appears conformable with the underlying late-Quaternary sediments.

Holmes (1981) reports a 10-km wide zone of partially buried carbonate reef-like structures in the water depth range of 70 to 90 m. He designated this zone as the "Central Reef Complex". This zone corresponds to the areas of irregular sea floor topography noted above (Figure 2-18). The subbottom profile records show this feature to be partially exposed or covered with a thin sand layer on Transects B through E. However, no evidence of reef-like structures was seen on the northernmost profiles, Transect A.

2.4.1.4 Outer Shelf

The outer shelf extends from water depths of 100 m out to the limit of the survey area at the 200-m isobath. This zone is approximately 10 km wide on Transect E but rapidly widens northward to 50 km on Transect D and 65 km on Transect A. The slope averages 0.2° (3.5 m per km) with local maximums up to 1° (17 m per km). The outer shelf is broken by wave cut terraces (Figure 2-5)

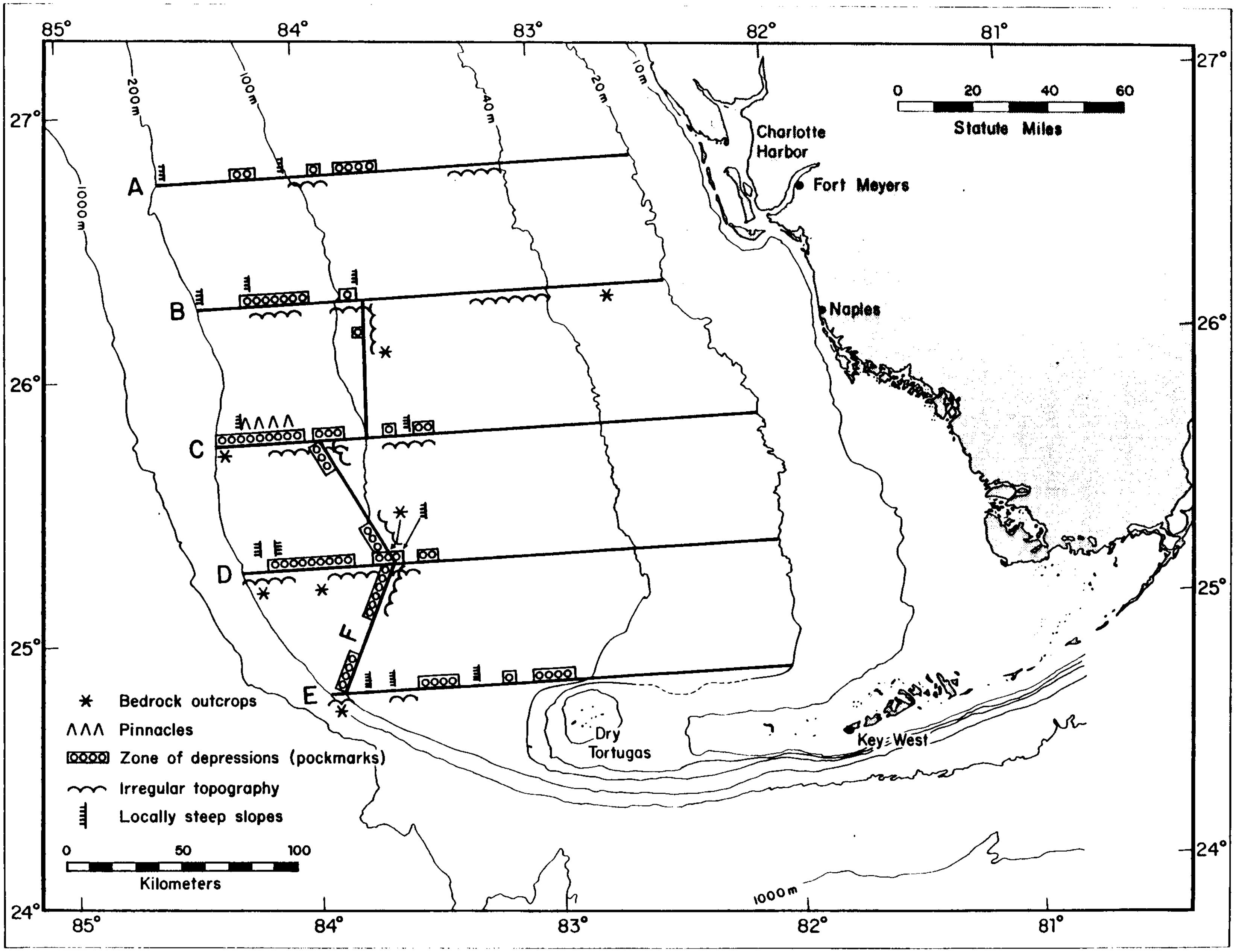


Figure 2-18. Sea floor topographic features (generalized from the Marine Habitat Atlas).

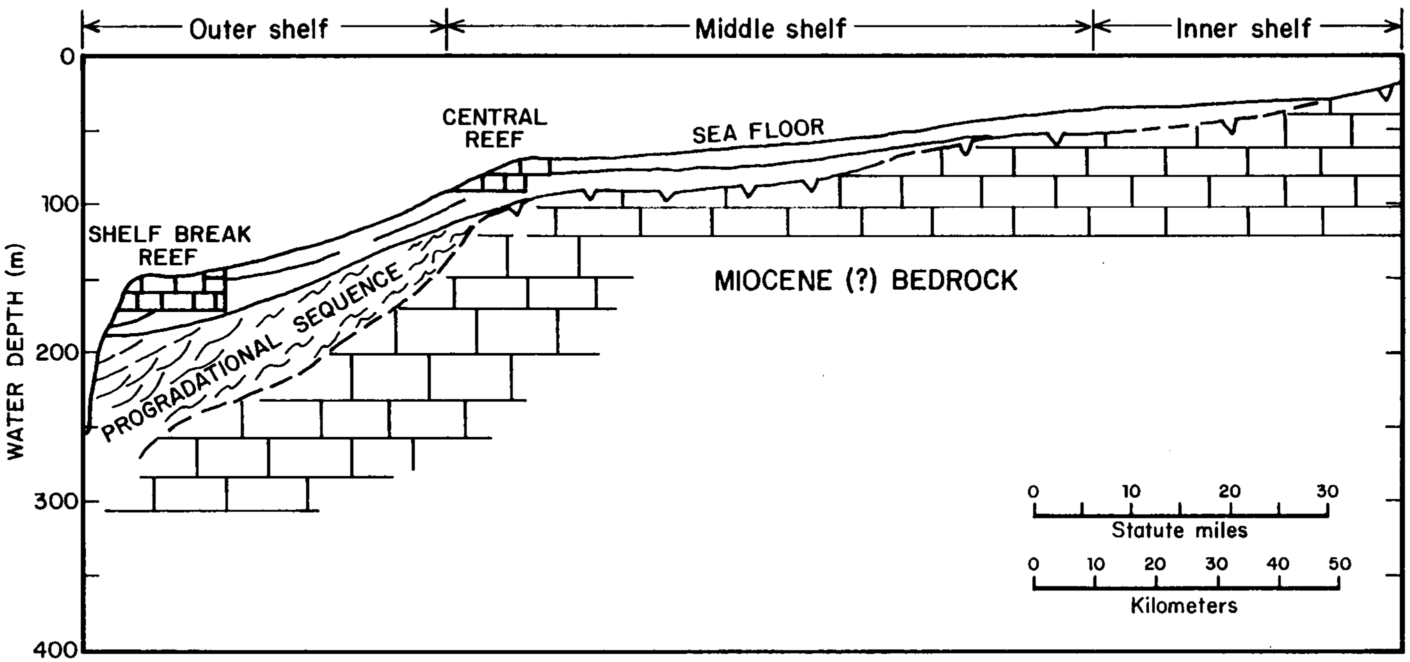


Figure 2-19. Diagramatic cross section of the southwest Florida shelf. Generalized from the Marine Habitat Atlas (see Section 4.1) and Holmes, 1981.

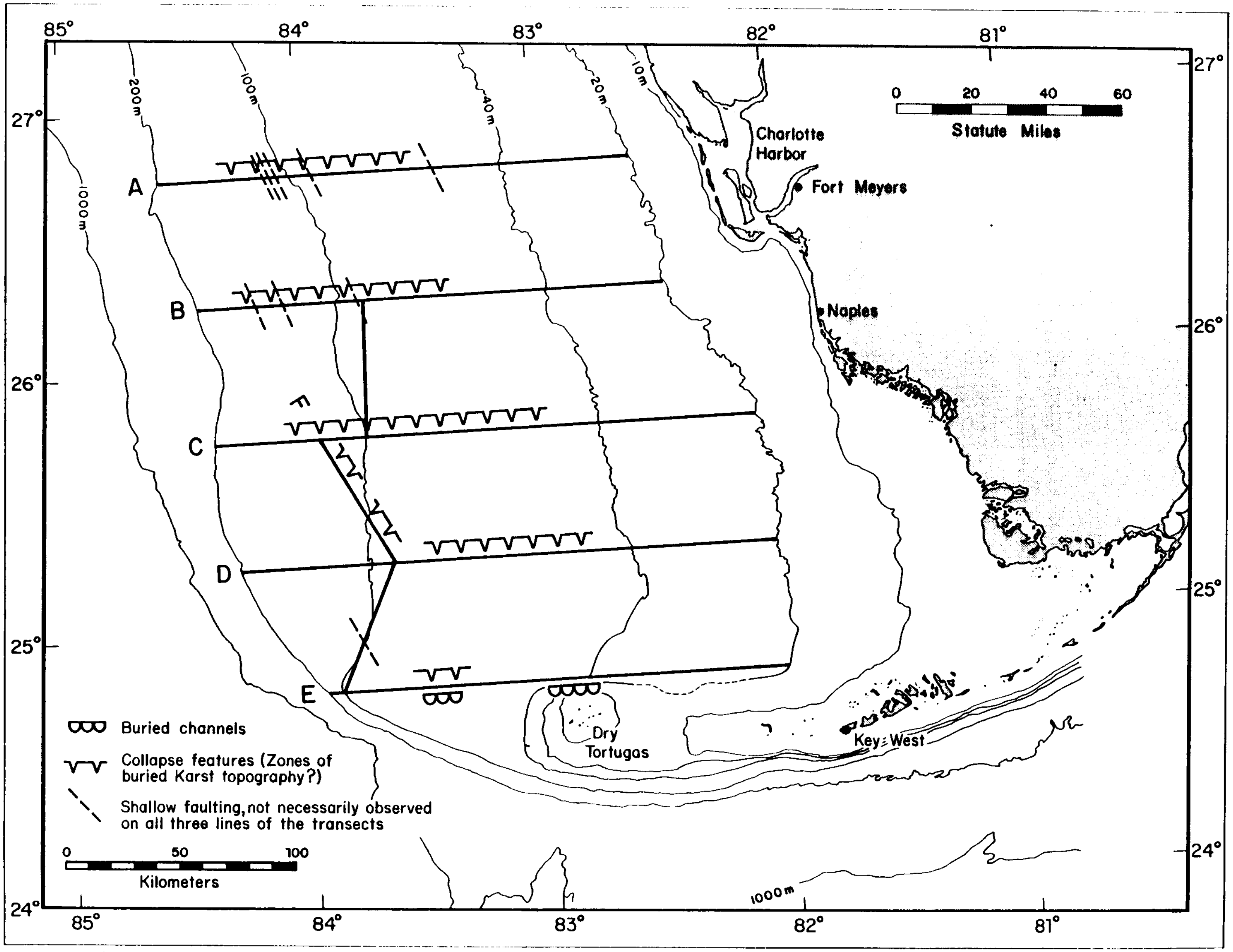


Figure 2-20. Buried geologic features of the southwest Florida shelf (generalized from the Marine Habitat Atlas).

believed to have been formed during hiatuses in the rise of sea level (Holmes, 1981). The sea floor depressions noted on the middle shelf are also found on the outer shelf, primarily in water depths of 100 to 150 m. However, they existed out to the 200-m isobath on Transect E (Figure 2-18).

The sea floor on the outer shelf is generally covered with a sand veneer, although several outcrop areas were noted on Transects C, D, E, and F (Figure 2-6). These outcrops are distinguished from the scattered outcrop areas with sand veneer found on the inner shelf by a greater horizontal extent and associated biological live bottom assemblages (Section 3).

Holmes (1981) noted a double-reef complex at the shelf break. The shallowest reef is described as a bioherm and appears to be partially exposed through a thin sand cover. The shallowest reef crests at 130 to 150 m water depth and veers landward north of latitude 25°10'N. This feature has been named the Howell Hook and is seen on Transect D. Further north, evidence of shallow-buried bioherms is found on the subbottom profile records from Transect C (water depths of 137-167 m) and Transect B (water depths of 140-150 m). On Transect C the bioherm contains many exposed pinnacles of dead coral that extend one to three metres above the sand covered sea floor. Although the bioherms on Transects B and C occur in the same general depth range as the Howell Hook feature, the wide spacing of the transects does not allow direct correlation.

2.4.2 Geologic Hazards and Design Considerations

2.4.2.1 General Observations

The basic shallow geologic and physiographic features of the southwest Florida shelf may be identified from the bathymetric/substrate maps and geologic cross sections presented in the Marine Habitat Atlas. Several categories of potential geologic design constraints for sea floor oil and gas facilities are also evident on these maps and cross sections. However, the regional nature of the survey and the small mapping scale preclude extension of the mapped zones of occurrence of these features and limits the discussion to a description of the features and a summary of their observed locations on specific transects as shown on Figures 2-18 and 2-20.

2.4.2.2 Sea Floor Features

The sea floor slopes gently to the west throughout the southwest Florida shelf (Figure 2-5). Slopes are generally less than 0.25° (4.4 m per km) and only occasionally approach 1° (17 m per km) on the wave cut terraces noted on the middle and outer shelves (Figure 2-18). The southwest Florida shelf surficial sediment layer is generally very thin (<1 m) although occasional sand accumulations of up to 10 to 12 m are noted. Beneath the thin sediment cover is a hard substrate of Miocene (?) carbonate rock on the inner shelf, and late Tertiary to Quaternary rock on the middle and outer shelves. Shallow buried reef complexes were noted at the edge of the middle shelf (70 to 90 m) and on the outer shelf of Transects B, C, and D. The latter complex is partially exposed on Transect C and contains dead coral pinnacles extending one to three metres above the sea floor. The sea floor is generally irregular over these features. Sea floor depressions (pockmarks) are found throughout the southwest Florida shelf, generally in water depth ranges of 75 to 160 m. The depressions are up to 20 to 30 m across and 2 to 3 m in depth. The origin of the pockmarks is not known but they may be related to sea floor springs and/or the subsurface karst features. The karst features are generally buried 10 to 30 m and a one-to-one correspondence between a depression and karst feature has not been established.

2.4.2.3 Subbottom Features

Figure 2-20 illustrates the approximate locations of shallow buried geologic features that were mapped from the subbottom profile data. Buried karst features are evident on the UNIBOOM records from Transects A, B, C, and the northern half of F. These may be solution sinks or collapse features. They occur in the water depth range of 55 to 200 m and are generally buried under 10 to 20 m of late Tertiary and Quaternary sediment.

Near-surface buried channels were noted on the UNIBOOM records only on Transect E in the water depth range of 40 to 50 m. The base of the channels rests on a strong reflecting horizon at about 10 m beneath the sea floor.

Near-surface faulting is found on Transects A, B, and F (northern half). The faults appear to be buried 15 to 30 m and have only minor vertical offset. Their depth extent cannot be determined from the UNIBOOM records nor can they be correlated laterally between the lines of the study transects. The faults do not offset the shallow sediment horizons and it may be assumed that the age of faulting predates the deposition of Recent sediments.

2.5 Literature Cited

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3.0 UNDERWATER TELEVISION AND STILL CAMERA OBSERVATIONS

3.1 Introduction

The purposes of the underwater television observations and still camera photography were to "ground-truth" the substrate types identified by the geophysical remote sensing observations (Section 2.0) and to collect data on the composition and distribution of biological assemblages along the survey transects. The combined geophysical and visual observations were then used to map the extent of various substrates and biological assemblages along the transects and to select stations for subsequent water column and biological sampling.

Visual observations (television and still camera) proved to be an important tool in the investigation of the types and distributions of the benthic communities on the southwest Florida shelf. Relatively accurate assessments of community distribution and structure were made with most of the dominant and prominent indicator biota being identified to the genus level. This level of detail permitted successful development of a reasonably objective, workable, biological assemblage classification scheme.

The television and still camera data were also useful in the assessment of substrate types along the survey transects. These substrate types were often closely related to the biological assemblages and their presence was reflected by the appearance of certain characteristic biota. The data base from the visual observations thus allowed generation of a sea floor substrate classification scheme, described, along with the previously mentioned biological assemblage classification, in this section.

To ensure both completeness and consistency between this report and the Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1982), this section describes the television and still camera data collected during both the first and second years of the Southwest Florida Shelf Ecosystem Study (Year I, Cruise II, October 10-21, 1980 and Year II, Cruise I, July 7-15, 1981).

3.2 Methods

3.2.1 Field

Figure 3-1 shows the geographic locations of the television/still camera transects. Continuous television coverage was recorded along five east-west transects from 20 to 200-m water depths and one north-south transect in water depths of approximately 73 to 126 m. Approximately 16,000 35-mm still camera color photographs were taken along the transects to supplement the 240 h of (black and white) videotape. Figure 3-2 outlines study procedures followed for the visual observations data.

Video footage of the sea floor and benthic biota was recorded with a Hydro Products Model TC-125 underwater television camera, Model LT-7 thallium iodide light with a 250-w thallium iodide lamp, Model SC-303 television system control unit, an Elgar Model 121 power source (frequency stabilizer), and a Sony VO Model 1800 videocassette recorder. The camera had an f/1.4 lens with remotely controlled focusing. Navigation fixes and time of day were recorded on the audio track of the videocassette tapes.

A Benthos Model 372 35-mm deep-sea camera with data chamber, a Model 382 deep-sea flash, and Ektachrome ASA 200 35-mm color slide film were used to verify substrate and benthic biotal types. Both the television camera and still photo camera were mounted on a Model RP-3 pan and tilt unit which, in turn, was attached to a television/still camera photo system sled (see Section 5.2.2.2).[1] This system was towed at a height of about one to two metres above the bottom at a speed of one to two knots. The still camera shutter was surface activated by scientific personnel viewing the shipboard television monitor. The television and still camera were aligned in such a manner that the picture taken with the still camera was the same as the field of view of the television camera at the time of shutter activation. Through use of a data chamber, the day, hour, minute, and second that the photograph was taken, along with the distance between the camera and the ocean floor in tenths of metres

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[1] See Appendix A-7 for additional equipment specifications.

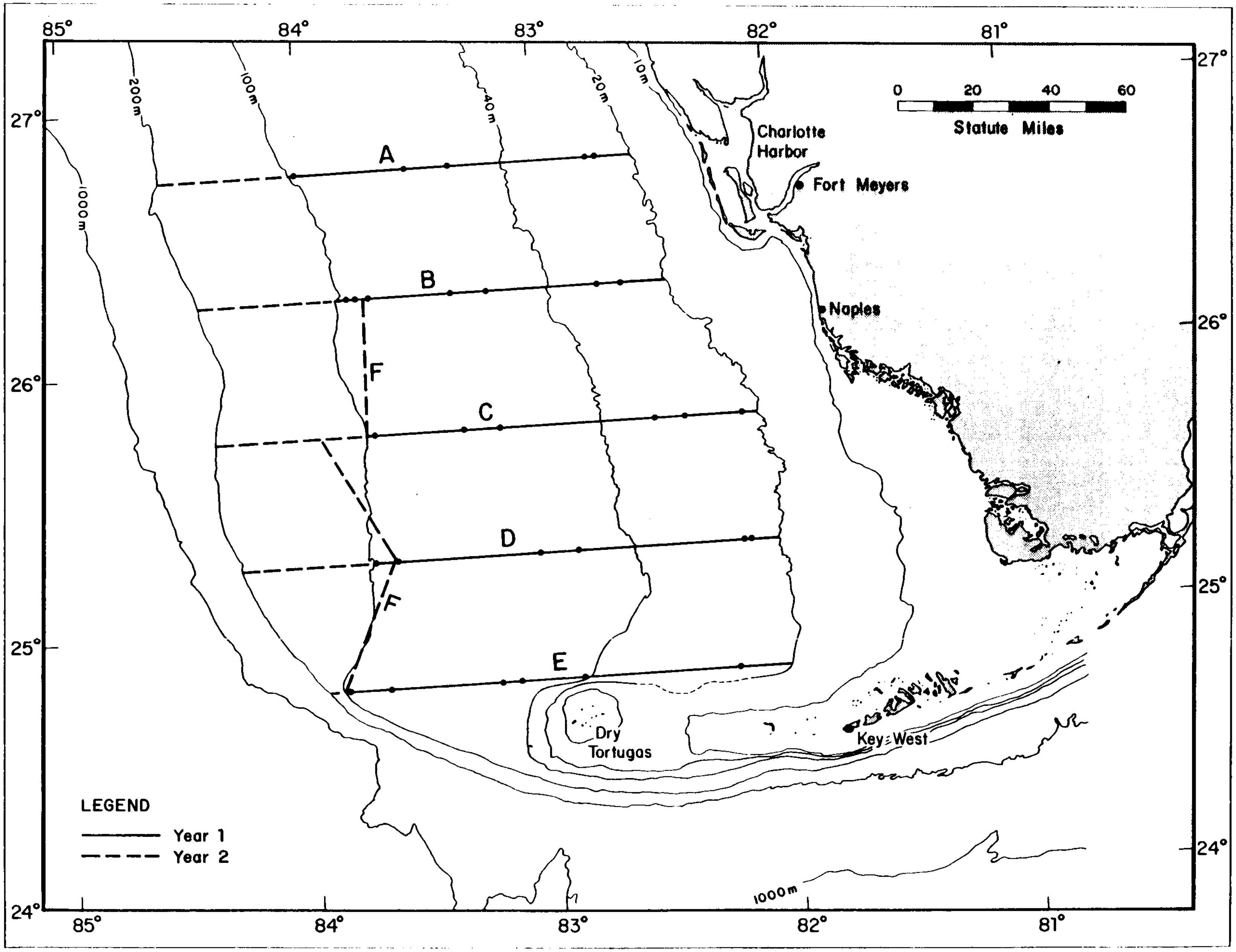

Figure 3-1. Television/still camera cruise transects.

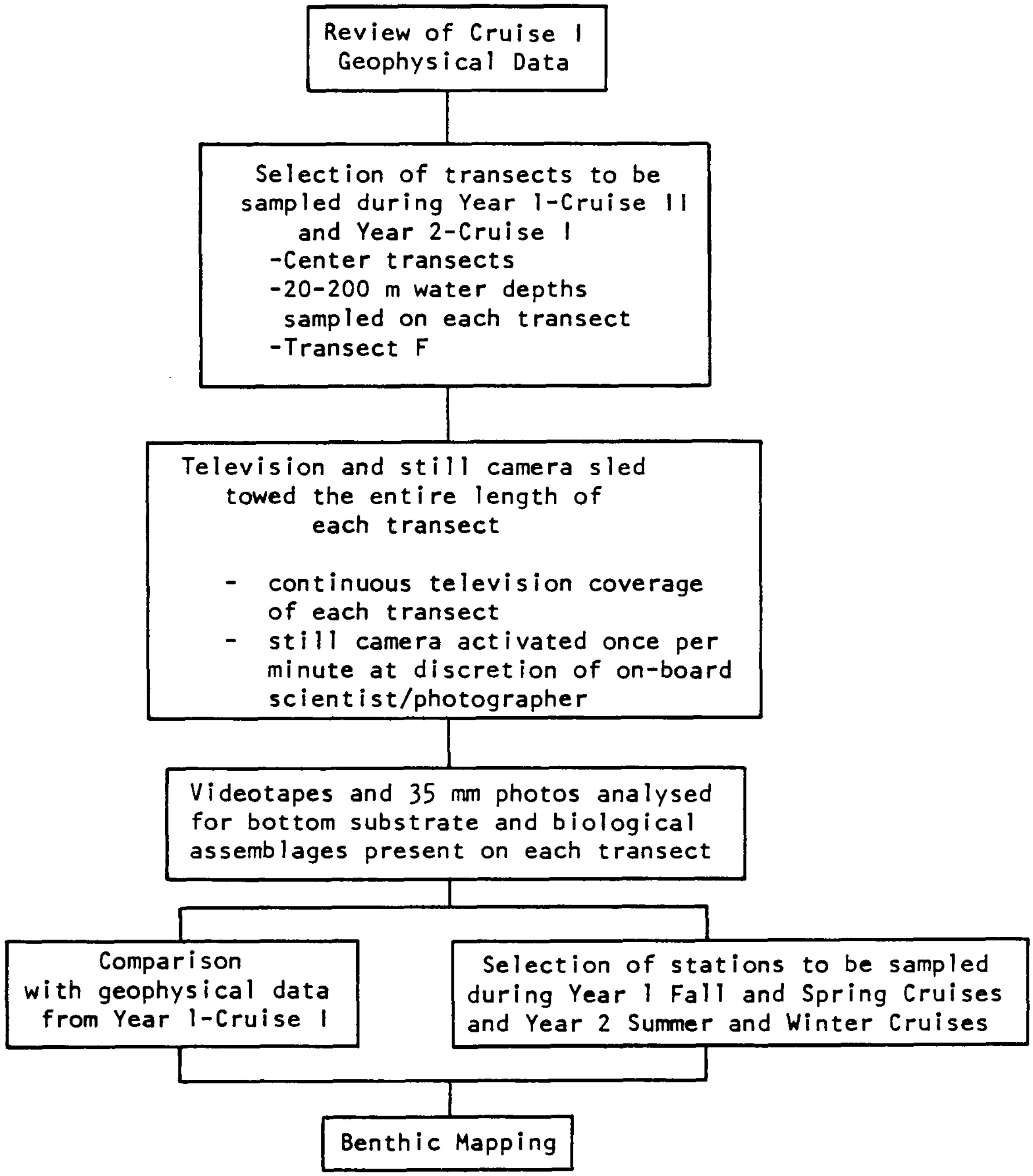

Figure 3-2. Visual observations study procedures.

(using a Benthos Model 2110 altimeter), were recorded in a data insert on each still camera slide. Still photographs were taken at an average of one per minute. Biological assemblages, substrates and any other items of interest were photographed at the discretion of the scientist observing the television monitor.

3.2.2 Analysis of Data

The biological assemblages and substrate types were identified, described, and plotted on standard basemaps after analysis of the videotape and still photographic data. Due to the intergrading of various biological assemblages, the dominant assemblage, occurring along a 10 fix-point interval (approximately 1,500 m), was used to characterize that section of the survey transect. Where live bottom patches were distributed throughout a sand bottom assemblage, the area was categorized as a live bottom assemblage. In areas where abrupt breaks between biological assemblages were apparent, that change was recorded to the nearest fix point.

The biota chosen to characterize specific assemblages were collected at various stations along the survey transects during the biological sampling cruises (Section 11.0) and were generally identified to at least the genus level. These taxa were selected because of their abundance and distinct physical characteristics. This selection permitted their positive identification in still camera slides. Fish were not used as characteristic species of assemblages due to their motility, avoidance of the television/still camera sled, and the difficulties of making positive visual identifications for a majority of the species.

The substrate characterization was based on the various types of sea bottom observed in the videotapes and still camera slides. Key biological organisms such as gorgonians and sponges, which are indicative of a hard bottom (because of their requirement for attachment to a solid substrate), were used to distinguish hard bottom areas covered by a thin sand veneer from sand bottom areas.

The data and conclusions presented in this section are based exclusively on the visual observations as described above. Subsequent comparison of the television and still camera "ground truth" data with results obtained from geophysical remote sensing techniques led to a more complete and refined analysis of both data sets. The results of this intercomparison of the two data sets are presented in Section 4.

3.3 Results

3.3.1 Substrate

The visual observations of substrate types were used to construct a generalized classification system for the sea floor substrate types characteristic of the southwest Florida shelf. This bottom characterization system is comprised of the following substrate types (Figure 3-3): Rock Outcrops/Hard Bottom, Thin Sand over Hard Substrate (flat, hard bottom areas covered with a thin sand veneer), Sand Bottom/Soft Bottom (soft bottom, often with sand waves and evidence of bioturbation), Coralline Algal Nodule Layer over Sand, and Algal Nodule Pavement with *Agaricia* Accumulations. The general features of each of these substrate types is outlined in the following paragraphs.

3.3.1.1 Rock Outcrops/Hard Bottom

Typically this bottom type takes the form of rocky ledges or exposed low-relief rock areas which are covered with distinctive indicator epibiotas. The following biological assemblages are associated with this bottom type: Inner Shelf Live Bottom Assemblage I, Inner and Middle Shelf Live Bottom Assemblage II, Outer Shelf Prominences Live Bottom Assemblage, and Outer Shelf Low-Relief Live Bottom Assemblage. (These, and other biological assemblages are described in subsection 3.3.2.)

3.3.1.2 Thin Sand over Hard Substrate

This bottom type is transitional between Rock Outcrops/Hard Bottom and Sand Bottom/Soft Bottom. It consists of a thin veneer of sand covering a more consolidated (hard) substrate. The presence of key biological organisms was

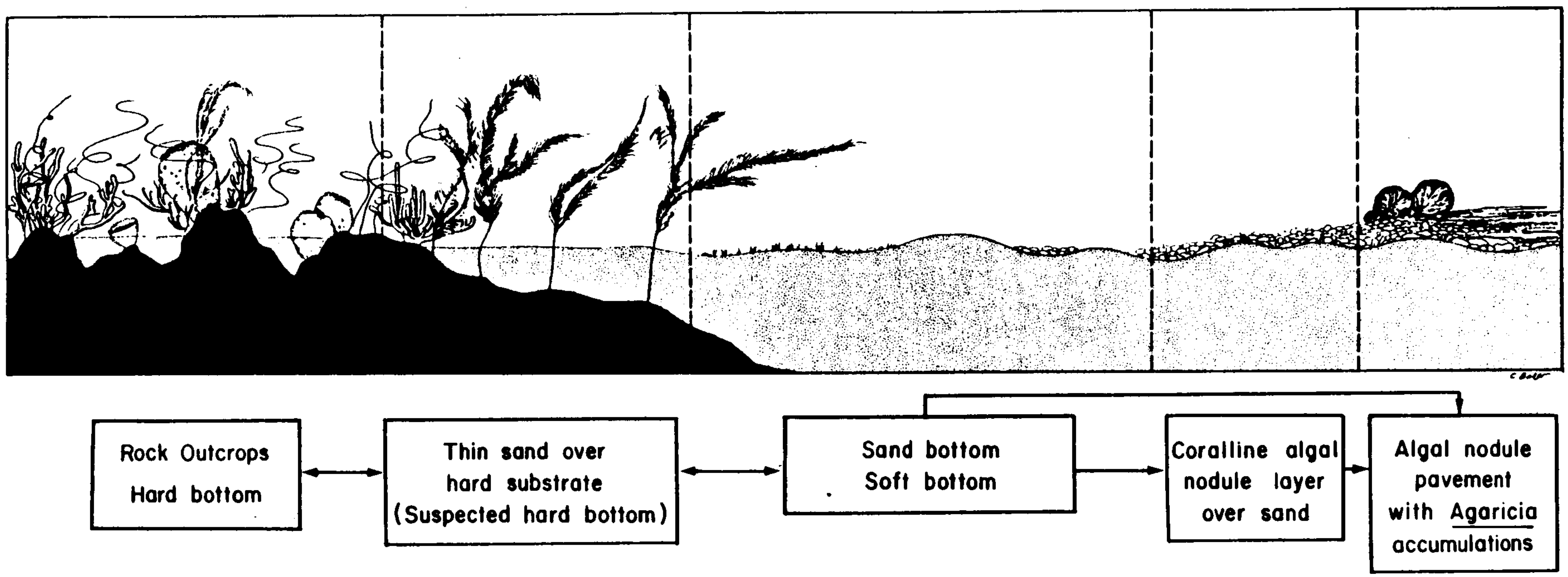

Figure 3-3. Generalized classification scheme for sea floor substrate types.

used to identify this substrate type. Large gorgonians and sponges, for example, attach to and are indicative of stable hard bottoms, and can remain above the shifting sand veneer and survive partial inundation. The Inner Shelf Live Bottom Assemblage I and the Inner and Middle Shelf Live Bottom Assemblage II were found associated with this bottom type.

3.3.1.3 Sand Bottom/Soft Bottom

This bottom type is morphologically variable and encompasses thick-layered, open sand bottoms. A variety of forms may be present, including open, planar bottoms, areas of sand waves and ripples, bioturbated areas, and soft bottoms covered with varying amounts of algae. Sediment grain size and chemical composition are variable. These constituents are often transitional and range from quartz to carbonate clastics. This bottom substrate was found over large areas of the southwest Florida shelf region. The Inner and Middle Shelf Sand Bottom Assemblage and Outer Shelf Sand Bottom Assemblage are both associated with this bottom type.

3.3.1.4 Coralline Algal Nodule Layer over Sand

This bottom type consists of patches of coralline algal nodules and rubble covering soft bottom areas. This bottom type is encountered in deeper water (greater than 60 m) and its presence is reflected in the occurrence of the Middle Shelf Algal Nodule Assemblage.

3.3.1.5 Algal Nodule Pavement with *Agaricia* Accumulations

This bottom type is similar to the Coralline Algal Nodule Layer over Sand substrate, but differs in having a fused coralline algae-dead hard coral pavement overgrowing apparent soft bottom areas. Characteristically, the sea floor in these areas is covered with living coralline algae and extensive growths of the coral *Agaricia* spp. The *Agaricia* Coral Plate Assemblage is closely associated with this bottom type.

3.3.1.6 General Distribution of Substrate Types

An analysis of the substrate data shows that approximately 50% of the sea floor that was videotaped and photographed along Transects A through F was Sand Bottom/Soft Bottom substrate (Figures 3-4 and 3-5). This bottom type occurred in all water depths studied (i.e., 20 to 200 m) and was observed on all transects (i.e., A through F).

The Thin Sand over Hard Substrate bottom type was found to be intermixed with the Sand Bottom/Soft Bottom substrate on all transects. The occurrence of this bottom type on Transect E was very limited.

Less frequently encountered substrate types were Rock Outcrops/Hard Bottom, Coralline Algal Nodule Layer over Sand, and Algal Nodule Pavement with *Agaricia* Accumulations. The Rock Outcrops/Hard Bottom substrate type was identified in 20-m water depths on Transects C[2] and D[2], at approximately 75 to 80-m water depths on Transect B[2], and scattered across the 100 to 185-m water depth range on Transects C, D, E, and F. The Coralline Algal Nodule Layer over Sand occurred scattered along Transects B, D, E, and F, in water depths of approximately 62 to 108 m. Algal Nodule Pavement with *Agaricia* Accumulations was found only on Transect E in 72 to 80-m water depths (Figure 3-4).

The Coralline Algal Nodule Layer over Sand and the Algal Nodule Pavement with *Agaricia* Accumulations substrates appear to be deeper water successional stages of the Sand Bottom/Soft Bottom substrate (as suggested in Figure 3-3). It is hypothesized that coralline algal nodules form in the troughs of sand waves in the Thin Sand over Hard Substrate bottom type (evidenced on Transect B in the 60 to 70-m depths). An increase in the size and weight of the nodules over time would decrease their mobility in currents and thus allow the nodules to gradually form solid beds. The Algal Nodule Pavement with *Agaricia* Accumulations bottom type may be a further evolution of the Coralline Algal Nodule Layer over Sand substrate, with the algal nodules growing together and forming a solid coralline algal pavement. The cementation process may also be

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[2] Outcrop areas too small to show up in Figures 3-4 and 3-5.

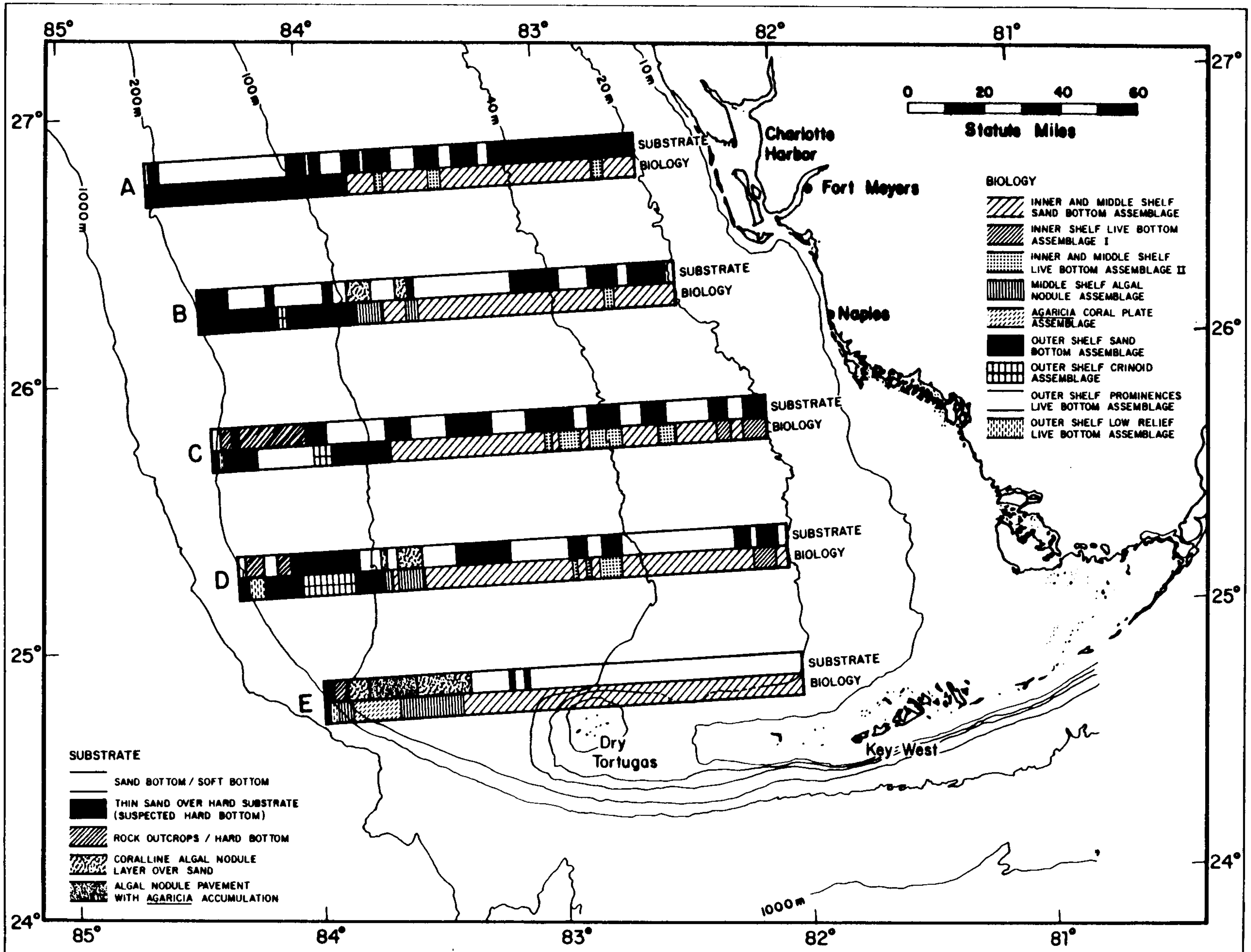

Figure 3-4. Distribution of substrate types and biological assemblages as interpreted exclusively from television and still camera observations.

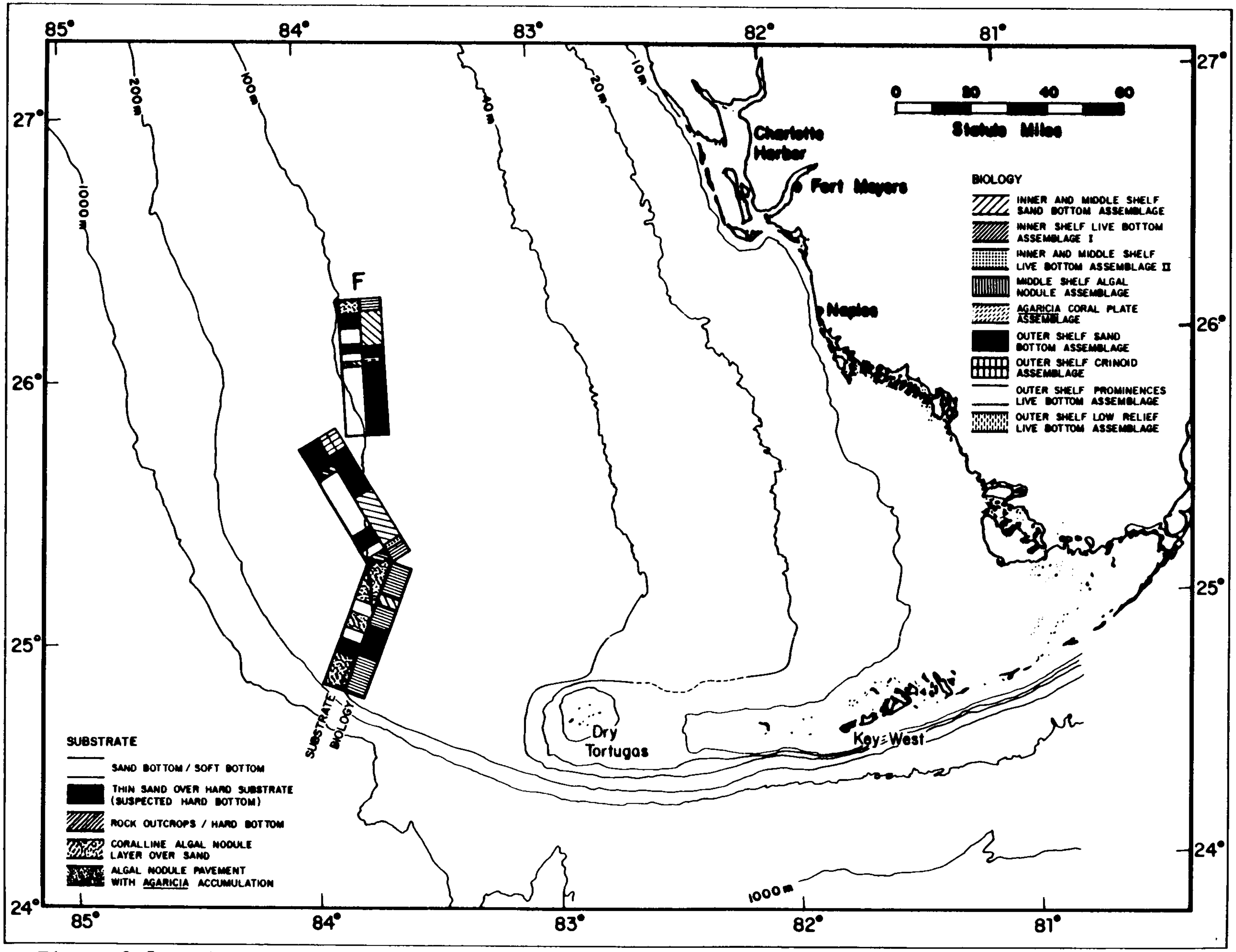

Figure 3-5. Distribution of substrate types and biological assemblages as interpreted exclusively from television and still camera observations.

aided by encrusting sponges and hard corals which find this substrate conducive to colonization. The end result is an apparent "hard bottom" substrate overlying what the geophysical subbottom profiles indicate is unconsolidated sediment soft bottom.

3.3.2 Biological Assemblages

Nine major biological assemblages were distinguished during the television and still camera observations (Figures 3-4 and 3-5). Two of the assemblages were soft bottom related and seven were classified as "live bottom" assemblages. Soft bottom assemblages (by arbitrary definition) had an attached macroepifaunal density which was generally less than one individual per m^2; live bottom assemblages had much higher macroepifaunal densities. Live bottom algal nodule assemblages were defined for areas with greater than 10% coverage by algal nodules.

A classification scheme that correlates characteristic macrobiota with an identifiable substrate type is outlined below. This scheme uses a series of assemblage "types" (a particular set of dominant organisms) that can be readily identified from television observations. This system, although helpful in determining general patterns of distribution across the southwest Florida shelf, cannot be used in "fine resolution" analyses. The general assemblage "types" are intergradational in nature and may not represent objectively definable, discrete biological entities. Areas of overlap were frequently encountered and have been merged into the assemblage "type" that appeared to be more prevalent.

3.3.2.1 Inner and Middle Shelf Sand Bottom Assemblage

This biological assemblage predominated on sand bottom substrates with an attached macroepifaunal density of less than approximately one individual per m^2. Associated biota consists of algae (*Caulerpa* spp., *Halimeda* spp., *Udotea* spp., and coralline algae), 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 *Lytechnius* spp.), holothuroids, sea pens, and sponges (Geodia neptuni). Algae covered up to 75% of the sea floor in certain photos taken in this assemblage, while epifauna was found 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 differentiated as "live bottom" assemblages. Occurrences of biota, including algae, asteroids, bryozoans, corals, echinoids, sea pens, and sponges were recorded within this assemblage. Sand waves, ripple marks and evidence of bioturbation were sometimes present. The assemblage was found in water depths ranging from 20 to 90 m. The biota from this assemblage was found to be interspersed in sand bottom areas among the Inner Shelf Live Bottom Assemblage I, Inner and Middle Shelf Live Bottom Assemblage II, and the Middle Shelf Algal Nodule Assemblage (Figures 3-4 and 3-5).

3.3.2.2 Inner Shelf Live Bottom Assemblage I

This live bottom biological assemblage consisted of patches of various algae (Caulerpa spp., Halimeda spp., and Udotea spp.), ascidians, hard corals (Siderastrea spp.), large gorgonians (Eunicea spp., Muricea elongata, Pseudoplexaura spp., and Pseudopterogorgia spp.), hydrozoans, and sponges (Geodia neptuni, Haliclona spp., Ircinia campana, and Spheciospongia vesparia). Individual organisms were generally larger, and the fauna exhibited a higher biomass per unit area, than in the Inner and Middle Shelf Live Bottom Assemblage II. This assemblage was identified from water depths of 20 to 27 m.

3.3.2.3 Inner and Middle Shelf Live Bottom Assemblage II

This live bottom biological assemblage consisted of algae (Halimeda spp. and Peysonnellia spp.), ascidians (Clavelina gigantea), bryozoans (Celleporaria spp. and Stylopoma spongites), hard corals (Oculina spp. and Siderastrea spp.), small gorgonians, hydrozoans, and several sponges (Cinachyra alloclada, Geodia neptuni, Ircinia spp., Placospongia melobesioides, and Spheciospongia vesparia). It appeared to have both a higher number of sponge species and a lower biomass per unit area than the Inner Shelf Live Bottom Assemblage I. Live Bottom Assemblage II occurred in water depths of 25 to 71 m.

3.3.2.4 Middle Shelf Algal Nodule Assemblage

This live bottom biological assemblage consisted of coralline algal nodules formed by two genera of algae, Lithophyllum spp. and Lithothamnium spp., combined with sand, silt, and clay particles. Algae (Halimeda spp. and Udotea spp.), corals, and small sponges (Cinachyra alloclada and Ircinia spp.), were also present. The assemblage was identified from water depths of 62 to 108 m.

This assemblage appears to be very similar to the "Algal-Sponge Zone" extending from 50 to 85-m water depths in the northwestern Gulf of Mexico including the Flower Garden Banks, Jakkula Bank, Elvers Bank, Geyer Bank, Rezak-Sidner Bank, Alderdice Bank, 18 Fathom Bank and 28 Fathom Bank. This Algal-Sponge Zone includes Lithothamnium spp. coralline algal nodules, the algae Halimeda spp., the hard coral Madracis sp., and various sponges (Texas A&M University, 1981).

A previous television and photographic survey conducted at Sweet Bank in the northwestern Gulf of Mexico (Continental Shelf Associates, Inc., 1980) defined an "Algal Nodule-Sponge Zone" in water depths of 75 to 80 m. The biota observed at Sweet Bank included coralline algae, leafy algae, sponges, gorgonians, antipatharians, and small tropical fish.

3.3.2.5 Agaricia Coral Plate Assemblage

This biotal assemblage consisted of a dead hard coral-coralline algae substrate covered with living algae (Anadyomene menziesii and Peyssonnelia spp.), live hard corals (Agaricia spp. and Madracis spp.), gorgonians, and sponges. It was identified from water depths of 64 to 81 m (Figure 3-4, Transect E).

3.3.2.6 Outer Shelf Sand Bottom Assemblage

The deep water sand bottom biological assemblage was distinguished by an apparent 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, and various anemones, crustaceans, and occasional hexactinellid sponges. This biological assemblage was interspersed between the Outer Shelf Crinoid Assemblage, the Outer Shelf Low-Relief Live Bottom Assemblage, and the Outer Shelf Prominences Live Bottom Assemblage. Generally, assemblages of this type were noted in water depths of 74 to 200 m (Figures 3-4 and 3-5).

3.3.2.7 Outer Shelf Crinoid Assemblage

This biological assemblage consisted of large numbers of crinoids of the species *Comactinia meridionalis*, *Neocomatella pulchella*, and *Leptonemaster venustus*, living on a coarse sand or rock rubble substrate. Small hexactinellid sponges may also be associated with this assemblage. The assemblage was identified from water depths of 118 to 168 m.

3.3.2.8 Outer Shelf Prominences Live Bottom Assemblage

This biological assemblage consisted of the soft coral *Nicella guadalupensis*; the antipatharian corals *Antipathes* spp., *Aphanipathes abietina*, *A. filix*, and *A. humilis*; the hard coral *Madrepora carolina*; crinoids; the hydrozoan *Stylaster* sp.; and medium to large hexactinellid sponges in the Order Dictyonina. All of these organisms were attached to "rock" prominences. The prominences generally emerge from a sand covered bottom and have a vertical relief of up to two metres. (Geophysical evidence subsequently indicated that these prominences are most likely dead coral pinnacles -- remnants of old, shallow buried, reefs.) The Outer Shelf Prominences assemblage extended from water depths of 136 to 169 m on Transect C (Figure 3-4).

3.3.2.9 Outer Shelf Low-Relief Live Bottom Assemblage

This live bottom biological assemblage consisted of various soft corals (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 identified from a low-relief rock surface with a thin sand veneer. Characteristically, this type of assemblage was identified in water depths of 125 to 185 m on Transects C and D and from 108 to 198-m water depths on Transect E (Figure 3-4).

The Outer Shelf Low-Relief Live Bottom Assemblage may be analogous to the drowned reefs reported in the northwestern Gulf of Mexico at Diaphus Bank, Rezak-Sidner Bank, Alderdice Bank, 28 Fathom Bank, and the East Flower Garden Bank (Texas A&M University, 1981). A similar assemblage was also reported in the northwestern Gulf of Mexico at Phleger Bank in water depths of 122 to 173 m (Continental Shelf Associates, Inc., 1980). The latter assemblage consisted of one to two-metre diameter, low-relief "rock" outcrops with attached epifauna, including cup-shaped sponges, gorgonians, and crinoids.

3.3.3 General Distribution of Biological Assemblages

3.3.3.1 Distribution by Depth Across the Southwest Florida Shelf

An across-shelf analysis of the biological assemblages reveals a general distribution pattern based on water depth ranges. Although depth range was used to denote the biotic zonation, depth as a factor is probably not decisive in determining the distribution of biotic assemblages. Other parameters, such as grain size, availability of suitable substrate, and hydrographic climate, are probably more important; however, data on these parameters were not collected during the television/still camera surveys of the transects. Delineation of the biotic "zones" was determined by the presence or absence of large and/or abundant epibiotal species and groups of species along the transects. This depth-distribution trend concurs with preliminary results from data collected west of Tampa Bay and Fort Myers during the Hourglass Cruises (Lyons, 1982). Lyons and Collard (1974) have also described west Florida shelf depth zonation patterns in the benthic invertebrate communities. Their "Shallow Shelf" and "Middle Shelf I" zones appear to generally correspond to this study's Inner Shelf Live Bottom Assemblage I and Inner and Middle Shelf Live Bottom Assemblage II, respectively.

The nine biological assemblages described above were found to occur in certain water depth ranges across the southwest Florida shelf (Table 3-1). Appendix B-1 provides more detailed information on this zonation -- transect by

Table 3-1. Percent coverage of biological assemblages along combined transects (A through F) in 10-metre depth intervals.

	10-Metre Depth Intervals Along Transects																	
Biological Assemblages	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150	150-160	160-170	170-180	180-190	190-200
Inner and Middle Shelf Sand Bottom Assemblage	83.2	86.9	77.2	87.9	73.1	41.6												
Inner Shelf Live Bottom Assemblage I	14.1																	
Inner and Middle Shelf Live Bottom Assemblage II	2.7	13.1	22.8	12.1	3.0	2.4	4.1											
Middle Shelf Algal Nodule Assemblage					21.9	38.9	59.5	5.0										
Agaricia Coral Plate Assemblage					2.0	7.7	12.5											
Outer Shelf Sand Bottom Assemblage						9.4	23.9	92.1	91.2	73.4	55.5	37.0	49.2	64.4	78.2	80.2	97.3	90.0
Outer Shelf Crinoid Assemblage								0.4	5.1	21.6	40.9	52.2	8.1		0.9			
Outer Shelf Prominences Live Bottom Assemblage												9.8	31.0	27.7	13.2			
Outer Shelf Low-Relief Live Bottom Assemblage								2.5		5.0	3.6	1.0	11.7	7.9	7.7	19.8	2.7	10.0

transect -- with a breakdown of each transect into 10-m depth intervals and a listing of the percent coverages of the assemblages within these intervals on each transect.

Three major biological depth zones are readily distinguishable from a summary of the television/still camera biological assemblage survey data (Table 3-1). The 20 to 60-m water depth zone contained the Inner and Middle Shelf Sand Bottom Assemblage, the Inner Shelf Live Bottom Assemblage I, and the Inner and Middle Shelf Live Bottom Assemblage II.

The 60 to 90-m water depth zone contained the previously mentioned Inner and Middle Shelf Sand Bottom Assemblage and Inner and Middle Shelf Live Bottom Assemblage II. The Outer Shelf Sand Bottom Assemblage occurred in this zone as well as in the 90 to 200-m water depth zone. The 60 to 90-m water depth zone thus appears to be a transition area between the two shelf sand bottom assemblages. The Agaricia Coral Plate Assemblage was restricted to this zone, while the Middle Shelf Algal Nodule Assemblage occurred here but extended out to 110-m water depth on Transect E.

The 90 to 200-m bathymetric zone was dominated in percent coverage by the Outer Shelf Sand Bottom Assemblage, with the Outer Shelf Crinoid Assemblage, the Outer Shelf Prominences Live Bottom Assemblage, and the Outer Shelf Low-Relief Live Bottom Assemblage restricted to this depth zone.

3.3.3.2 Comparison of Biological Assemblage Distributions Between Transects

Due to the distance between the northern and southern boundaries of the study area (almost two degrees of latitude), differences in the composition and distribution of biological assemblages among the transects are expected. These latitudinal differences are augmented by the various geological and habitat differences observed between transects. Table 3-2 lists the relative percent coverage of the nine biological assemblages along each survey transect.

Note that three biological assemblages were identified from Transect A, with the Inner and Middle Shelf Sand Bottom Assemblage and the Outer Shelf Sand Bottom Assemblage occurring over 90% of the transect. The Inner and Middle

Table 3-2. Relative percent coverage of biological assemblages along each survey transect.

Biological Assemblages	Transects A	B	C	D	E	F
Inner and Middle Shelf Sand Bottom Assemblage	50.1	58.5	47.3	57.7	70.6	23.9
Inner Shelf Live Bottom Assemblage I			5.9	4.4		
Inner and Middle Shelf Live Bottom Assemblage II	9.3	1.8	14.8	5.4	1.5	2.3
Middle Shelf Algal Nodule Assemblage		7.4		6.0	16.2	28.5
Agaricia Coral Plate Assemblage					9.4	
Outer Shelf Sand Bottom Assemblage	40.6	30.0	17.5	14.0		38.3
Outer Shelf Crinoid Assemblage		2.3	3.1	9.0		5.3
Outer Shelf Prominences Live Bottom Assemblage			10.3			
Outer Shelf Low-Relief Live Bottom Assemblage			1.1	3.5	2.3	1.7

Shelf Live Bottom Assemblage II occurred scattered along the transect from 25-m to approximately 65-m water depths, with no significant live bottom assemblages found deeper than 65 m.

Transect B, also exhibited almost 90% sand bottom assemblage coverage. In addition, Inner and Middle Shelf Live Bottom Assemblage II and the Middle Shelf Algal Nodule Assemblage were well represented. The Outer Shelf Crinoid Assemblage was also observed (2.3%) on this transect.

Transects C, D, and E exhibited between 65% and 72% sand bottom assemblage coverage, a significant decrease over Transects A and B. More than 35% of Transect C was occupied by various live bottom assemblages. Inner Shelf Live Bottom Assemblage I was present at the nearshore end of Transect C. Inner and Middle Shelf Live Bottom Assemblage II had extensive coverage along this transect between 30 and 60-m water depths. The Outer Shelf Prominences Live Bottom Assemblage was restricted to Transect C, located in the 135 to 165-m depth zone. The Outer Shelf Crinoid Assemblage (3.1%) and Outer Shelf Low-Relief Live Bottom Assemblage (1.1%) were also observed on this transect.

Transect D was generally similar to Transect C with six biological assemblages in common. Major differences were the presence of the Middle Shelf Algal Nodule Assemblage on Transect D, and its absence on Transect C, and the lack of the Outer Shelf Prominences Live Bottom Assemblage on Transect D. Both transects contained examples of the Outer Shelf Crinoid Assemblage and Outer Shelf Low-Relief Live Bottom Assemblage.

Transect E was dominated by the Inner and Middle Shelf Sand Bottom Assemblage with 71% coverage, and the Middle Shelf Algal Nodule Assemblage with 16% coverage. This transect was unique in encompassing the *Agaricia* Coral Plate Assemblage, found in approximately 65 to 81-m water depths. The almost complete absence of Inner and Middle Shelf Live Bottom Assemblage II and the absence of the Outer Shelf Sand Bottom Assemblage are noteworthy. The absence of the latter reflected the steep rocky scarp occupying water depths from 110 to 200 m. The Outer Shelf Low-Relief Live Bottom Assemblage was also identified (2.3%) on this transect.

Transect F was oriented in a north-south direction through Transects B, C, D, and E. At its intersection with Transects B, D, and E, extensions of the Middle Shelf Algal Nodule Assemblage were observed with a coverage of greater than 28%. Five additional assemblages were present; sand bottom assemblages covered approximately 62% of the transect (Figure 3-5).

3.3.4 Sample Station Selection Rationale

Following a review of the television videotapes from the Year I television/still camera cruise, 30 stations (15 soft bottom and 15 live bottom) were selected for water column and biological sampling. Station locations, relative to the previously described substrate and biological assemblages, are illustrated in Figure 3-6[3]. Rationale for station selection was based on locations that appeared to typify broad substrate and biological zones, as well as significant biological assemblages.

Soft bottom stations were selected primarily to fall within comparable water depth ranges (20 to 45, 45 to 70 and 70 to 100 m) on each transect (a stipulation in the MMS studies contract). This was possible on each transect except E, where no soft bottom area could be found within the 70 to 100-m depth zone. A station was selected at 38 m to replace the deep water soft bottom station on this transect.

Live bottom stations were selected primarily to sample dominant or widespread biological assemblages along the five east-west survey transects. Due to the patchy distribution of the various live bottom assemblages, it was not possible to select a live bottom station within each of the three previously mentioned water depth zones. For example, on Transect A, no significantly different live bottom assemblage was observed in greater than 70-m water depths. An additional live bottom station was therefore added to Transect B in the 70 to 100-m bathymetric zone. Also, on Transect E, no live bottom assemblage was

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[3] In examining Figure 3-6, it should be noted that not all biological assemblages could be mapped at the scale used. For a more complete presentation see Appendix B-1.

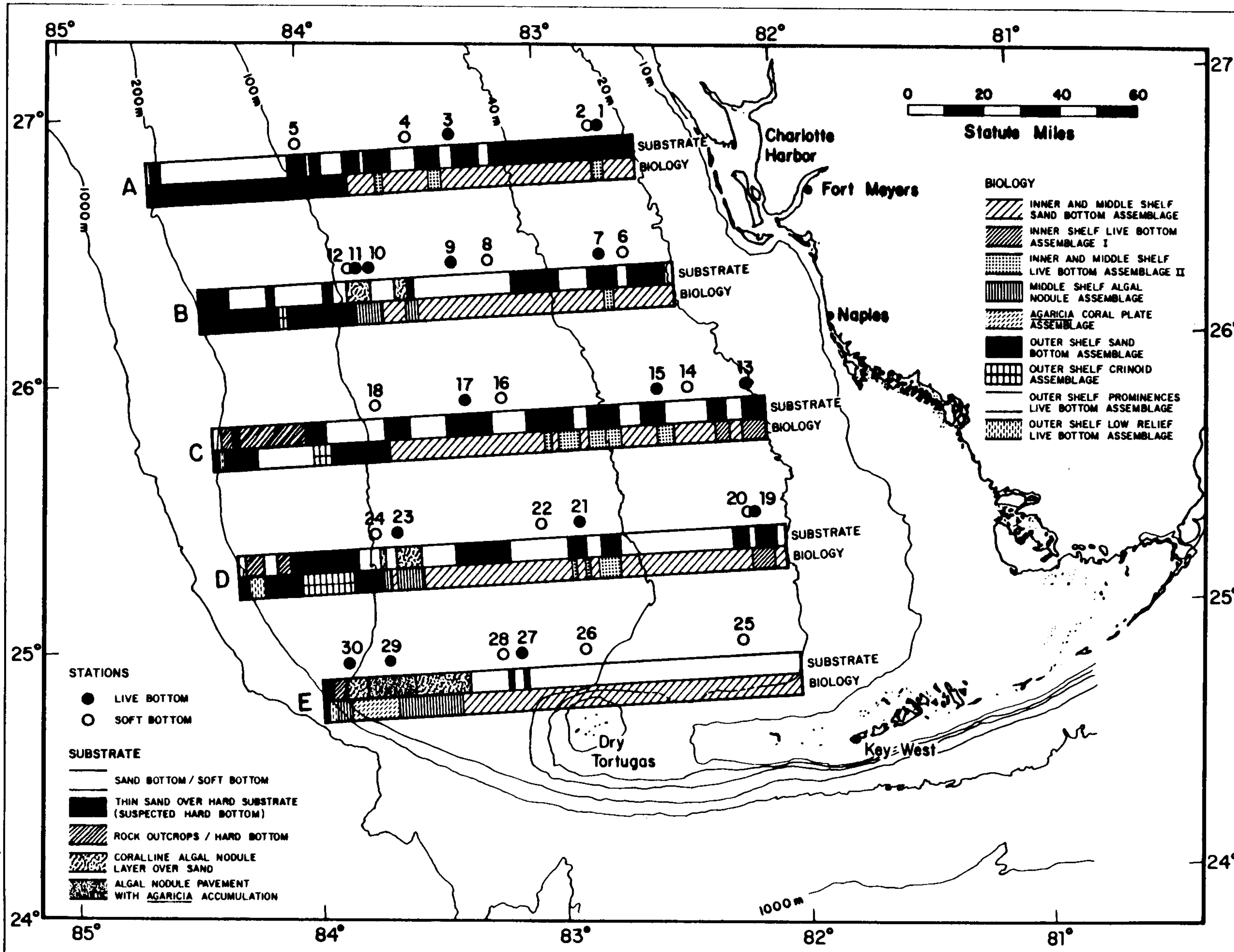

Figure 3-6. Live and soft bottom sampling stations relative to generalized substrate and biological assemblage distributions.

observed inside the 50-m bathymetric profile, thus, a station was selected at 62.5 m in the Middle Shelf Algal Nodule Assemblage.

3.3.5 Additional Television/Still Camera Observations

In addition to the substrate categories and biological assemblages described above, television and still camera observations permitted identification of turbidity fronts and sea floor depressions, or "pockmarks."

Turbidity Fronts

Localized areas of very turbid water were observed along Transect D during Year 1, Cruise II (October 1980). These discrete areas generally extended from 150 to 2,700 m in length along this transect in water depths of 53 to 75 m. During Year 2, Cruise I (July 1981), turbid areas were observed at water depths of 97.5 to 115 m on Transect A; at 103 to 104.5 m and 114 m on Transect B; at a water depth of 103 m on Transect C; and in 122 m of water on Transect D. Transect F had turbid areas just north of its intersection with Transect D. Visibility decreased to less than 30 cm in some instances. It appeared that the turbidity was caused by resuspension of surficial bottom sediments. The mechanism for resuspension may have been internal waves, although no direct evidence is available to verify this. These areas of high turbidity coincided with the Inner and Middle Shelf Sand Bottom Assemblage and the Outer Shelf Sand Bottom Assemblage, with one exception. In 122 m of water on Transect D, an area of high turbidity was located within the Outer Shelf Crinoid Assemblage.

Depressions/Pockmarks

Depressions in the sea floor, termed "pockmarks" by Neurauter (1979), were noted during the geophysical cruise, and both television cruises. These depressions varied in size from 1 to 25 m in diameter and were generally less than 2 m deep. Side scan sonar and television records indicate that some of these features may have had a cratered form with a low, gentle rim of sand or silt. Some depressions had a rocky bottom, along with aggregations of fish. The origin of these features is unknown but may reflect either the presence of underwater springs or karst features (Holmes, 1981). Depressions were observed on Transect A in 161 to 185-m water depths; on Transect B at 97.3 m; on Transect D at 65, 64, 78, 139.5, and 140 m; and along Transect F at 78 to 87, 91.5, and 126-m water depths.

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4.0 INTEGRATION OF THE GEOPHYSICAL AND GROUND-TRUTH DATA SETS

4.1 Description of the Marine Habitat Atlas

The interpretations of the geophysical data (Section 2) were integrated with the results of the underwater television and still camera (ground-truth) surveys (Section 3) and presented as a Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, 1982).

The Atlas is presented in two volumes. Volume 1 contains index and summary maps at a scale of 1:500,000 and the detailed maps and cross-sections of the survey transects at a scale of 1:48,000. Volume 2 discusses the field surveys, data analyses, and mapping procedures. It also includes more complete descriptions of the habitat (substrate types, biological assemblages, and shallow geologic features) than can be presented in the legend for the maps.

The 1:48,000 scale maps (Figure 4-1) are presented on a series of 43 sheets. Each sheet covers approximately six lease blocks in an east-west direction for Transects A through E and in a north-south direction for Transect F. Each sheet is divided into three sections. The top section shows lease area and lease block boundaries, Universal Transverse Mercator (UTM) and latitude/longitude coordinates, and the navigation data from the various cruises. The central section shows the marine habitat including bathymetry, substrate type, biological assemblage, and characteristic biota. At the bottom is a geological profile (i.e., vertical cross-section at 40x vertical exaggeration) showing the subsurface strata and shallow geologic features as interpreted from the subbottom profile data along the centerline of each transect.

Figures 4-2 and 4-3 are generalized maps of the marine habitat that were reduced directly from the data presented in the Marine Habitat Atlas. These figures show the relationships between the bathymetry, substrate, and biological assemblages.

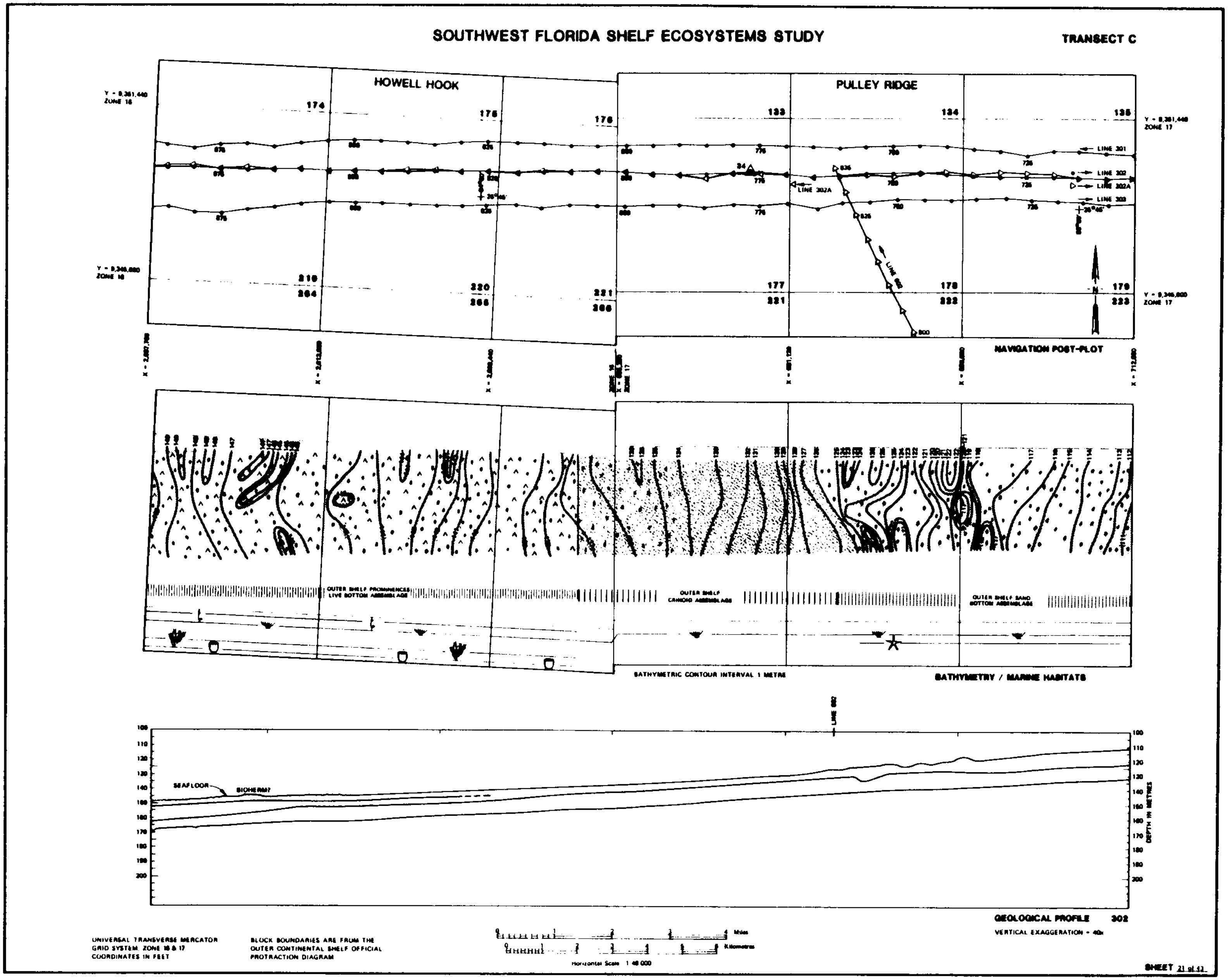

Figure 4-1. Example of a 1:48,000 scale map which appears in the Marine Habitat Atlas.

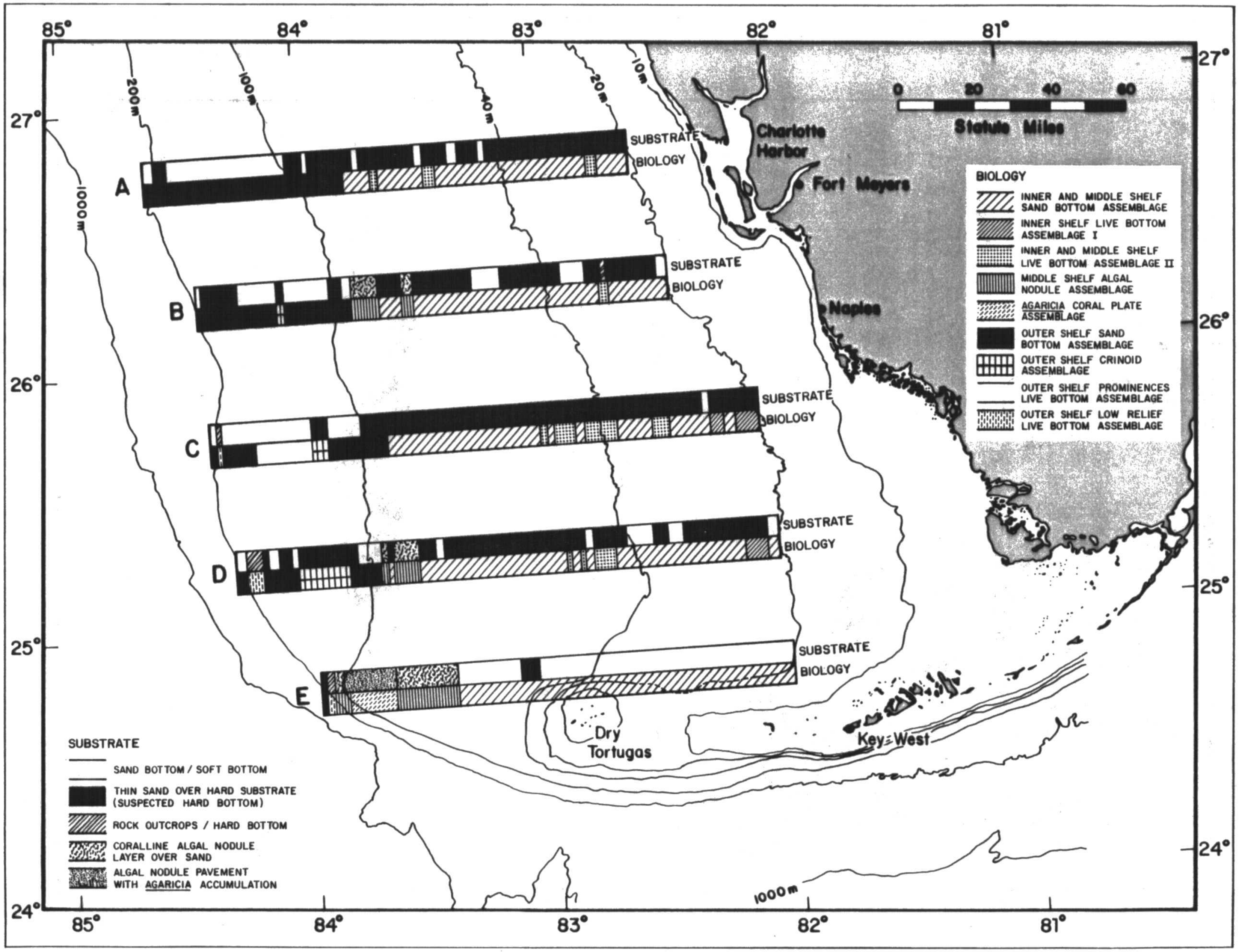

Figure 4-2. Generalized map of marine habitats along Transects A through E.

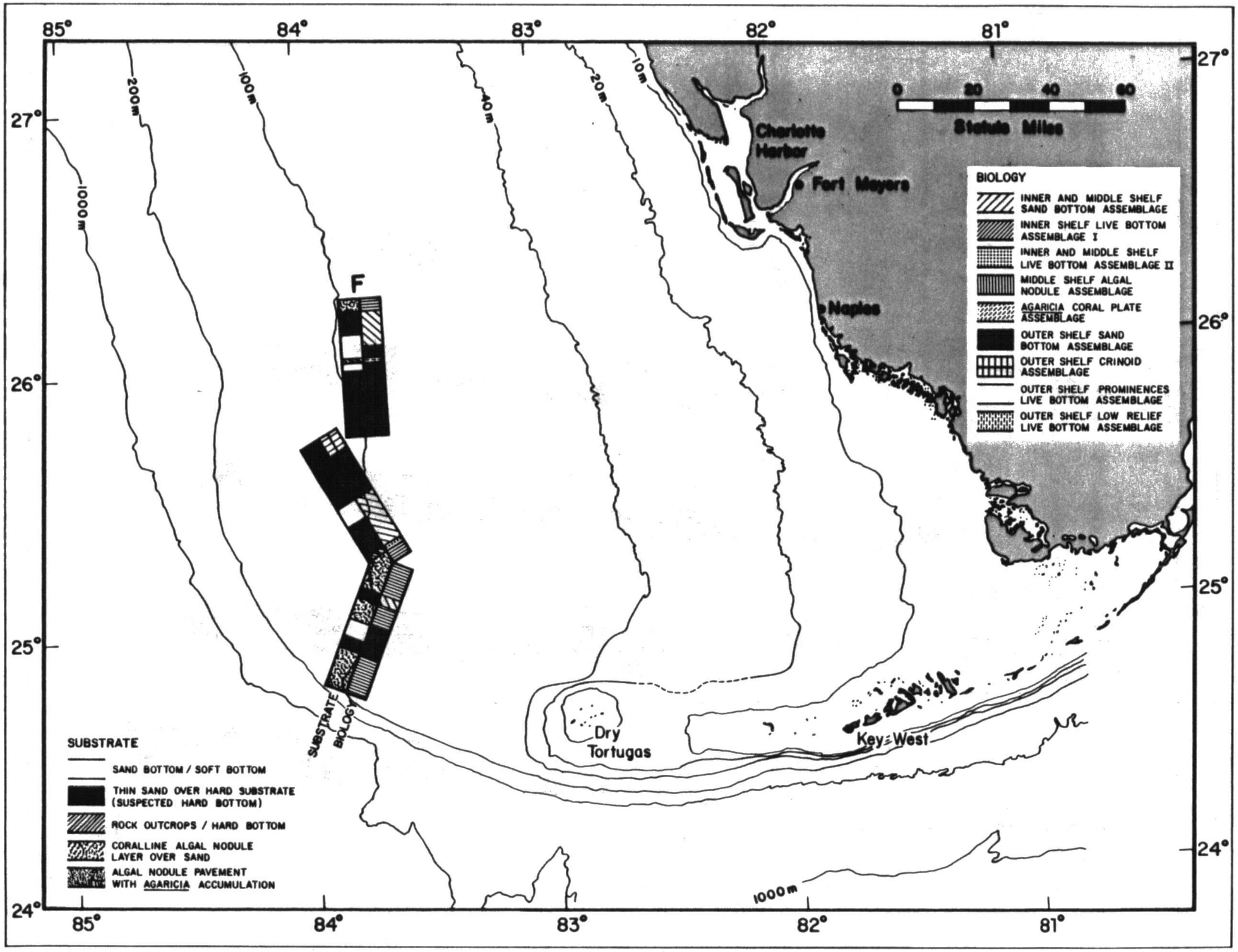

Figure 4-3. Generalized map of marine habitats along Transect F.

The data reduction and mapping procedures used to produce the shiptrack maps, bathymetry maps, and geologic cross-sections for the Marine Habitat Atlas are discussed in Section 2. The procedures for biological assemblage classification and mapping are presented in Section 3. The remainder of Section 4 addresses the procedures used to integrate the ground-truth and geophysical data sets to map the sea floor substrate types.

4.2 Comparison of Substrate Categories and the Geophysical Data

4.2.1 Substrate Categories

The classification system that was developed for the presentation of the substrates is based solely on the observations of the ground-truth data (underwater television videotapes, still camera slides, and bottom samples). In addition to the direct observation of bottom sediment or rock, key biological organisms such as gorgonians and sponges, which are indicative of a hard bottom, were used to distinguish hard bottom areas covered by a thin sand veneer from sand bottom areas. Bottom samples taken during the biological sampling cruises were also utilized for positive identification of the algal nodules, the *Agaricia* accumulations, and the bottom sediment characteristics (Section 7).

The following substrate categories are shown on Figures 4-2 and 4-3 and described in Section 3.

- Rock Outcrops/Hard Bottom
- Thin Sand over Hard Substrate
- Sand Bottom/Soft Bottom
- Coralline Algal Nodule Layer over Sand
- Algal Nodule Pavement with *Agaricia* Accumulations

4.2.2 Sea Floor Characteristics Mapped from the Geophysical Data

During the initial stages of the investigation, prior to the ground-truth surveys, several categories of side scan sonar patterns were recognized. These patterns were correlated with subbottom profile records to produce preliminary maps of the sea floor showing the following areas:

- Bedrock
  - Bedrock outcrops
  - Areas of scattered bedrock outcrops
- Sediment Bottom
  - Uniformly reflective surface (with and without secondary features)
  - Mottled patterns (striped and circular)
- Secondary Features
  - High density of scattered, low-relief, surface reflectors
  - Pinnacles
  - Depressions
  - Bedforms

These geophysical data mapping categories are described in Section 2.3 and their generalized distribution over the survey transects is illustrated in Figure 2-6. The categories primarily reflect the surficial geologic conditions, although the side scan sonar patterns and secondary features undoubtedly include reflections from some of the more prominent biological assemblages.

4.2.3 Comparison of the Data Sets

One of the objectives of this investigation was to develop an integrated interpretation of the geophysical and ground-truth data sets in order to extend the mapping of marine habitats over a greater area of the sea floor than can be viewed on a single ground-truth transect.

A comparison of the substrate maps (Figures 4-2 and 4-3) with the geophysical interpretation map (Figure 2-6) indicates that there is not always a one-to-one correspondence between a side scan sonar survey pattern and the substrate categories developed from the ground-truth data.

Table 4-1 summarizes the comparisons of the two data sets. This comparison table was developed from the large scale maps and some caution must be exercised in making detailed comparisons between the small scale generalized maps such as presented in this report. Habitats are often intermingled on a

Table 4-1. Comparison of substrate categories and geophysical data interpretations.

GEOPHYSICAL DATA	SUBSTRATE CATEGORIES: ROCK OUTCROPS/ HARD BOTTOM	THIN SAND OVER HARD SUBSTRATE	SAND BOTTOM/ SOFT BOTTOM	CORALLINE ALGAL NODULE LAYER OVER SAND	ALGAL NODULE PAVEMENT WITH *AGARICIA* ACCUMULATIONS
Exposed Bedrock					
Extended outcrops	X				
Areas of scattered outcrops	X	X			
Sediment Bottom					
Uniformly reflective		X	X	X[b]	
Mottled patterns		X[a]	X[a]		
With pinnacles and/or bioherms	X				
With a high density of scattered surface reflectors				X	X

[a] See Sections 4.3.3 and 4.3.4

[b] See Section 4.3.5

scale that is too small to illustrate in this volume and boundaries between both the substrate zones and the biological assemblages are often gradational rather than sharp as indicated on the small scale maps. Therefore, generalization and presentation of the data on a regional scale results in some loss of accuracy.

4.3 Identification and Mapping of Substrates

4.3.1 General Observations

Geophysical survey techniques are commonly used for mapping large scale geologic features. However, the successful application of these techniques for mapping the marine habitat (specifically the substrate) requires that the distinguishing characteristics between the various mapping categories are within the resolving power of the geophysical systems or that the categories are directly related to surface or subsurface features that can be detected with the geophysical systems.

Table 4-2 summarizes the operating characteristics and resolving power of the ground-truth and geophysical systems as they were deployed on this project. The values in Table 4-2 are average values provided for general comparison purposes only. In actual practice the quality and resolution of the records will depend on many factors that are under the control of the operator (e.g., instrumentation settings and towing speed) or reflect local environmental conditions (suspended sediment, available light, etc.). The advantages and limitations of the various instrumentation systems are apparent from the table.

The underwater television and still camera systems provided high resolution records of the sea floor in a form that allowed for identification of both the substrate and the associated biota. In addition, the records were easily enlarged to facilitate examination. The geophysical systems provided subsurface information, much greater fields of view, and higher rates of data collection. However, the resolution of the geophysical systems is much less than that of the ground-truth systems.

Table 4-2. Ground-truth and geophysical data collection system comparisons.

	SYSTEM			
	UNDERWATER TELEVISION	STILL CAMERA	SIDE SCAN SONAR	UNIBOOM PROFILER
<u>Operational Characteristics</u>[a]				
Record Type	Videotape (Continuous)	35 mm slides	11" chart (Continuous)	19" chart/tapes (Continuous)
Record Contrasts	Black & White (High Contrast)	Color (High Contrast)	Grey Shades	Grey Shades
Field of View (Total Surface)	~10 m	5-10 m	300 m	Profile
Depth of Subsurface Data	0 m	0 m	0 m	10 - 30 m
<u>Record Resolution</u>[b]	<1 cm	<0.5 cm	T~3 m; R~1 m	0.5 - 2 m
Acoustic Operating Frequency	--	--	~100 kHz	~1 kHz
Average Towing Speed	1.5 - 2 knots	1.5 - 2 knots	4 - 6 knots	4 - 6 knots

[a] Average values for the systems as they were deployed on this project.

[b] Without enlargement or enhancement. Resolution refers to the minimum separation between two objects so that they will be recorded as separate objects. T = transverse resolution along line of travel; R = range resolution perpendicular to the line of travel.

The above comments, and Table 4-2, apply to the systems as they were used on this project. Obviously, the underwater television and still camera systems could have been towed at a greater elevation above the sea floor and at a higher speed with a resulting increase in field of view and subsequent loss of resolution. The side scan sonar system could have been deployed with a high-resolution transducer (500 kHz), set on a short range (25 m), and towed at a slower speed with a subsequent increase in resolution and a decrease in field of view.

The following paragraphs discuss the specific ground-truth data, geophysical data, and other criteria used for identifying and mapping the extent of the substrates as shown in Figures 4-2 and 4-3.

4.3.2 Rock Outcrops/Hard Bottom

This substrate included hard bottoms in the form of emergent rock outcrops, rocky ledges, or exposed low-relief (<1 m) rock areas. Typically this substrate was covered with distinctive indicator epibiotas. These outcrop areas were readily recognized on the underwater television and side scan sonar records and confirmed from the subbottom profile records. The geophysical data were useful in identifying the extent of the outcrop areas and their relative abundance beyond the viewing range of the television system. Where the exposed rock outcrops were limited in extent to less than 300 m (two navigation fix points) or generally covered with a thin layer of sand, they were mapped as the Thin Sand over Hard Substrate category. Also included in this category are areas where bioherms (rather than bedrock outcrops) are providing the substrate for the live bottom communities. Examples of the side scan sonar record of the pinnacles and the subbottom profile record of an exposed bioherm are included in Section 2.

4.3.3 Thin Sand over Hard Substrate

This bottom type is transitional between the rock outcrops and sand bottom areas. It is very common throughout the southwest Florida shelf (Figure 4-2) and, in most areas, represents a thin, mobile, veneer of sand covering a bedrock substrate. However, the term "hard substrate" is not necessarily synonomous with bedrock and may reflect a thin calcrete layer or a calcareous rubble layer overlying softer sediment.

On the underwater television and still camera records key biological organisms were used to differentiate between this substrate and the sand bottom substrate. Large gorgonians and sponges, which attach to and are indicative of a stable hard bottom, can remain and survive partial inundation by the shifting sand veneer.

Side scan sonar records taken over this substrate generally indicate a mottled pattern (Section 2). On short range (i.e., higher resolution) records, the dark areas are shown to be composed of numerous small targets probably reflecting the exposed substrate, attached epibiota communities, and coarse rubble. On the longer range records (150 m), the resolution of the system is insufficient to separate the individual targets and the entire sections appear darker than the adjacent sand bottom. The subbottom profile records often show gentle undulations of the sea floor reflecting local thickening and thinning of the sand veneer.

4.3.4 Sand Bottom/Soft Bottom

The sand bottom category includes thick sand, silt, or mud bottoms that primarily support soft bottom communities. Several morphological forms are seen including open planar bottoms, areas of sand waves and ripples, bioturbated areas, and sandy bottoms covered with varying amounts of algae. Sediment grain size and chemical composition are also variable and often transitional, ranging from quartz to carbonate clastics (Section 7).

Key criteria for distinguishing this substrate from the previously discussed Thin Sand over Hard Substrate category include: the absence of attached epifauna as determined from the ground-truth data; a uniformly reflective side scan sonar record generally devoid of highly reflective targets; and, where the sediment thickness exceeded 0.5 m, the character of the subbottom profile records.

Since the sand bottom and thin sand bottom categories are found interspersed throughout the shelf, only extensive areas (>1500-m track length) devoid of attached epifauna were individually mapped as this category.

4.3.5 Coralline Algal Nodule Layer over Sand

This substrate represents soft (sand) bottom areas that are covered by varying thicknesses of coralline algal growths, usually in the form of loose nodules. The nodules are a few centimetres in diameter and were found over extensive areas on Transects B, D, and E.

The typical long-range (150 m) side scan sonar records obtained during Year 1 Cruise I were not diagnostic for this substrate and appeared similar to the records obtained over an open sand bottom. A few short-range (35 m) records obtained during Year 2 Cruise I showed a more granular signature for this substrate than the sand bottom, but such a signature would not necessarily be interpreted as algal nodules without ground-truth data for confirmation. Because of the small size of the nodules, identification of this substrate from side scan sonar data will probably require the use of the newer high-resolution (500 kHz) transducers. Some of the subbottom profile records taken over this substrate show a thin, highly reflective bottom surface overlying a transparent sediment layer. However, this is an occasional correlation and may be a function of the thickness or density of the algal nodule layer.

4.3.6 Algal Nodule Pavement with *Agaricia* Accumulation

This substrate differs from the previous category by having a fused pavement of coralline algal growths, coralline debris, sponges, and corals overgrowing a soft sediment layer. Characteristically, this substrate includes extensive beds of the encrusting coral, *Agaricia* spp.

Side scan sonar records obtained over this substrate contain a high density of scattered surface targets giving a dark background with isolated shadows. The shadows (white areas on Figure 2-11) probably reflect the minor relief of the encrusting coral plates or surface rubble. Neurauter (1979), in a study of the Florida Middle Ground Reef, suggested that records exhibiting a "granular" high reflectivity were related to a coral-algal pavement. Subbottom profile records from this substrate show the highly reflective sea floor previously noted over the coralline algal nodule layers.

Side scan sonar data taken at short ranges would appear to be useful in mapping the extent of algal nodule pavement areas and the high-resolution subbottom profile records will identify the hard-over-soft bottom conditions. However, these geophysical record characteristics are not necessarily unique to this substrate and positive identification of this substrate requires ground-truth data.

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5.0 SAMPLING DESIGN, FIELD METHODS, AND STATISTICAL ANALYSES FOR LIVE AND SOFT BOTTOM STATIONS

5.1 Introduction

The purpose of the sample and data collection was to characterize both the water column and benthic environments at each of the selected sampling stations. This characterization permitted development of between-station and between-cruise comparisons in order to assess the spatial and temporal variability of the marine ecosystem. This section describes the sampling design, field methods, and statistical analyses used in these assessments at selected live and soft bottom stations.

5.2 Types of Data and Samples Collected

5.2.1 General Station Description

Sample stations for the Fall and Spring Cruises were selected after analysis of the videotapes and logs from the Geophysical Cruise. Station selection rationale has been discussed in Section 3.0.

Fifteen live bottom and 15 soft bottom stations were sampled on both the Fall and Spring Cruises; Figure 5-1 shows the relative locations of these stations on the shelf. There were three live bottom and three soft bottom stations on each of five east-west transects, i.e., except for Transects A and B. A suitable live bottom area was not found at the western end of Transect A. Thus, an additional live bottom station was added to Transect B at a depth of approximately 70 m.

Each station consisted of a 1,000-m square block situated around the selected station center point; all samples taken within this square. Table 5-1 lists the station numbers, their bottom type, depth, and dates sampled; Table 5-2 lists their locations in terms of latitude, longitude, and Loran C coordinates. Table 5-3 indicates the various types of samples and data collected at the live bottom and soft bottom stations. A television/still camera system tow was the first set of data collected upon arrival at a station. This was followed by

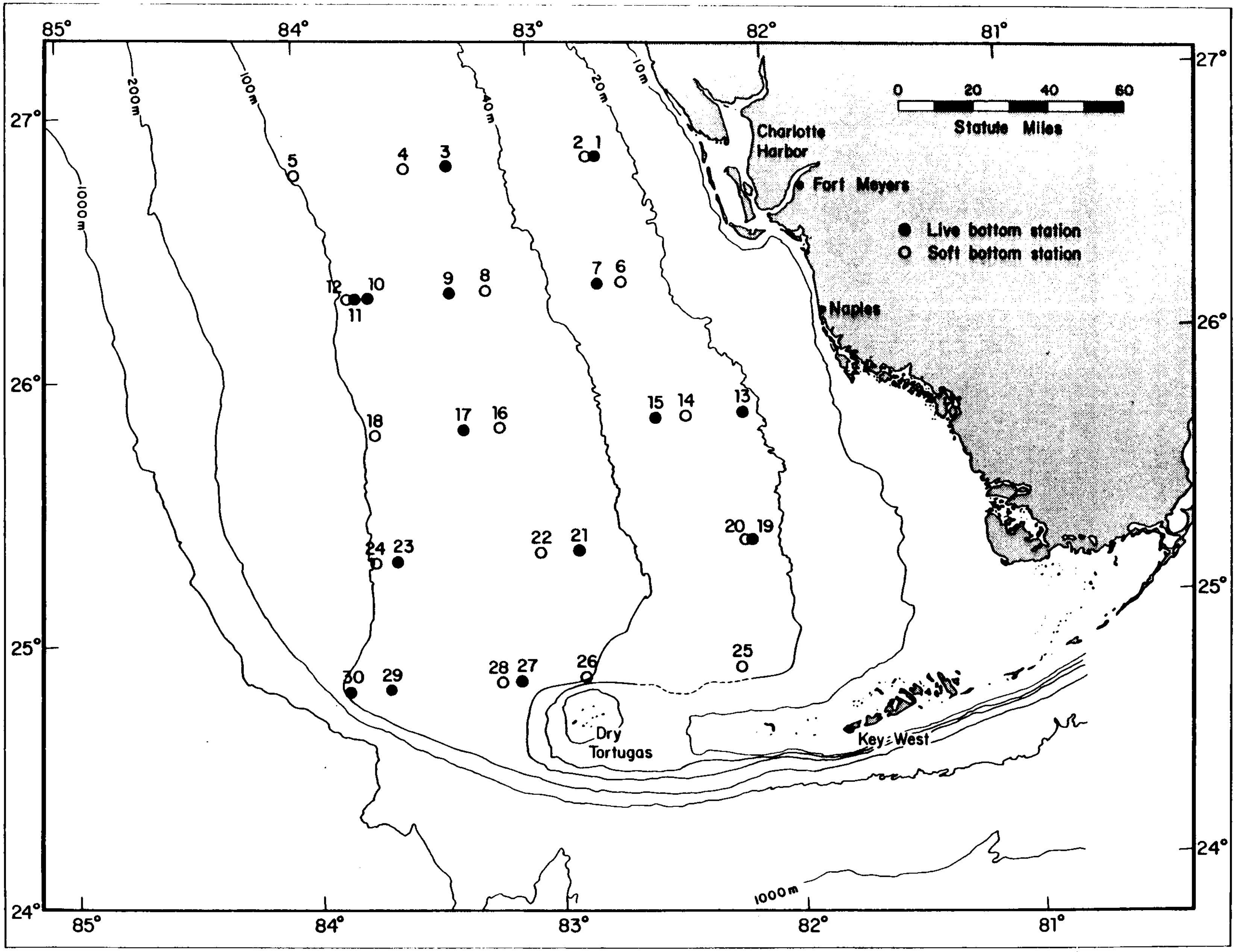


Figure 5-1. Sampling station locations for biological/hydrographic studies.

Table 5-1. Bottom type, water depth, and date of sampling of live and soft bottom stations.

Station	Bottom Type	Depth (m)	Date Sampled Fall Cruise (1980)	Date Sampled Spring Cruise (1981)
1	Live	24.0	October 27	May 2
2	Soft	25.2	October 27	May 2
3	Live	50.2	October 29	May 1-2
4	Soft	55.2	October 28	May 1
5	Soft	89.8	November 2	May 1
6	Soft	26.2	November 6	May 2-3
7	Live	30.4	November 6	May 3
8	Soft	48.4	November 5	May 3
9	Live	55.5	November 5	May 3-4
10	Live	71.3	November 3-4	April 30
11	Live	77.0	November 4	April 29-30
12	Soft	89.8	November 3	April 29-30
13	Live	19.6	November 8	April 27-28
14	Soft	26.1	November 8	April 28
15	Live	31.5	November 8-9	April 28
16	Soft	53.7	November 9	April 28-29
17	Live	58.5	November 15	April 29
18	Soft	86.1	November 16	April 29
19	Live	22.5	November 18	April 27
20	Soft	22.7	November 18	April 27
21	Live	44.2	November 18	April 26
22	Soft	52.2	November 17	April 26
23	Live	70.0	November 16-17	April 26
24	Soft	88.2	November 16	April 25
25	Soft	24.0	November 19	April 23
26	Soft	38.0	November 19	April 23
27	Live	53.5	November 20	April 23-24
28	Soft	58.6	November 20	April 24
29	Live	62.5	November 21	April 24-25
30	Live	76.1	November 21	April 25

Table 5-2. Station position data.

Station	Latitude	Longitude	Loran C Coordinates	
1	26°45.77'	82°43.11	14075.2	44314.0
2	26°45.84'	82°45.18	14070.6	44330.7
3	26°45.86'	83°21.44	13979.3	44609.3
4	26°45.81'	83°32.12	13949.2	44687.4
5	26°45.70'	84°00.13	13863.1	44883.5
6	26°16.79'	82°38.35	14020.2	44156.1
7	26°16.82'	82°44.02	14007.0	44199.1
8	26°16.72'	83°12.81	13934.3	44411.1
9	26°16.83'	83°23.81	13904.5	44490.2
10	26°16.73'	83°42.81	13849.1	44621.8
11	26°16.72'	83°46.82	13836.9	44649.0
12	26°16.72'	83°47.67	13834.3	44654.8
13	25°45.93'	82°09.35	14019.4	43856.6
14	25°46.01'	82°23.82	13988.2	43958.7
15	25°45.89'	82°31.62	13970.3	44013.2
16	25°45.70'	83°11.07	13872.1	44285.4
17	25°45.58'	83°20.24	13847.0	44346.8
18	25°45.37'	83°42.22	13783.6	44490.8
19	25°17.36'	82°09.00	13964.6	43807.4
20	25°17.34'	82°09.73	13963.0	43812.0
21	25°17.26'	82°52.16	13864.4	44083.4
22	25°17.18'	83°02.07	13839.1	44146.4
23	25°16.89'	83°37.79	13740.9	44369.1
24	25°16.90'	83°43.18	13725.2	44402.1
25	24°47.95'	82°13.26	13901.6	43799.4
26	24°47.82'	82°52.07	13810.5	44025.3
27	24°47.76'	83°08.01	13769.8	44118.5
28	24°47.11'	83°13.08	13756.4	44148.0
29	24°47.51'	83°41.19	13678.6	44310.0
30	24°47.41'	83°51.15	13649.5	44366.4

Table 5-3. Types of samples and data collected at the live and soft bottom stations.

WATER COLUMN (all stations)

- STD/DO Profile
- Salinity Samples (Near-Surface and Near-Bottom)
- Dissolved Oxygen Samples (Near-Surface and Near-Bottom)
- Temperature (Reversing Thermometer)
- Transmissivity Profile
- Photometer Profile (daylight only)
- Nutrients (Inorganic Nitrogen, Phosphate and Silicate)
- Chlorophyll *a*
- Yellow Substance

BENTHIC

- Television Videotapes (black and white) (all stations)
- Still Camera Photographs (35 mm color) (all stations)
- Box Cores (soft bottom stations)
    - Macroinfauna (soft bottom stations)
    - Sediment Grain Size (soft bottom stations)
    - Sediment Total Carbonate (soft bottom stations)
    - Sediment Hydrocarbons (soft bottom stations)
    - Sediment Trace Metals (Ba, Cd, Cr, Cu, Fe, Pb, Ni, Va, Zn) (soft bottom stations)
- Triangle Dredge Epifauna and Macroalgae (live bottom stations)
- Otter Trawl Epifauna and Macroalgae (all stations)

water column sampling and hydrographic profiling, and then by biological sampling. Specific sampling times (day vs. night) for a given sampling technique were generally arbitrary and depended solely upon when the ship was "on station".

The water column at each sampling station was characterized by measurements of salinity, temperature, dissolved oxygen, transmissivity, light penetration, nutrients, chlorophyll a, and yellow substance.

The benthic environment was determined through visual observations (television videotapes and still camera photographs), and analyses of surficial sediment samples (soft bottom stations only). The latter analyses consisted of grain size, percent carbonate, trace metals, and hydrocarbons. The benthos were very difficult to sample adequately and required more than one type of sampling gear (McIntyre, 1956, 1971).

Visual observations (television videotapes and still camera photographs) were made at both soft and live bottom stations to assess qualitatively and quantitatively the percent coverage and spatial patterns of the epibiota. Quantitative assessment of epifauna and macroalgae at all live bottom stations was accomplished using 35-mm color photographs. Quantitative sampling of live bottom assemblages by more conventional techniques (e.g., cores, grabs, trawls, or dredges) was not believed possible for a number of reasons. These reasons included: (1) specimens from different bottom types were often mixed in a sample; (2) the exact area sampled was difficult to estimate; (3) specimens were often too damaged for identification or enumeration; and (4) many epifaunal species were colonial and, therefore, could not be accurately enumerated.

Photographic sampling potentially avoided many of these problems and presented several distinct advantages for ecological investigations. Major advantages were: (1) permanent records contained a great deal of information that was easily duplicated and quickly analyzed; (2) sampling did not disturb the organisms present thereby facilitating long-term studies; and (3) analysis of still photographs was objective, precise, and very accurate for estimating the percent cover of taxa. Bohnsack (1976, 1979) reported that underwater photography has been compared to more traditional sampling methods by Vevers (1951, 1952), McIntyre (1956), Laughton (1959), Menzies et al. (1963), Emery et al. (1965), Fell (1967), Marshall and Bourne (1967), Mertens (1970), Lundalv (1971), and Torlegard and Lundalv (1974). These investigations concluded that photography was well suited for observing epifauna and hard bottom organisms and that the most information could be obtained by using color film and by photographing small areas. Extensive bottom photography along with minimal discrete sampling (trawl) has also been shown to be effective in characterizing benthic epifaunal populations and macroalgae at soft bottom stations (Hsu, 1974).

Television videotape footage was used in conjunction with 35-mm still camera results to characterize the benthic environment at each station. The television camera provided qualitative data over a much larger area than the still photographs, and thereby facilitated assessment of how adequately a photograph characterized an area. The television also provided the onboard scientist-photographer with a view of potential subjects prior to taking the photographs.

Triangle dredges (at live bottom stations) and otter trawls (at live and soft bottom stations) were used to sample the stations qualitatively . These data were used to aid in the identification of epibiota observed in the visual data as well as to provide an assessment of the species richness at each station. A box corer was used at the soft bottom stations to quantitatively sample the macroinfauna.

This assembly of sampling gear allowed for an adequate qualitative and quantitative sampling of most of the benthos at each of the stations. The meiofauna were not sampled nor were the deep burrowing, rare fauna which would have required a macroinfauna dredge (e.g., anchor dredge-Sanders et al., 1965) in addition to the epibiotal dredge employed. Fish were observed and recorded during the visual observations and sampled by the dredge and trawl. The types of trawl and dredge used, however, were chosen for their abilities to sample the epibiota and not the ichthyofaunal populations. It is believed, therefore, that the ichthyofauna were probably sampled inadequately.

5.2.2 Sample Collection Methodology

5.2.2.1 Navigation

The primary navigation system used during the Fall Cruise was a Decca Pulse-8 Loran C medium-range positioning system. The Decca Pulse-8 navigation system is a hyperbolic electronic positioning system which utilizes the Loran C navigation net; this net is established and maintained by the U.S. Coast Guard. The system is capable of operating at ranges in excess of 800 km, with an established accuracy of approximately ± 50 m at 500 km.

An EPSCO integrated Loran C positioning system was used during the Spring Cruise. This system consisted of a C-NAV XL receiver and a C-Plot-II 10-in plotter. In addition, a Digitec Model 6410 alphanumeric printer was interfaced into the system. The receiver displayed the survey vessel's position either as latitude/longitude coordinates or as the selected pair of Loran C secondary station time delays to a resolution of 0.1 μs (19.8 to 61.0 m/μs in the study area). When activated, the printer recorded the time delays for all four of the available secondary stations. Information from the receiver was also transferred to the plotter, as a means of tracking the survey vessel's progress.

On both the Fall and Spring Cruises, a 1,000-m square block was established around each station center location. Station coordinates were keyed as the center of the block; the ship's position was tracked relative to the station center. Navigation fixes for locations of all collected data or samples were marked on the plotter, recorded by the Autocarta or Digitec printer, and also recorded by the navigator in the navigation log. The fixes were recorded at the points of bottom contact and estimated lift off for all dredge and trawl samples. They were also taken at one-minute intervals during the television/still camera system tows. Beginning and ending positions for all water column profiles were recorded, as well as the position of each box core sample, relative to the station center. Appendix A-1 presents station maps showing the specific collection locations of the different data and samples from the Fall and Spring Cruises. Appendix A-7 presents additional specifications on the various navigation equipment used during the program.

5.2.2.2. Television/Still Camera Data Collection

The television and still camera system used was the same as that described in Section 3.0 (Figure 5-2). The only change in the system was that the television and light were mounted in a position to view the bottom ahead of the television/still camera sled while the still camera and strobe were oriented to provide a field of view directly beneath the sled. An iron sash weight was suspended from the end of a wooden rod forward and to the right of the sled and appeared in the right side of the television camera's field of view. The bottom end of the sash weight was suspended a distance of approximately one-half metre below the bottom of the television/still camera sled. The still camera was mounted with the lens at a distance of approximately one-half metre above the bottom of the sled. Using this system, the sled was towed at a nearly constant height above the bottom (under ideal conditions). Still photos were taken by the scientist-observer watching the shipboard television monitor. This method yielded slides covering a known area (approximately 0.5 m^2) for quantitative comparison of percent cover within and between sampling stations. Only underwater still camera slides from live bottom stations were analyzed quantitatively for percent cover. Slides from soft bottom stations were analyzed to give a rough estimate of macroalgae abundance.

Depending upon weather and sea conditions at each station, the camera system was towed in a "G"-shaped or "X"-shaped pattern at a speed of one to two knots within the boundaries of the 1,000-m square station. A typical tow pattern is illustrated in Figure 5-3. The scientist-observer took approximately three photographs per minute at specific time intervals; items of interest were photographed at the scientist's discretion. An attempt was made to take a large number of photographs within each of the live bottom patches encountered. Generally, about 200 photographs were taken at each station using Ektachrome 200 ASA color slide film. Television data were recorded on 1.9-cm (3/4-in) black and white videocassette tapes (as outlined in Section 3.0). Navigation fixes were recorded on the audio track of the videocassette tapes every minute, with areas of concentrated live bottom fauna, algae, or other epibiota recorded in the television log at corresponding navigation fix points. Upon completion of a particular roll of film, the last one-half metre was developed onboard ship to ensure proper camera performance. Appendix A-7 presents additional

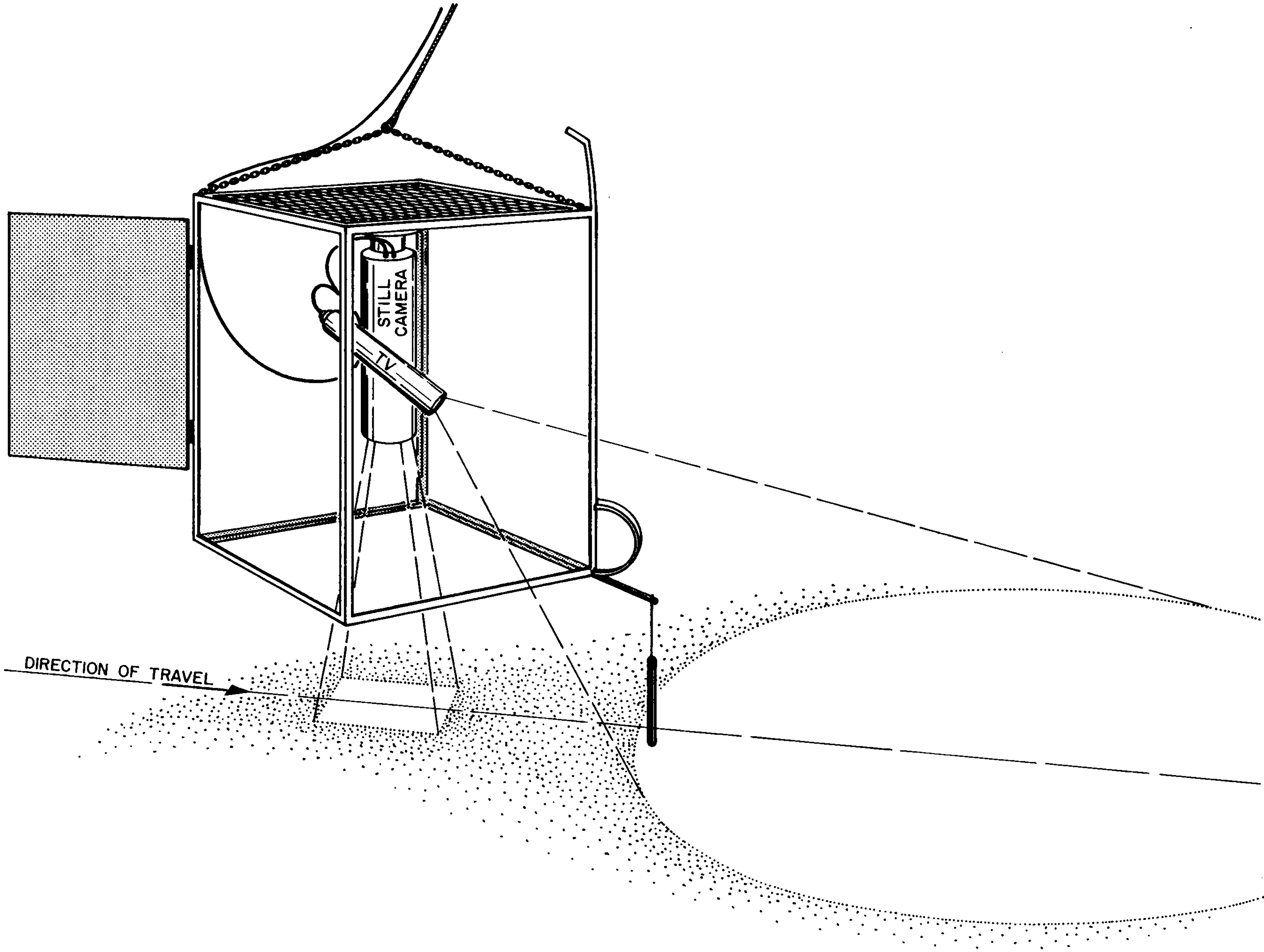


Figure 5-2. Generalized schematic of television and still camera sled set-up.

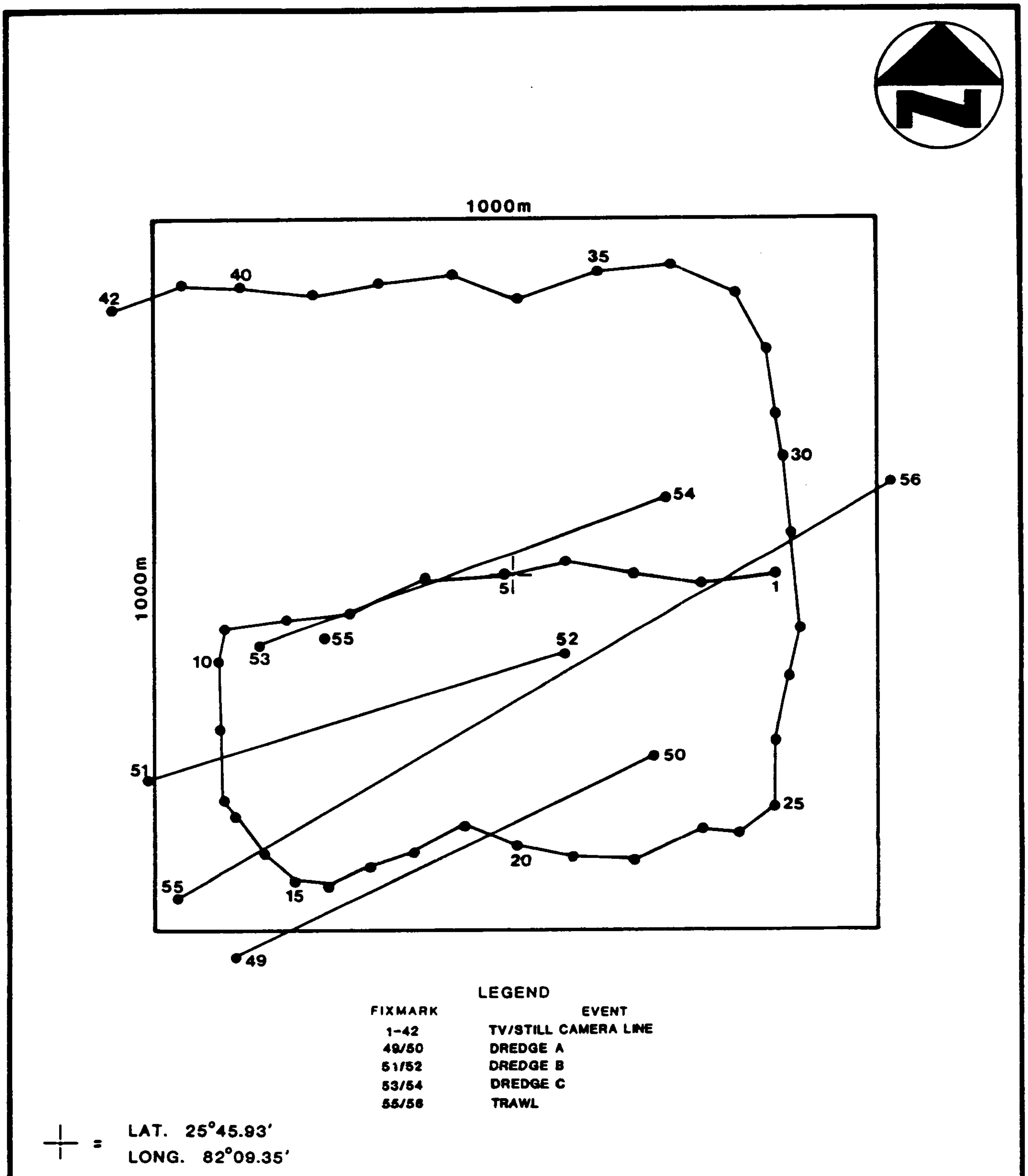


Figure 5-3. Example of camera sled tow pattern within a (live bottom) sampling station block.

specifications on the various television and still camera equipment used during the program.

5.2.2.3 Bathymetry

Bathymetric data were recorded with a Raytheon DE-719 recording fathometer (Appendix A-7). Depth measurements were recorded at all sample and data collection points. The fathometer was run continuously during both the television/still camera system tow and during dredge and trawl sampling. This procedure permitted recording of the bathymetry of areas being sampled and determination of advance warning of any steep ledges or other obstacles which may have fouled sampling gear.

All fathometer charts were labeled with the station numbers, date, time, sampling gear, and the scale setting. All navigation fix marks were automatically marked on the fathometer trace at the time of occurrence and numbered appropriately.

5.2.2.4 Biological Sample Collection

Video observations at each live bottom station were used to delineate areas of epibiotal concentrations to be sampled with the dredges and trawl. At a live bottom station, three dredge samples were taken on each sampling cruise using a Kahlsico triangle dredge. The dredge has a 0.6 m wide opening and mesh openings of 1.2 cm in diameter. It was towed through areas of live bottom biotal concentrations at speeds less than two knots for distances up to 300 m.

Towing direction was dependent upon wind and sea conditions. Navigation fix marks were recorded as described in Section 3.0.

One trawl sample, using a Marinovich 7.6-m (25-ft) semi-balloon 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, was also taken at each live bottom station. The trawl was towed through areas of high biotal concentrations which were observed on the television monitor. The length of the tow varied from approximately 500 to 1,000 m, depending upon observed macrobiotal concentrations at the station. Navigation fixes were recorded in the same manner as the dredge samples.

At each soft bottom station, one trawl sample was taken using the previously described otter trawl, but without the rollers. The trawl was towed diagonally across the block with navigation fix marks recorded (Figure 5-4).

Five box core samples were collected at each soft bottom station using a modified Reineck box core sampler (Bouma and Marshall, 1964; Farris and Crezee, 1976). The dimensions of the box were 15 cm x 30 cm x 40 cm. Each box core sample was taken as close to the station center as possible with a navigation fix mark being recorded upon impact of the box corer with the bottom (Figure 5-4).

5.2.2.5 Taxonomic Procedures for Biological Samples

Specific laboratory procedures for biological sample analyses are presented in Sections 10.0 and 11.0 (soft and hard bottom biota, respectively). However, it is important to mention certain guidelines which were followed in the treatment of taxonomic information obtained from the sample analyses. Throughout this project specimens were generally identified to the lowest possible taxonomic level. The resulting data, as treated, consist of mutually exclusive taxon groups or categories. For example, consider the sponge family Dysideidae. Some specimens could only be identified to the family level (either as a result of the physical condition of the specimen, life stage of the specimen, etc.). These specimens were recorded and treated separately as "Dysideidae". Others may have been identified to lower, more specific taxonomic levels (e.g., *Dysidea* sp. or *Dysidea fragilis*). In many analyses and most discussions, the integrity of these categories has been maintained. Thus, the reader must be cautioned against concluding that related categories (e.g., Dysideidae and *Dysidea fragilis*) overlap. Unless specifically stated otherwise, such is not the case.

Another procedure requiring clarification is the use of "sp.", "sp. x" (where x represents a specific letter or number) or "spp." following a genus name. Throughout this report, "sp." indicates that the specimens referred to under

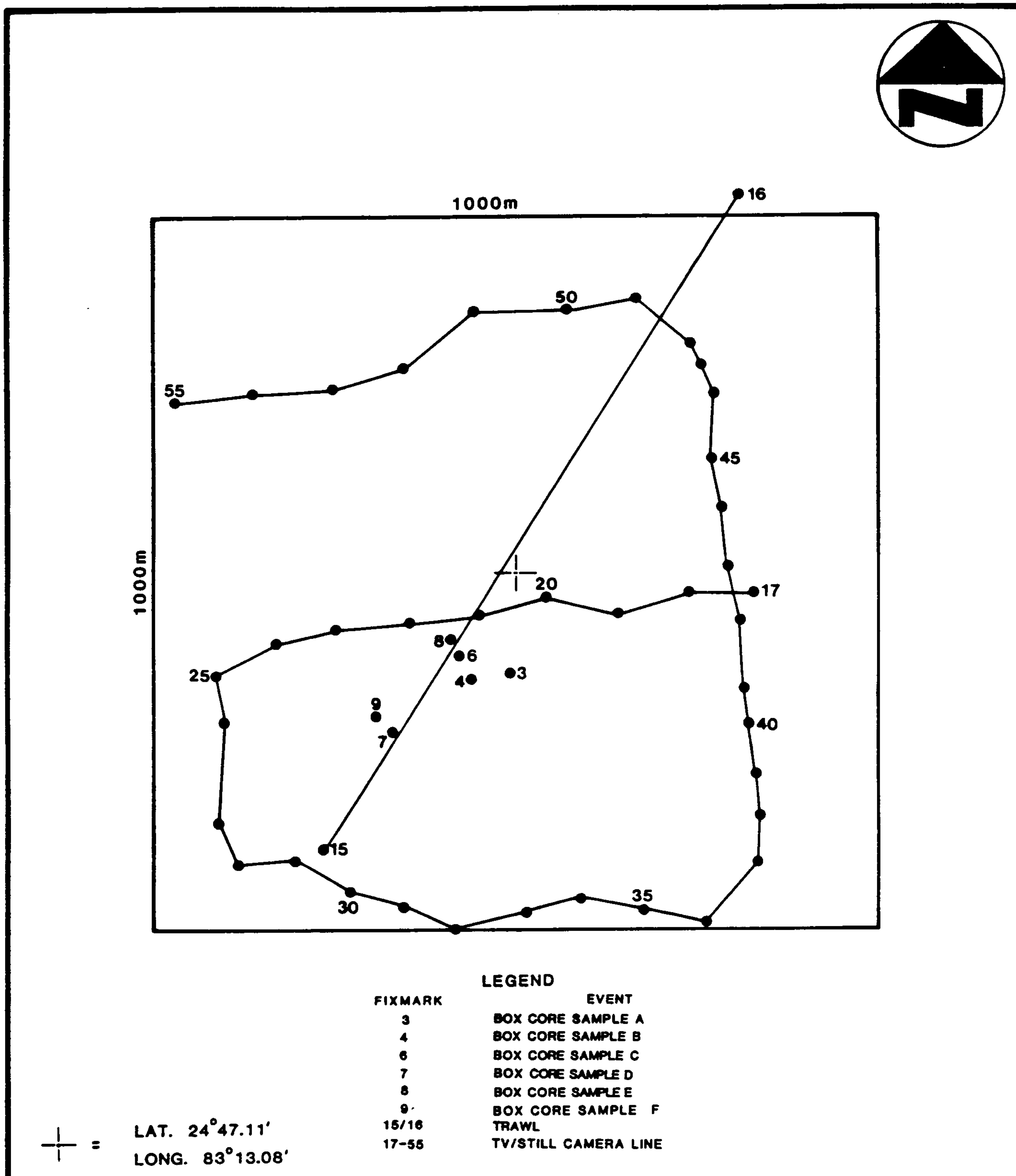


Figure 5-4. Example of biological sampling pattern within a (soft bottom) station block.

that genus all belong to the same unidentified species. "Spp." indicates that more than one unidentified species is being grouped under a given genus. If a number of different unidentifiable species are distinguishable, each is assigned a specific species letter or number (i.e., "sp. x").

5.3 Data Management and Analysis - Methods

5.3.1 Introduction

The primary functions of the data management effort were (a) to provide a single interface between Minerals Management Service (MMS) and the Principal Investigators relative to all parametric data, and (b) to coordinate the collection, processing, dissemination, and status reporting for all data produced by each of the scientific teams. In addition, the data management team was responsible for assisting Principal Investigators in the interdisciplinary data analyses as authorized by the Program Manager. Further, data outputs were coordinated with the National Oceanographic and Atmospheric Administration/Environmental Data Information System (NOAA/EDIS) for timely and orderly dissemination of the data to secondary users. These various functions were accomplished in three steps:

1. Inventory and control of scientific data;
2. Data synthesis and analysis;
3. Record and data archiving.

5.3.2 Data Management

5.3.2.1 Inventory and Control

The function of the inventory and control effort was: (a) to coordinate the collection of data by each of the scientific teams; (b) to perform sample inventories of all field and laboratory data; (c) to implement data management and quality control systems for tracking and validating data as they were prepared for entry into the data base; (d) to manage the data base files, (e) to assure the integrity and security of all data base entries; and (f) to coordinate monitoring of analytic progress and status reporting for all data produced by the Principal Investigators and processed by the data management team.

5.3.2.2 Ship and Laboratory

Sample/data logs were prepared to ensure that all required samples and data collected were properly identified. A Station Register was used to record positional information of all sample stations and the fix mark locations on bathymetric/geophysical lines and television/still camera transects. Each collected sample was assigned a unique sample number. Information recorded for each sample included date, time, depth, location, type of sample, and comments regarding sample characteristics. Appropriate sample labels were placed inside and attached to the outside of sample containers with the biological and geological samples. Recording forms supplementing the Sample Log and Station Register forms were used for the following samples or data: Weather Log, Geophysical/Bathymetric Survey Operational Log, Water Column Profile Data Form, Underwater Television, Still Camera Data Recording Form, Underwater Photograph Data Recording Form, and Benthic Sample Log. In addition, the completion of each task at each station was recorded on a station check list.

5.3.2.3 Data Selection and Entry

Data chosen for computerized summarization or analysis were recorded on appropriate keypunch forms by the Principal Investigators. Completed forms were checked for accuracy and completeness and forwarded for data base entry.

Figure 5-5 illustrates the flow of data selected for entry into the system. Keypunched data were transferred to disk storage for quality checks and preliminary processing. Each data set was checked, both visually and through the use of error detection programs for missing and erroneous data. Questionable data were checked by either the data management group, or when necessary, the PI in charge of the data set. All necessary corrections were applied to the computerized data set and a backup magnetic tape was made. When each data set was considered complete and error free, the data set was transferred to an IBM mainframe computer for analysis and entry into a large scale data base management system.

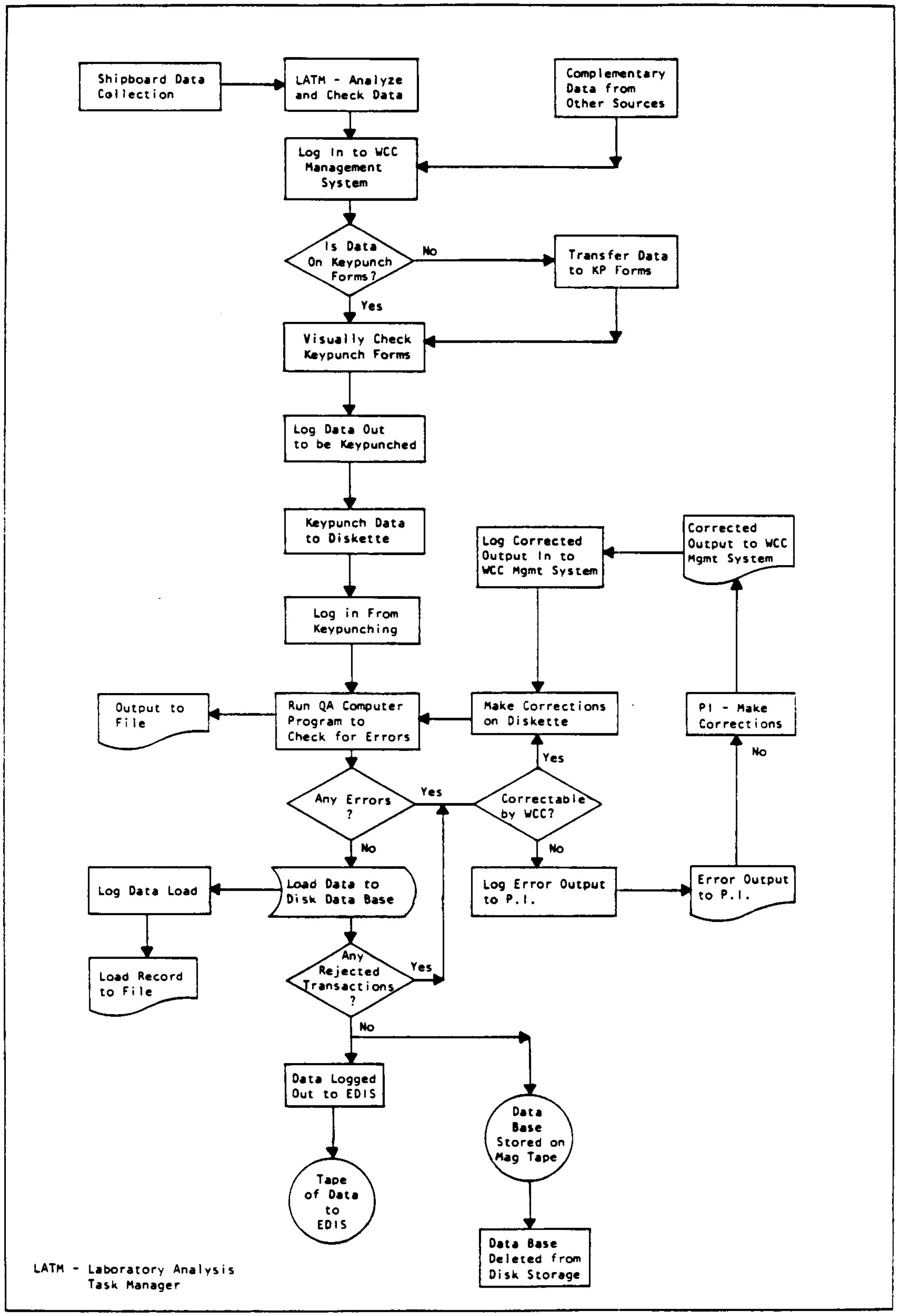


Figure 5-5. Data entry flow diagram.

Assignment of a unique identifier to each sample was crucial to sample identification and retrieval for analysis and data interpretation. The identification system used for biological sampling is illustrated in Table 5-4; for geological sampling in Table 5-5. The identifier for each sample includes codes for the cruise, transect, station, depth, type of sample or subsample, and replicate.

Inasmuch as specific species names are generally quite cumbersome, a modified coding system was utilized for taxonomic identification. The coding system established by the National Oceanographic Data Center (NODC) for use in Government sponsored studies and previously assigned codes published by the NODC in May, 1978 (National Oceanic and Atmospheric Administration, 1978) were adapted for use in this study. Few taxa found during this study were already contained in the NODC list; in many instances, this necessitated the assignment of new codes. Due to the amount of time required by the NODC to assign new codes, a number of temporary code assignments had to be developed. These temporary code assignments were developed in accordance with the basic NODC system in order to retain taxonomic order and hierarchy. The NODC coding scheme consists of a 2 to 12-digit code, based on the idea that each taxonomic level can be represented by one 2-digit number (National Oceanic and Atmospheric Administration, 1978). Five sets of double digits can represent five taxonomic levels, with a provision for two additional digits to represent subspecies or variety in some of the taxonomic groups. The "standard" five levels represented are either phylum, class, family, genus and species, or class, order, family, genus and species.

As an example, consider:

Code	Taxon	Level
50	Annelida	Phylum
5001	Polychaeta	Class
500101	Aphroditidae	Family
50010101	*Aphrodita*	Genus
5001010101	*Aphrodita japonica*	Genus, Species

Table 5-4. Biological sample identification system.

Cruise	:	III (Fall, 1980), IV (Spring, 1981)
Transect	:	1, 2, 3, 4, 5 (North to South)
Sampling Station	:	01, 02, . . . 30
Replicate	:	a, b, c, d, e, f
Sample type	:	(see below)
Subsample	:	a, b
Sample depth (m)	:	1, 2, . . . 100

Examples:

III-1-1-a-STM-a-10 = trace metal sample during Cruise III (Fall, 1980) at Transect 1, Station 1, Replicate a, Subsample a, in 10 m of water.

III-1-1-b-CLA-b-10 = second subsample of second replicate of chlorophyll <u>a</u> sample taken on the same cruise, at the same station.

<u>Sample Types</u>

BCH	Box Core Hydrocarbons
BCI	Soft Bottom Biology - Box Core Infauna Samples
CLA	Chlorophyll a ("Acid Method")
CLF	Chlorophyll a (Flourometer)
CLT	Chlorophyll a (Trichromatic)
DOH	Dissolved Oxygen (from Hydrolab)
DOT	Dissolved Oxygen (Titration Values)
NAT	Inorganic Nitrogen
NIT	Nitrite
OTH	Hard Bottom Biology - Otter Trawl Samples
OTS	Soft Bottom Biology - Otter Trawl Samples
PHA	Phaeopigments ("Acid Method")
PHF	Phaeopigments (Flourometer)
PHO	Photometer Readings
PHS	Phosphate
QSA	Quantitative Slide Analysis
SIL	Silicate
STM	Sediment Trace Metals
SWS	Salinity
TDS	Hard Bottom Biology - Triangle Dredge Samples
TEH	Temperature (from Hydrolab)
TER	Temperature (from Reversing Thermometer)
TET	Temperature (from Transmissometer)
TRA	Transmissometer Readings
YSS	Yellow Substance Values

Table 5-5. Geological sample identification system.

Transect	:	A, B, C, D, E (North to South)
Line	:	101, 102, 103, . . . (North to South)
Shot point/moving (navigation) fix	:	1, 2, 3, . . . (150 m intervals along each line; East to West)

Examples:

A/101-1	=	Northernmost line of northernmost transect, shot point 1 (i.e., inshore)
E/501-3	=	Northernmost line of southernmost transect, shot point 3

Note: All geological samples were taken during Cruise I (Geophysics Cruise).

In order to accomodate further levels that are necessary but supplemental to the "standard" levels, a system of multiple entries is used.

As another example, consider:

Code	Taxon	Level
92	Mammalia	Class
9217	Cetacea	Order
9218	Cetacea Odontoceti	Order, Suborder
921802	Delphinidae	Family
92180206	*Delphinus*	Genus
9218020601	*Delphinus delphis*	Genus, Species
9219	Cetacea Mysticeti	Order, Suborder

This system enables an animal to be coded to the level to which it is identified. As still another example, if a large cetacean is sighted but it cannot be identified further, that is, it cannot be identified as a whalebone or a toothed whale, the animal is coded as 9217. However, if it is identified as a common dolphin, *Delphinus delphis*, it can be coded to species as 9218020601.

For taxa which contain more than 99 subtaxa, multiple codes have already been assigned [e.g., protozoans (34 and 35) and insects (62 through 65)]. In those cases where taxa expand to include more than 99, (e.g., a genus which includes over 100 species), an additional number (i.e., the next available number) would be assigned.

5.3.2.4 Data Files

Separate files were maintained for each parameter within the data base (Table 5-6). Where several methods were used to measure one parameter, a separate field was used for each method. All information on sample location and time was retained in each file for unique sample identification and to allow the combination of information from several disciplines for synthesis and analysis.

A RAMIS II data base management system was used to create data summary tables and to perform some of the less complex calculations such as obtaining means

Table 5-6. List of data base files used for the Southwest Florida Shelf Ecosystems Study.

Parameter Code	RAMIS File Name	Contents
BCH	BCH	Box Core Hydrocarbons
CLA	CLO	Chlorophyll a ("Acid Method")
CLF	CLO	Chlorophyll a (Flourometer)
CLT	CLO	Chlorophyll a (Trichromatic)
DOH	DOX	Dissolved Oxygen (from Hydrolab)
DOT	DOX	Dissolved Oxygen (Titration Values)
NAT	NUT	Inorganic Nitrogen
NIT	NUT	Nitrite
PHS	NUT	Phosphate
STM	STM	Sediment Trace Metals
SIL	SIL	Silicate
PHO	PHO	Photometer Readings
PHA	PIG	Phaeopigments ("Acid Method")
PHF	PIG	Phaeopigments (Flourometer)
SWS	SWS	Salinity
TEH	TEH	Temperature (from Hydrolab)
TER	TER	Temperature (from Reversing Thermometer)
TET	TET	Temperature (from Transmissometer)
TRA	TRA	Transmissometer Readings
YSS	YSS	Yellow Substance Values
SCAD	SCAD	Sediment Carbonate Analysis (Detail)
SCAS	SCAS	Sediment Carbonate Analysis (Summary)
GSAD	GSAD3	Sediment Grain Size Analysis (Detail) - Cruise 3 (Fall)
	GSAD4	Sediment Grain Size Analysis (Detail) - Cruise 4 (Spring)
GSAS	GSAS3	Sediment Grain Size Analysis (Summary) - Cruise 3 (Fall)
	GSAS4	Sediment Grain Size Analysis (Summary) - Cruise 4 (Spring)
SEDD	SEDD	Sediment Grain Size Distribution (Detail)
SEDS	SEDS	Sediment Grain Size Distribution (Summary)
OTS	FLORIDA	Soft Bottom Biology - Otter Trawl Samples
BCI	FLORIDA	Soft Bottom Biology - Box Core Infauna Samples
OTH	FLORIDA	Hard Bottom Biology - Otter Trawl Samples
TDS	FLORIDA	Hard Bottom Biology - Triangle Dredge Samples
QSA	FLORIDA	Quantitative Slide Analysis (Hard Bottom)

and ranking taxa based on their frequency of occurrence or abundance. The RAMIS II system uses an indexed hierarchical data file structure (Mathematica Products Group, 1980) to provide for efficient storage and retrieval of data. Sample identifiers (Cruise, Transect, Station, Depth, Replicate) were stored in identical formats between files to allow for the combination of several files for analysis or generation of tables. Appendix B-2 contains descriptions of the contents and format of each data file.

Biological sampling data for soft bottom stations (Otter Trawls and Box Cores) and hard bottom stations (Otter Trawls and Triangular Dredges) were stored in the RAMIS file "FLORIDA". Sample Method was stored on the first level of the hierarchy to facilitate efficient processing, whether a single method was selected or a comparison between methods was made. Sample identifiers were stored in a manner identical to the other parameters to allow matching of physical parameters when desired. Water column parameters were each stored in a separate file: Chlorophyll, Dissolved Oxygen, Nutrients, Photometer Readings, Phaeopigments, Salinity, Temperature, Transmissometer, and Yellow Substance. The sample identifiers (Cruise, Transect, Station, Depth, and Replicate) occupied the first five fields of each record, and sample measurements occupied the remaining fields (see Appendix B-2).

The sediment grain size data were broken into several logical files. Replicate data were analyzed and submitted in tabular form as both raw (detail) and summarized (summary) data. Sediments in the size range from 0.063 mm to >4.00 mm were sorted into one-phi categories for the Fall Cruise, and refined to one-half phi categories for the Spring Cruise. This necessitated a division of the sediment data into eight files; four of these files contained summary data, four contained detailed data. The eight sets covered four categories, (1) Fall Cruise grain size categories 0.063 mm to >4.00 mm; (2) Spring Cruise grain size categories 0.063 to >4.00 mm; (3) Fall and Spring Cruises grain size categories <0.001 to 0.062 mm; and (4) Fall and Spring Cruises summary statistics.

5.3.3 Data Synthesis and Analysis

As shown schematically in Figure 5-6, the data synthesis and analysis effort consisted primarily of extracting selected data from the data base and subjecting them to summarization and/or statistical analysis. Table 5-7 summarizes the data synthesis and analysis products. Initial data processing efforts consisted of summary table generation showing taxonomic presence and abundance at each sample site. The output was sorted to show the most frequent and most abundant taxa found at each station.

The following univariate analyses were next performed on the various data sets as appropriate:

- Arithmetic Mean
- Minimum
- Minimum >0
- Maximum
- Standard Deviation
- Skewness
- Kurtosis
- Frequency of Occurrence
- Cumulative Frequency of Occurrence
- Mean Number per Occurrence

Taxon abundance and presence histograms were examined in graphical form to illustrate the distribution of taxa collected using the various sampling methods. Each histogram arranged the bars in decreasing order of frequency or abundance to show differences in magnitude between abundant or frequently occurring taxa and rare taxa. The histograms were used primarily as an aid in determining truncation levels for subsequent multivariate analyses. As discussed below, it was necessary to reduce the number of taxa used in multivariate analyses due to computer program limitations.

Relationships between distributions of sediments, sediment trace metals, sediment hydrocarbons, and benthic taxa were examined using multiple correlation, clustering, and discriminant analysis techniques. Sediment grain size distribution, trace metal levels, and hydrocarbon levels were subjected to multiple correlation coefficient (R^2) and the significance level of R^2 analyses.

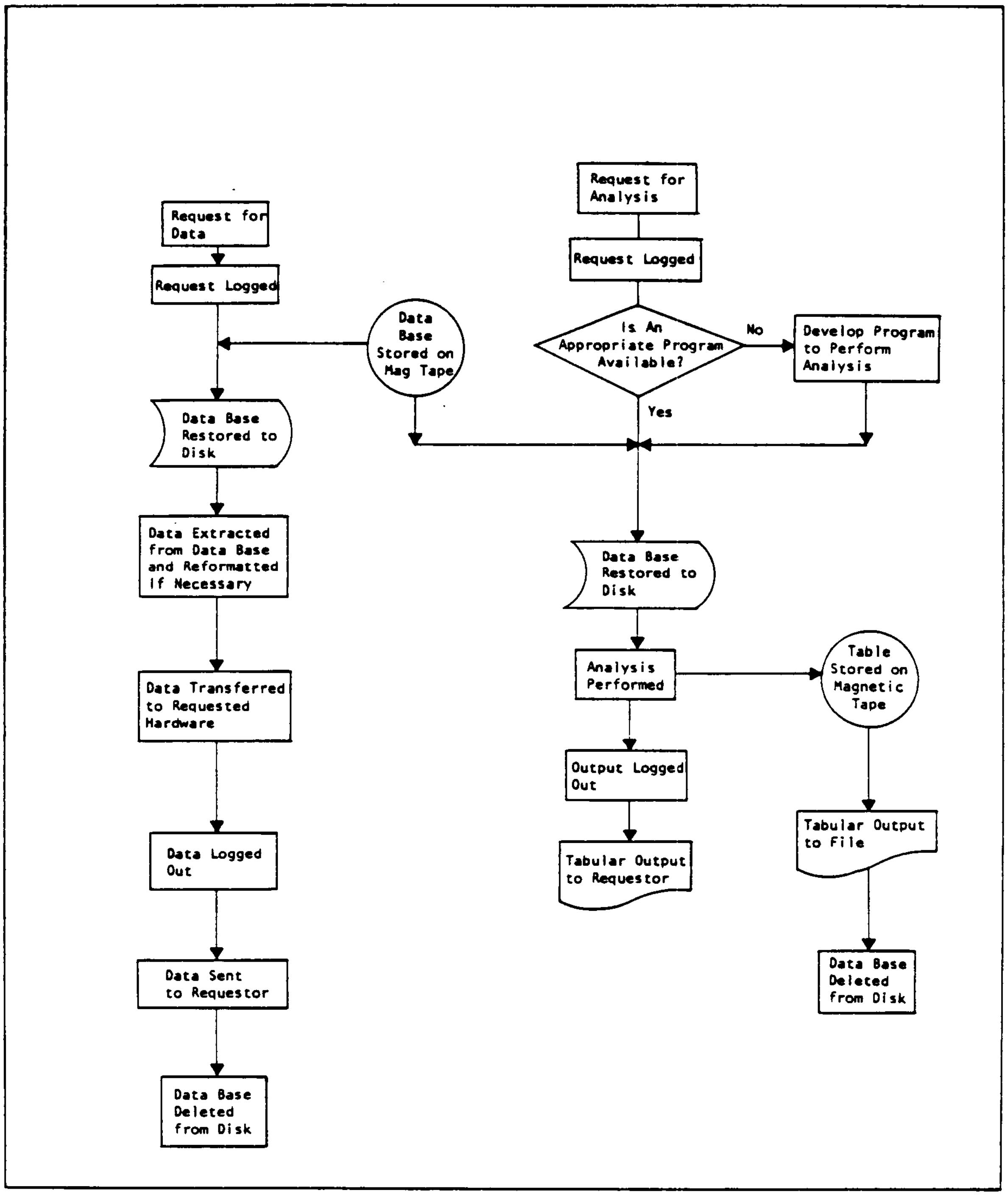


Figure 5-6. Data processing flow diagram.

Table 5-7. List of analyses performed.[a]

Analysis	Biological Data					Sediment Data					Water Column Data									
	OTS	BCI	OTH	TDS	QSA	SEDS	GSAS	SCAS	BCH	STM	CLO	DOX	NUT	SIL	PHO	PIG	SWS	TMP	TRA	YSS
Descriptive statistics	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Taxonomic listings	X	X	X	X	X															
Frequency of occurrence tables	X	X	X	X	X															
Abundance tables		X			X															
Frequency of occurrence rank order tables	X	X	X	X	X															
Abundance rank order tables		X			X															
Frequency of occurrence histograms	X	X	X	X	X															
Abundance histograms		X			X															
Multiple correlations		X				X	X	X	X	X										
Principal components analyses						X	X	X	X											
Q-mode cluster analyses	X	X	X	X	X					X										
R-mode cluster analyses	X	X	X	X	X															
Two-way coincidence tables	X	X	X	X	X															
Discriminant analysis	X	X	X	X	X		X	X	X	X										

[a]See Table 5-4 for complete explanations of sample type codes (column headings).

As a means of analyzing the box core samples, indices of taxonomic richness, equitability, and diversity were calculated for each station during each cruise. All taxa identified were included in computation of these indices for the soft bottom stations. At live bottom stations indices of taxonomic richness were determined for trawl and dredge sample data. However, only taxa identified to the species level (e.g., either *Anadyomene menziesii* or *Anadyomene* sp. A) were included in the computation of "species" richness at live bottom stations.

Taxonomic richness (S) was calculated as the total number of taxa at each station. The Shannon-Wiener Index (H') was used to describe diversity of these taxa at each station:

$$H' = -\Sigma P_i \log P_i \quad \underline{\text{Where}}: P_i = \frac{\text{\# of Individuals of Class i in Sample}}{\text{Total \# of Individuals in Sample}}$$

(Pielou, 1975)

Equitability (J') was calculated as:

$$J' = \frac{H'}{\log S} \qquad \underline{\text{Where}}: S = \text{Richness}, \quad H = \text{Shannon-Wiener Index}$$

(Pielou, 1975)

Each of these indices was biased due to the practical level of taxonomic identification for some groups. In the case of computations for the live bottom data, species richness values were underestimated because data from multispecific groups were not included in the analyses. In the case of the soft bottom data, taxonomic richness was also underestimated since multispecific taxa each contributed "1" to the taxonomic richness, while in reality the actual contribution may have been as high as the number of specimens contained within the group. Diversity computations were also underestimated because multispecific groups artificially increased dominance in the data. Similarly, equitability was reduced due to the artificial increase of dominance.

5.3.3.1 Transformation and Standardization

Whenever possible, data transformations or standardizations were avoided because they tend to increase the complexity of the analysis and make it more difficult to visualize directly, or to validate, subsequent analytical steps. Data transformations and/or standardizations were applied when it was necessary to meet the assumptions of a statistical test or to increase the precision of a statistical procedure (such as clustering or discriminant analysis). Transformations apply a mathematical function to every element of the input data matrix. Transformations utilized in this study included:

- Square Root: $X_{ij} = (X_{ij})^{0.5}$

Where: X_{ij} is the data element represented by the row (observation) i and the column (variable) j

- Binary: $X'_{ij} = 0, \text{ if } X_{ij} = 0$
  $\quad\quad\quad\quad 1, \text{ if } X_{ij} > 0$

Standardizations change the value of an element in the input matrix according to it's relationship with other elements of the matrix. Only one standardization was considered necessary:

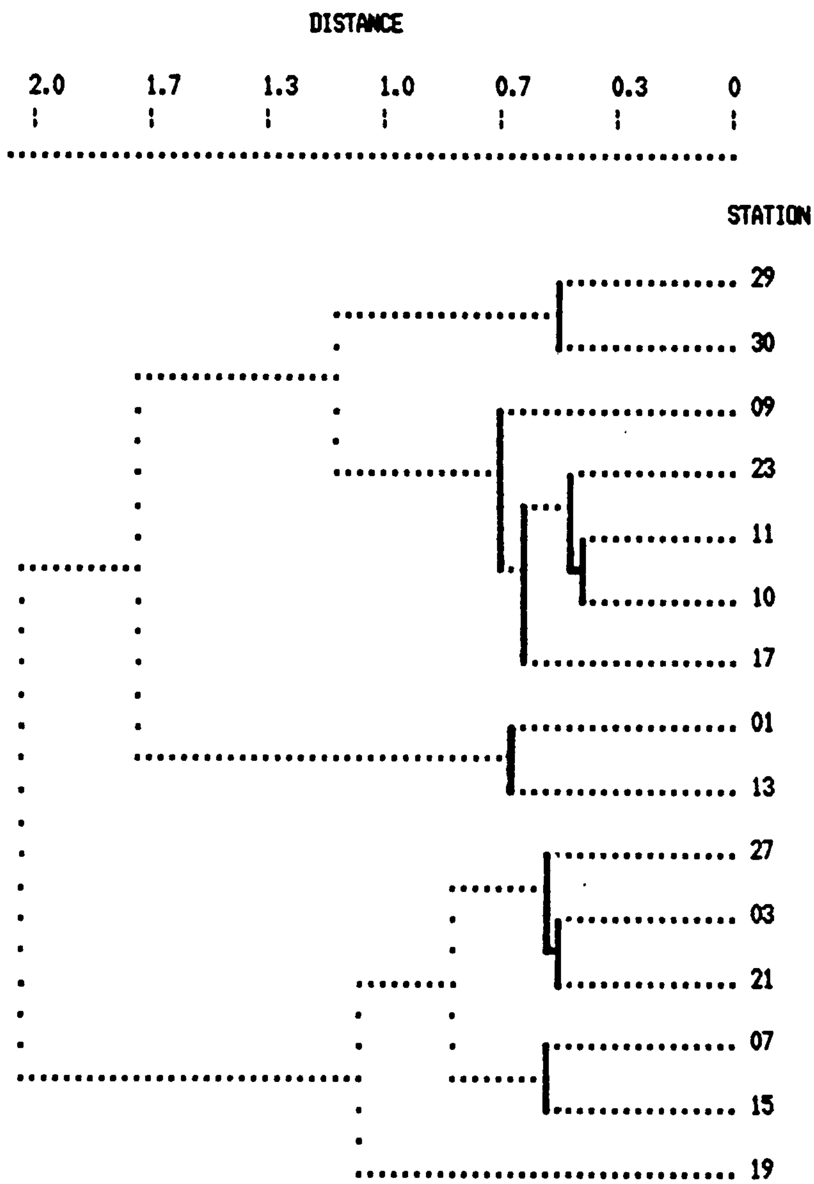
- Species - Mean: $X'_{ij} = X_{ij}/\bar{X}_i$

Where: $\bar{X}_i$ is the mean value of X for row (taxon) i

5.3.3.2 Cluster Analysis

Cluster analysis is one of several numerical methods used for classifying observations (such as sampling sites) into groups according to the similarity (or dissimilarity) of the variables (such as species composition and abundance) associated with each observation. Groups of similar entities are related to one another using a hierarchical tree structure called a dendrogram (Sneath and Sokal, 1973; Green, 1973; Figures 5-7 and 5-8). Groups formed in the dendrogram can be examined by the Principal Investigator for significance.

SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.7000 - % INCREASE ABOVE THRESHOLD= 24.55.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.7000 0.8000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .

Figure 5-7. Representative Q-mode dendrogram for grouping station catches by similarity in species composition and abundance.

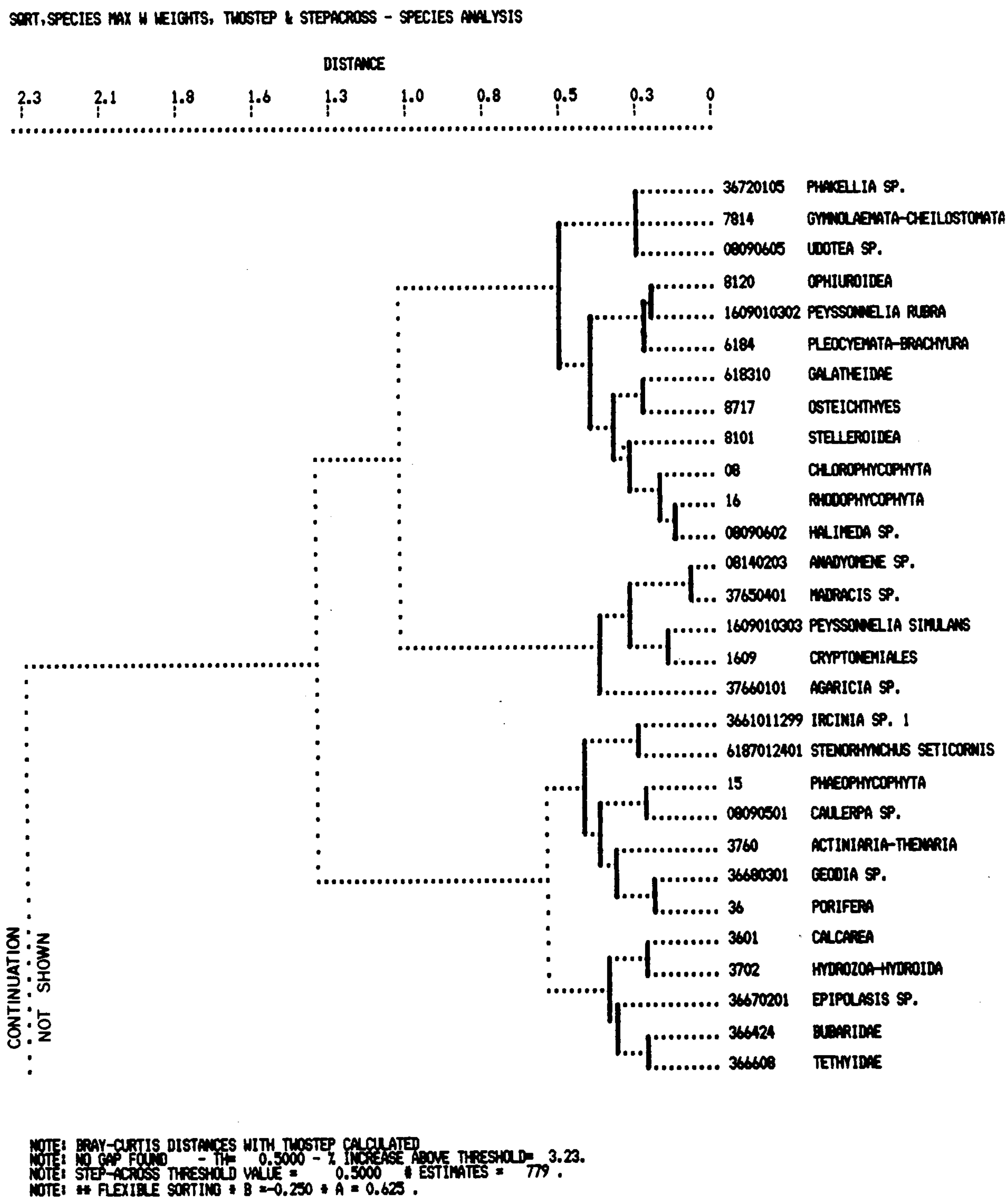


Figure 5-8. Representative R-mode dendrogram for grouping taxa by similarity of occurrence and abundance.

Breaks in similarity levels allow the Principal Investigator to define groups at a meaningful level of similarity.

A "DENDRO" procedure was used to perform agglomerative hierarchical polythetic cluster analyses on sampling stations (Q-mode) and taxa occurring at those stations (R-mode; Smith, 1981a). "DENDRO" allows several combinations of distance measure and sorting strategy to be used in building a dendrogram. The Bray-Curtis distance index (Bray and Curtis, 1957; Smith and Greene, 1976) was used for all cluster analyses involving biological data. "Flexible" sorting was used to relate groups as the dendrograms were built (Sneath and Sokal, 1973; Smith and Greene, 1976). The adjustable coefficient associated with this method was set at -0.25.

The nonlinear, nonmonotonic nature of biological data often causes distortion of the distance values (Swan, 1970). A method called the "step-across" procedure has been suggested by Williamson (1978) as a means of correcting for the distortion when presence-absence data are used. "PROC DENDRO" includes a generalization of this technique so that it can be applied to any distance matrix regardless of the original data type. It is the longer distances which are potentially the most distorted. The user specifies a threshold value (or a series of values to test) and all distances greater than or equal to this value are re-estimated by the step-across procedure (Smith, 1981b).

The algorithm which creates the dendrogram is enhanced to give a meaningful order of entities. This is done by the following procedure:

1. The distances are used to calculate polar ordination scores (axis 1 only) for each entity (Bray and Curtis, 1957). To avoid the choice of outliers for endpoints, the entities leading to a maximal value for $D_{ij}*S_i*S_j$ are used as endpoints. D_{ij} is the distance between entities i and j, and S_i and S_j are the standard deviations of the distances involving entities i and j, respectively. Outlier entities should have a relatively lower S_i or S_j value.

2. As the dendrogram is constructed, and entities and groups are fused, the group (or entity) with the lowest average ordination score is placed first

on the dendrogram, and the group with the higher average score is placed second. When this is done, the order of entities on the dendrogram will tend to follow the main trend in the input data.

There is a problem with agglomerative classification which involves ties between distance values. When there is more than one minimum distance in the current distance matrix, the distance chosen by most algorithms would be related to the order of entry of the entities into the program. Thus, with different orders of entry, there may be different results. The algorithm has been modified to avoid such a problem by using the polar ordination scores. When ties occur, the distance representing the entities with the lowest average score is chosen first. This should make the results independent of the order of input.

When species are classified, it is usually more meaningful to calculate distances based on relative habitat preference. The inter-species distances, as usually calculated, only measure inter-species overlap (distances are inversely proportional to overlap; Smith, 1976). These overlap measures were used to recalculate distances that are more related to relative habitat preference by a "TWOSTEP" (TWT) procedure (Smith, 1981a).

Following the cluster analysis, the two-way coincidence table was constructed using procedure "TWT" to depict relationships between Q-mode (station) and R-mode (taxon) clusters (Smith and Greene, 1976). The "TWT" procedure prints out the data matrix used in the cluster analysis, replacing the data values with symbols which correspond to the magnitude of the values. The rows and columns of the data matrix are rearranged to correspond with the order of the taxon and station dendrograms, respectively.

Clustering analyses of the live bottom and the soft bottom data were somewhat biased due to the inclusion of multispecific taxa in the analyses. These inclusions served to emphasize similarities. If two stations shared the same multispecific taxa, the similarity measure between the two stations would be increased; however, none of the species within the higher taxa may be shared by the two stations in reality. These two stations would, therefore, be computed as more similar than if all species within the group could have been practically identified.

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6.0 WATER QUALITY

6.1 Introduction

Hydrographic parameters play a major role in determining the biological and ecological features of a marine ecosystem. To describe the ecological characteristics of the southwest Florida continental shelf accurately, hydrographic data were collected at each station during both the Fall Cruise (Cruise III-25 October to 23 November 1980) and the Spring Cruise (Cruise IV-22 April to 5 May 1981) in support of the benthic biological data (Figure 6-1).

Hydrographic measurements included temperature, salinity, dissolved oxygen, transmissivity, light penetration, yellow substance, nutrients, and chlorophyll a. Temperature, salinity, and dissolved oxygen are interactive and are of primary importance to marine organisms. In sea water, density is a function of temperature, salinity, and depth. Rapid vertical changes in temperature (thermocline) or salinity (halocline) can therefore result in significant density gradients (pycnocline). These vertical density gradients serve as a differentiation zone between water masses. Although densities are not reported in this text, the term pycnocline has been used to generalize the boundary between the surface mixed layer and stratified bottom layers. Dissolved oxygen profiles are valuable in determining the presence of oxygen-minimum zones or near-bottom anoxic waters. Transmissivity, a measure of water clarity, is useful in identifying nepheloid (turbid water) layers that are present. Water clarity can be a limiting parameter to some marine species by regulating the amount of sunlight they receive. The analysis of dissolved micronutrients, nitrite-nitrate (NO_2-NO_3-N), phosphate (PO_4-P), and silica (SiO_2), provides an assessment of the amount of nutrients available to phytoplankton. The concentrations of these important nutrients may either limit or stimulate the growth of various species depending on their individual needs. Chlorophyll a measurements are indicative of the amount (standing crop) of phytoplankton occurring in the water. Phytoplankton are the basis for the food chains of many marine ecosystems. Yellow substance measurements describe the amount of dissolved organic materials, particularly humus, present in the water column and are good indicators of terrigenous and fluvial input. Hydrographic

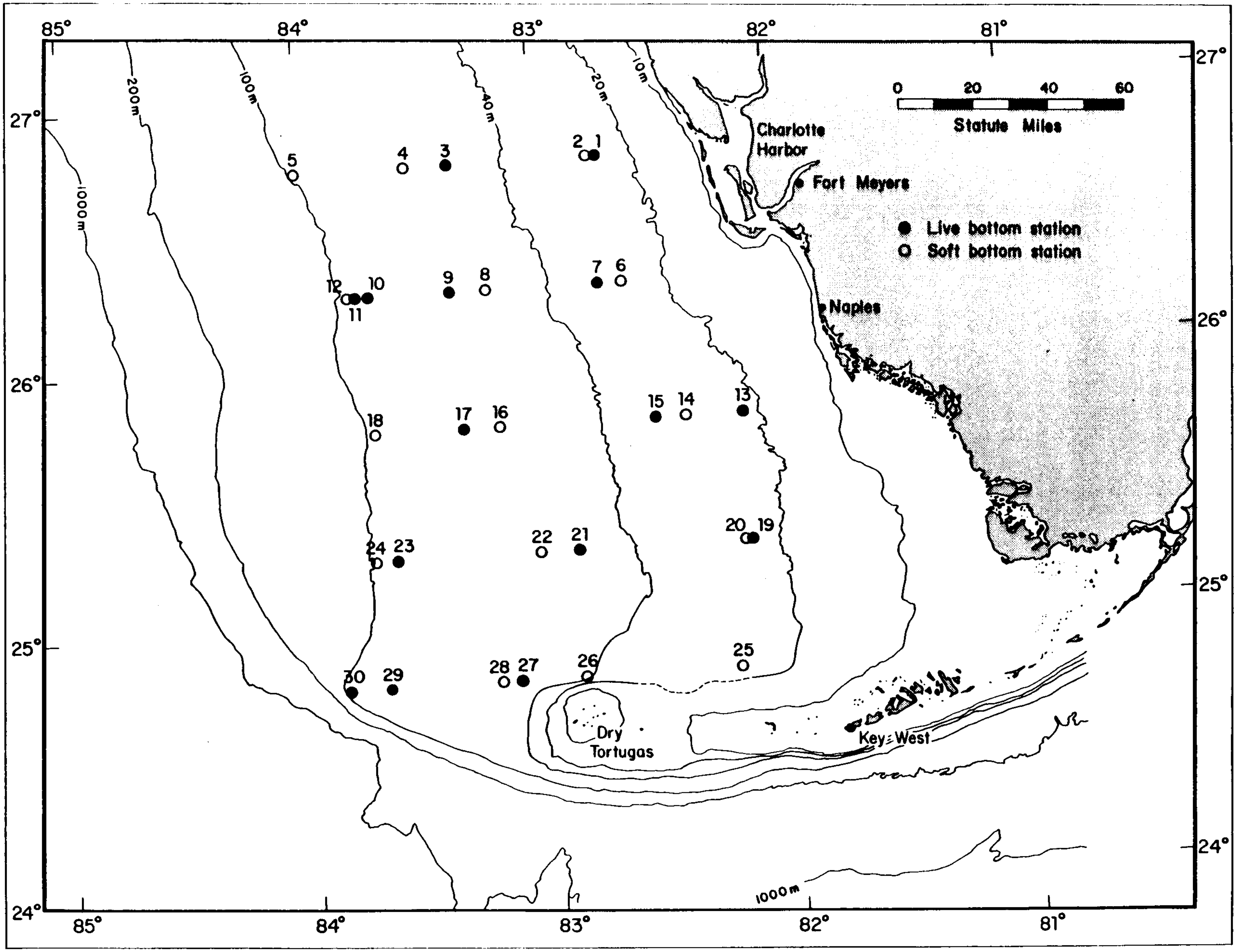

Figure 6-1. Geographic locations of hydrographic sampling stations.

parameters affect the ecological characteristics of an area in an interactive fashion; classically, they have been used by oceanographers to define water mass characteristics. Prior to this investigation there had been a lack of hydrographic data collected within the study area. A primary goal of this portion of the study was to collect these needed data.

This section presents a baseline assessment of water column variability and major trends affecting the study area during the time of the cruises.

6.2 Materials and Methods

6.2.1 Weather and Wave Observations

Observations of weather and sea conditions were recorded every four hours and at the time of sampling. Observations included weather element (cloud cover, precipitation, air temperature, etc.), visibility, wind direction and speed, sea state (wave height, swell direction and height), and barometric pressure. Observations requiring the judgement of an observer were coded according to the 1972 World Meteorological Organization Guidelines. All observations were recorded in a Marine Coastal Weather Log (NOAA Form 72-5b). Observation times were recorded as local time and later converted to Greenwich Mean Time.

6.2.2 Salinity, Temperature, Depth, and Dissolved Oxygen (STD/DO)

Temperature, salinity (conductivity), and dissolved oxygen were profiled with depth at each station using a Hydrolab Model 6D water quality analyzer. The manufacturer's stated accuracies are ± 2% of range (0-100 m) for depth, ± 0.25°C for temperature, ± 0.5% of full scale (0-100 μmho cm^{-1}) for conductivity, and ± 2% of reading for dissolved oxygen. Pre- and post-profile calibrations of the Hydrolab were performed at each station following the manufacturer's instructions. Also, temperature was calibrated at two points using an ASTM thermometer. All measurements were made at 10-m intervals throughout the water column with the deepest reading generally recorded within 1.5 m of the bottom.

One successful hydrocast was also performed at each sample station using five-litre Niskin bottles spaced at 10-m intervals. The near-bottom bottle was placed 1.5 m above the bottom weight on the hydrowire. Near-surface and near-bottom samples were used to confirm the salinity and dissolved oxygen measurements of the Hydrolab. Poor agreement between the Hydrolab salinities and the laboratory determined salinities for the near-surface and near-bottom samples led to the collection of additional salinity samples at all sampled depths during the Spring Cruise. Near-surface and near-bottom temperatures were verified through the use of Kahl Scientific Instrument Company protected deep-sea reversing thermometers attached to the Niskin bottles and read to ± 0.01°C.

The dissolved oxygen samples were analyzed on-board in duplicate using a Winkler titration (Stickland and Parsons, 1972a). The samples were immediately "fixed" upon collection, stored in the dark, and analyzed within four hours.

The hydrocast salinity samples which were stored in French square glass bottles and were analyzed in the laboratory using a Guildline Autosal Model 8400 induction salinometer. Due to the poor agreement between the Hydrolab salinities and the salinometer data, extra water (if available) from the Fall Cruise nutrient samples was analyzed with the salinometer.

The interrelationships of the analysis of the Hydrolab data and hydrocast samples are shown in Figure 6-2.

6.2.3 Transmissivity

A Hydro Products Model 915-S transmissometer (with temperature and depth sensors) was used to determine the transmissivity and temperature of the water column. The manufacturer's stated accuracies are ± 2% of full scale for transmissivity, ± 1.0% of scale (± 0.4°C) for temperature, and ± 1.4% of full scale (300 m) for depth. One successful lowering was made at each station. Transmissivity was recorded at five-metre intervals throughout the water column and within 1.5 m of the bottom.

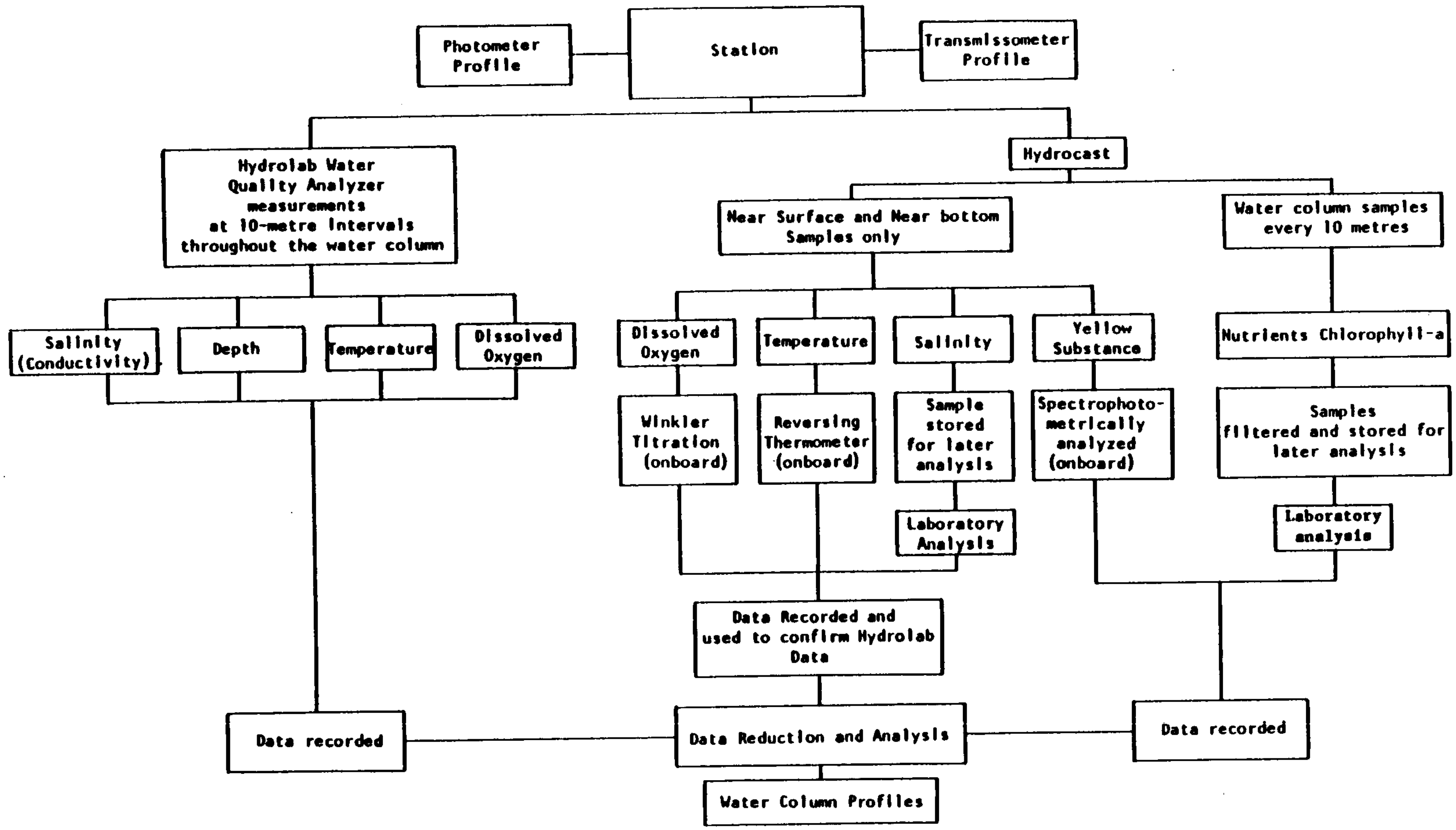

Figure 6-2. Summary of field and laboratory methodology for hydrographic parameters.

6.2.4 Light Penetration

An InterOcean System Model 510 marine illuminance meter was used to measure light penetration. The manufacturer stated that maximum sensitivity occurred at approximately 550 nm. Photometer profiles were performed only during the Fall Cruise (III) and at stations where the ship was on location between 0900 and 1500. No profiles were made during the Spring Cruise (IV) due to equipment malfunction. Readings were taken at five-metre intervals throughout the euphotic zone.

6.2.5 Yellow Substance

Samples for yellow substance were obtained by subsampling the near-surface and near-bottom hydrocast samples (Figure 6-2). Approximately 25-ml aliquots of each sample were syringe-filtered through Whatman GF/C filter paper into 10-cm cuvettes. Ultraviolet absorption was determined at 280, 310, and 350-nm wavelengths on a Bausch and Lomb Spectronic 21 UVD-spectrophotometer. The manufacturer's stated accuracy is ± 0.3% transmittance. A minimum of two readings per sample was recorded. Purified standard water (Millipore Super Q) was used as a standard.

6.2.6 Nutrients

Water samples for nutrients (phosphate, nitrite-nitrate, and dissolved silica) were collected by hydrocast at each station (Figure 6-2). Samples were obtained using five-litre Nisken bottles at 10-m intervals throughout the water column, with the deepest reading generally recorded within 1.5 m of the bottom. Approximately 200 ml of water from each bottle were pressure filtered (0.45-μm pore size, 47-mm diameter Nuclepore filters) and frozen in six-ounce Whirl-Pac bags (Fall Cruise) and four-ounce polyethylene bottles (Spring Cruise).

In the laboratory, the samples were prepared following Strickland and Parsons (1972b) and analyzed for dissolved inorganic nitrate, total nitrogen, phosphate, and dissolved silica on a four-channel Technicon Auto-Analyzer II.

6.2.7 Chlorophyll a

Water samples for chlorophyll *a* were collected from each Niskin bottle in the hydrocasts (Figure 6-2). One to three litres were vacuum filtered through Whatman GF/C filters in a Millipore filtering apparatus, fixed with magnesium carbonate, placed in vials, and stored in the dark within a desiccator at -20°C. There is mounting evidence that the standard methods of filtration (i.e., glass fiber filters) have allowed pico- and ultraplankton to pass through the filters. This suggests that most measurements of primary productivity (i.e., Carbon-14) and chlorophyll are erroneous, although, for the purpose of comparison, the standard measurements are acceptable.

In the laboratory, the filters were extracted and analyzed using procedures outlined by Strickland and Parsons (1972c). The analysis methods included: (1) fluorometric for chlorophyll *a* and phaeophytin, (2) spectrophotometric trichlorometric for chlorophyll *a*, and (3) spectrophotometric acid method for chlorophyll *a* and phaeophytin.

6.3 Results

As with all multi-disciplinary, geographically oriented studies, the hydrographic data collected during this study do not represent a nearly instantaneous, or synoptic, picture of the state of the shelf water column. This was particularly true for the Fall Cruise when the data collection encompassed a one-month period and collection intervals in two cases were separated by five days. In addition, atmospheric cold fronts began to penetrate the study area during the Fall Cruise. During the Spring Cruise sampling was conducted on a more rigorous schedule, i.e., within a 12-day period. Due to this lack of synopticity, a horizontal profiling approach to the analysis was not attempted.

6.3.1 Weather and Wave Observations

From October 25, 1980 to November 9, 1980, wind speeds ranged from nine to 46 km h^{-1} (5 to 25 kn) and were primarily from a north-to-northeasterly direction. Wave heights varied between 0.3 and 1.3 m. Swell heights were usually between 0.7 and 1.3 m. From November 10, 1980 to November 13, 1980, data were not collected due to the extreme conditions caused by Hurricane "Jean". This hurricane came within 563 km (350 mi) of the Dry Tortugas on November 11, 1980, bringing rains that dropped a record of 59.13 cm (23.28 in) of precipitation on Key West. This rainfall, however, only affected a small area that included the lower keys. Following Hurricane "Jean", between November 14, 1980 and November 17, 1980, wind speeds averaged 28 km h^{-1} (15 kn) from a south-southeasterly direction. Wind speeds greater than 37 km h^{-1} (20 kn), however, were often recorded. Wave heights generally ranged between 0.6 and 1.3 m. Swell heights usually varied between 1.3 and 2.0 m.

From November 18, 1980 to the completion of the cruise on November 23, 1980, the wind speeds averaged about 22 km h^{-1} (12 kn) and were primarily from a northerly direction. Wave heights usually ranged between 0.3 and 1.0 m with swell heights varying from 1.3 to 2.0 m.

Between April 23, 1981 and April 25, 1981 (Spring Cruise), winds were from a southeasterly direction with speeds usually of 9 km h^{-1} (5 kn) or less. Wave and swell heights were both 0.3 m or less during this time. From April 26, 1981 to May 4, 1981, the wind speeds averaged between nine and 19 km h^{-1} (5 and 10 kn) and were from a north-northeasterly direction. Wave heights ranged from 0.0 to 1.0 m and were less than 0.3 m for the majority of this time period. Swell heights varied between 0.0 and 2.0 m and were usually less than 0.3 m.

6.3.2 Temperature

Uncorrected temperature values were used from the Hydrolab. An attempt to determine correction factors using reversing thermometer data provided no consistent deviation. This most likely attributed to the fact that the measurements were made on separate casts, introducing both a time factor and a spatial (depth) error. It was assumed that the Hydrolab data were reasonably accurate, as many of the values compared well with the reversing thermometers.

The results of the Fall Cruise (III) showed that the surface mixed layer (located above the thermocline) had a temperature maximum of 27.5°C on

Transect A and a temperature minimum of 21.8°C on Transect E. The temperature range of the mixed layer is shown as part of a series of vertical contours for each transect in Figure 6-3. On most transects, the mixed layer exhibited a general temperature increase in an offshore direction. This was expected since, during this season, there would be a greater potential for heat loss at the shallower stations.

A mid-shelf temperature maximum was evident on Transects C through E, with a marked decrease at the outermost stations. Although Transect A also exhibited this trend, other data suggest that this may have been an artifact of the five-day separation in the sampling. This hiatus may also explain the 10-m uplift of the thermocline at Station 5 as compared to Station 4. Generally, the top of the thermocline was found at a depth of 40 to 50 m at each of the outmost stations. The leading edge of the thermocline was seen at the 40 to 50-m isobaths on Transects A through C and the 50 to 60-m isobaths on Transects D and E. A minimum Fall Cruise temperature below the thermocline of 16°C was observed at Station 5.

On the Spring Cruise (Figure 6-4), temperatures ranged from a maximum of 26.8°C (surface) to a minimum of 18.3°C, both on Transect E. Profiles were characterized by a shallow, surface mixed layer that ranged from approximately 8 to 20 m deep. The Spring Cruise temperature data are also profiled and extrapolated along transects in Figure 6-4. A summer thermocline development was observed at the inshore stations on all transects. The strongest development was observed on Transects A through C at Stations 1, 2, 6, 7, and 14. Progressing offshore, the water column was in a stratification process but a well-defined thermocline was not evident. The temperature minima on all transects were located in the mid-shelf region, with the most pronounced effects observed on Transect E.

6.3.3 Salinity

The results of the Fall Cruise showed that salinity patterns (Figure 6-5) conformed to temperature gradients. The mixed layer (Section 6.3.2) had a salinity minimum of 35.49°/oo on Transect C and a salinity maximum of 36.50°/oo

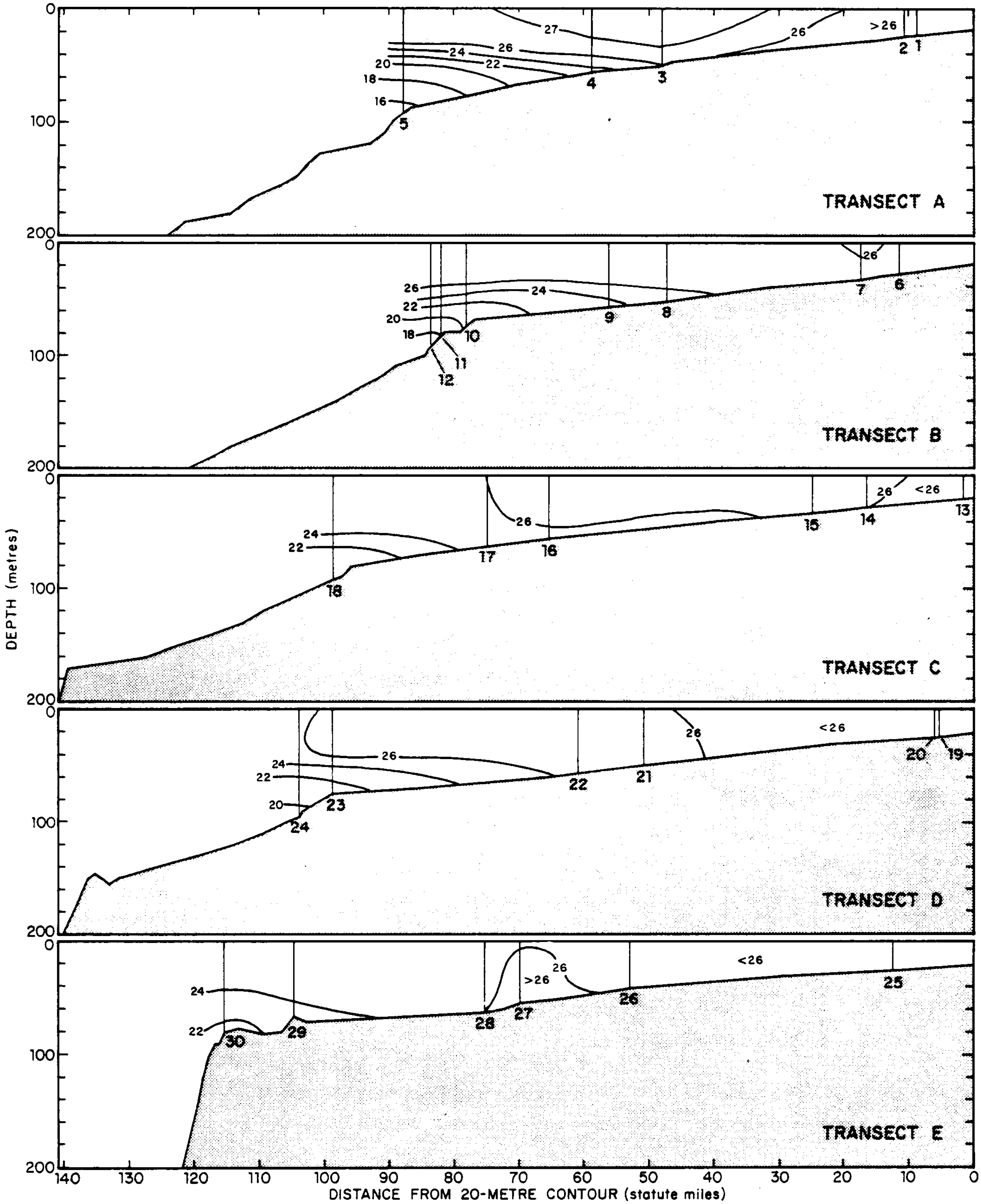

Figure 6-3. October-November 1980 temperature (°C) cross-sections.

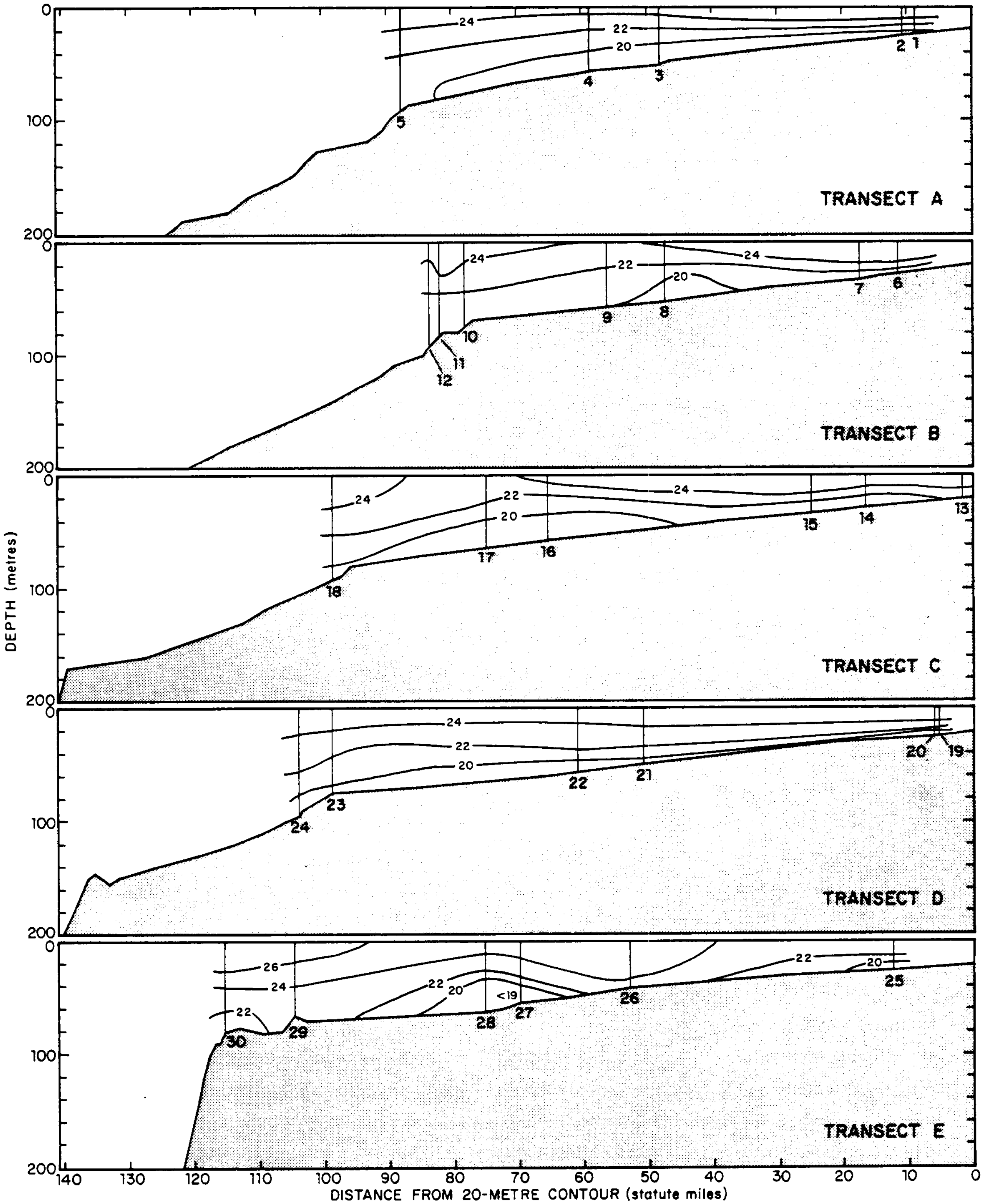

Figure 6-4. April-May 1981 temperature (°C) cross-sections.

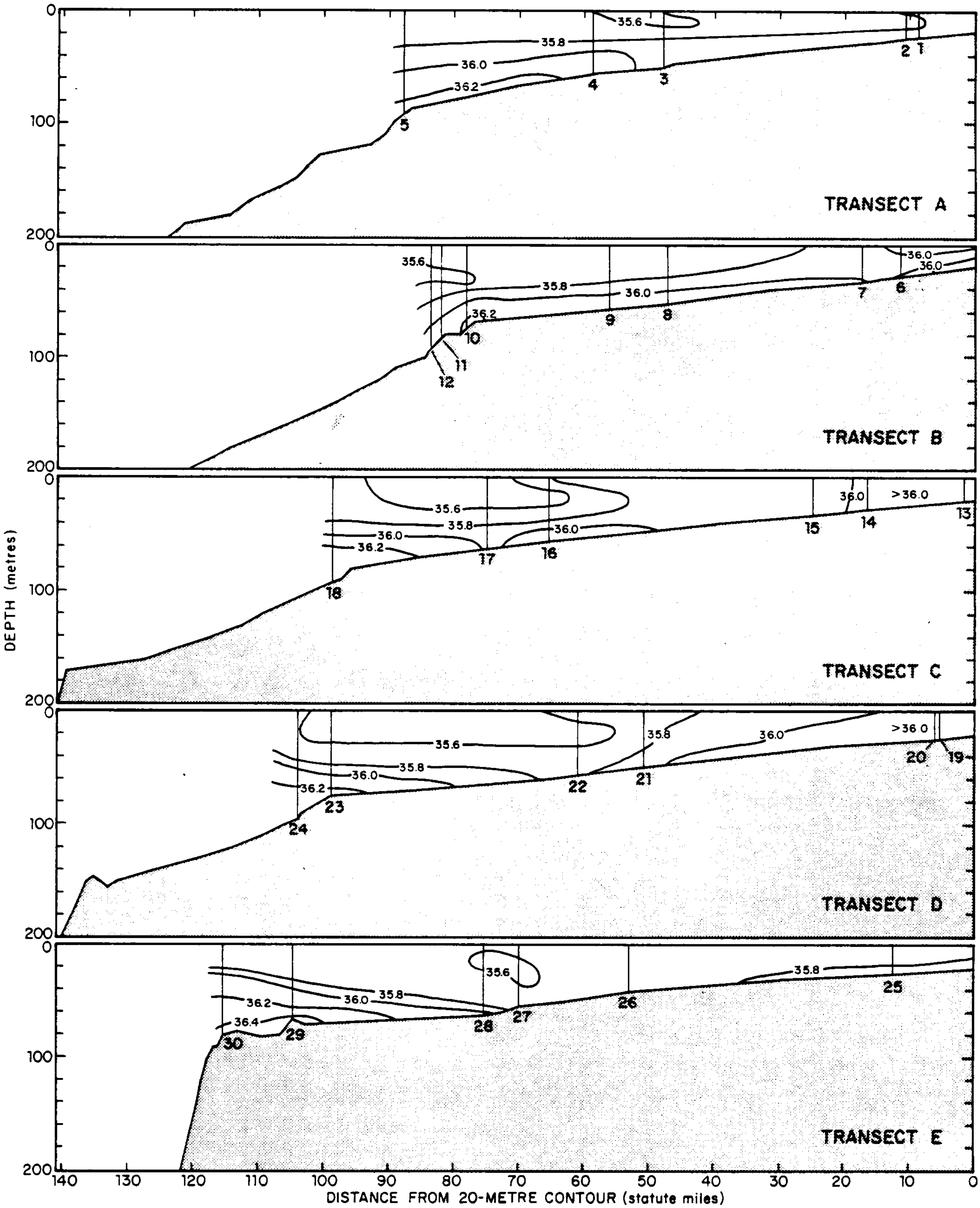

Figure 6-5. October-November 1980 salinity (°/00) cross-sections.

was found on Transect E. Transects A through D had maximum, mixed layer salinities at the nearshore stations and decreased salinities offshore. A mid-shelf salinity minimum was encountered on Transects C through E which correlated with the mid-shelf temperature maximum. The core of this water mass was found to be <35.6°/oo and penetrated to a depth of 30 m.

During the Fall Cruise, it was observed that the location of the bottom halocline generally coincided with the thermocline. Near bottom salinities at the outermost stations were found to increase in a southerly direction, from >36.2°/oo at Transects A through C, to >36.3°/oo on Transect D, and 36.5°/oo on Transect E. Transects B and C were found to have isolated near-bottom, relatively higher-salinity pockets at mid-shelf Stations 8, 10, and 16.

In passing, it might be noted that the Hydrolab salinity (conductivity) data generally showed a poor agreement with the salinometer data. The salinometer data were therefore used almost exclusively for these analyses. Some Fall Cruise salinometer data were unacceptable due to leakage in some of the nutrient samples which were analyzed for salinity.

The Spring Cruise salinity patterns were generally vertically homogeneous, in contrast to the more stratified salinity patterns of the Fall Cruise (Figure 6-6). Salinities during the Spring Cruise (IV) ranged from 35.02°/oo to 37.05°/oo. Transects C, D and E were characterized by pockets of relatively higher salinity at the mid-depth stations, generally coinciding with lower temperature pockets.

Generally, all salinities were found to increase in an offshore direction. Along Transect E, a surface pocket of lower salinity water (36.1°/oo) was found to have extended down to a depth of 20 m. Except for the interfaces between the isolated pockets of high and low salinities, no true halocline development was observed.

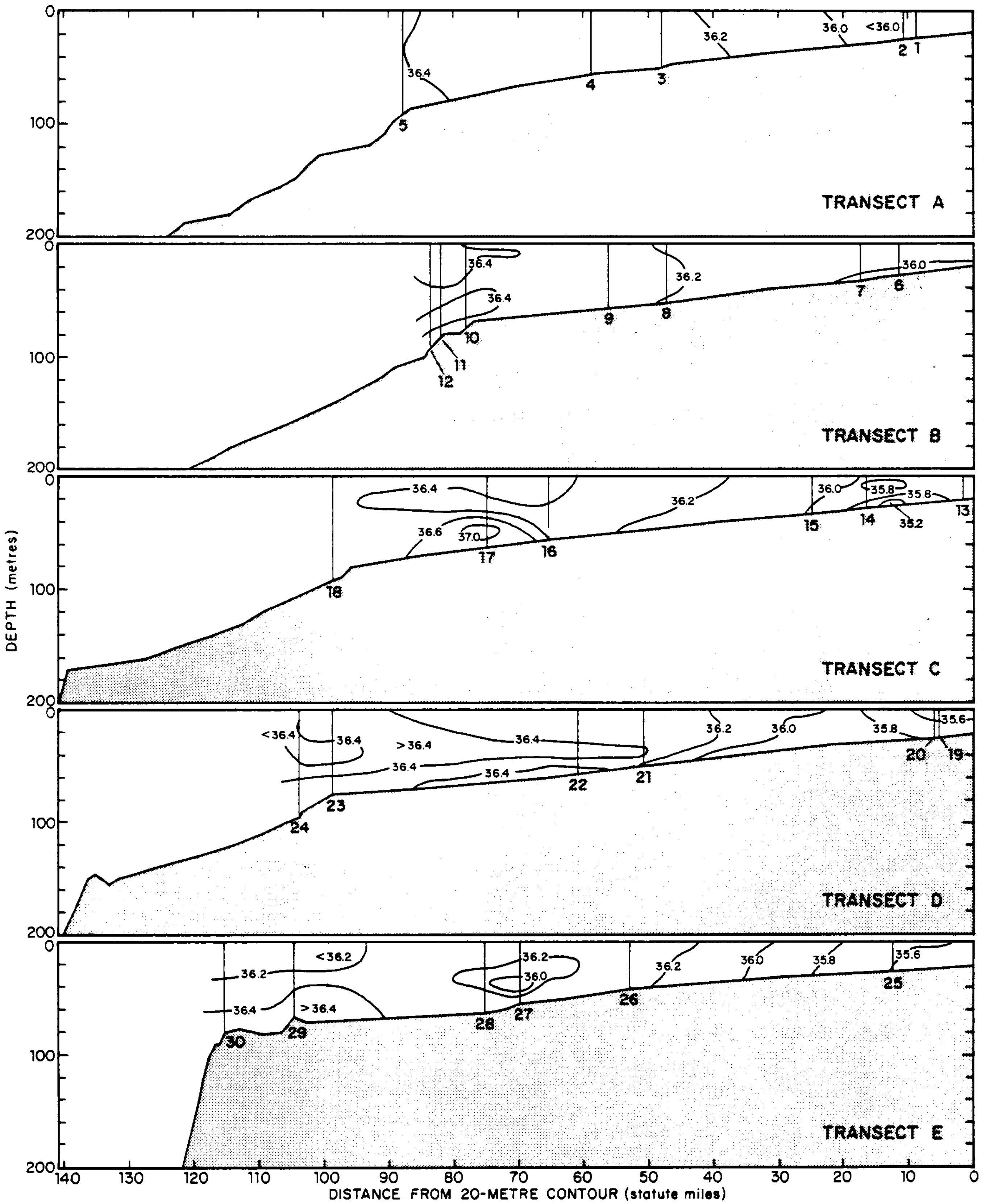

Figure 6-6. April-May 1981 salinity (°/00) cross-sections.

6.3.4 Dissolved Oxygen

Due to the low variation between the replicate Winkler titrations (mean difference = 0.07 ml l^{-1}) and the general inaccuracy of the Hydrolab (± 0.1 ml l^{-1} at best), the data from the Winkler titrations were primarily used in this analysis.

The data from the Fall Cruise (Figure 6-7) showed that dissolved oxygen (O_2) values were relatively uniform at the surface, ranging from 5.60 ml l^{-1} on Transect C to 6.79 ml l^{-1} on Transect B. Bottom values were generally consistent with the surface with the exception of below the thermocline at the outermost stations. Here, values were found to range from 4.06 ml l^{-1} at Station 5 to 5.15 ml l^{-1} at Station 30. A near-bottom low O_2 pocket (3.18 ml l^{-1}) was observed at Station 16. This isolated pocket coincided with the previously noted high salinity singularity.

As seen in the Fall Cruise (III), the O_2 values from the Spring Cruise (IV) (Figure 6-8) were essentially the same near the top and bottom of the water column. These values ranged from 5.76 ml l^{-1} to 7.71 ml l^{-1} and were consistent from surface to bottom.

6.3.5 Transmissivity

Transmittance is a measure of the transparency of the water. Values range from 100%T for absolutely clear water (slightly less than 100%T in reality) to 0%T in the extreme case of absolutely opaque water. During the Fall Cruise, the transmittance (%T) values ranged from 45%T on Transect E to 96%T on Transect A. These cross-sections are shown in Figure 6-9. The highest values (>95%T) were found at mid-depths on Transect A at Stations 3 and 4 and corresponded to a temperature maximum for the Fall Cruise of >27.0°C. A near-bottom value of <75%T was observed at Station 4, suggesting possible sediment resuspension. Increasing surface turbidity at Station 1 (<75%T) suggests an increased plankton concentration indicative of a nearshore environment. The water column sampled on Transects B through E was much more vertically mixed and was increasingly turbid in the shoreward direction. Storm front passage prior to sampling these transects would have affected overall water column turbidity,

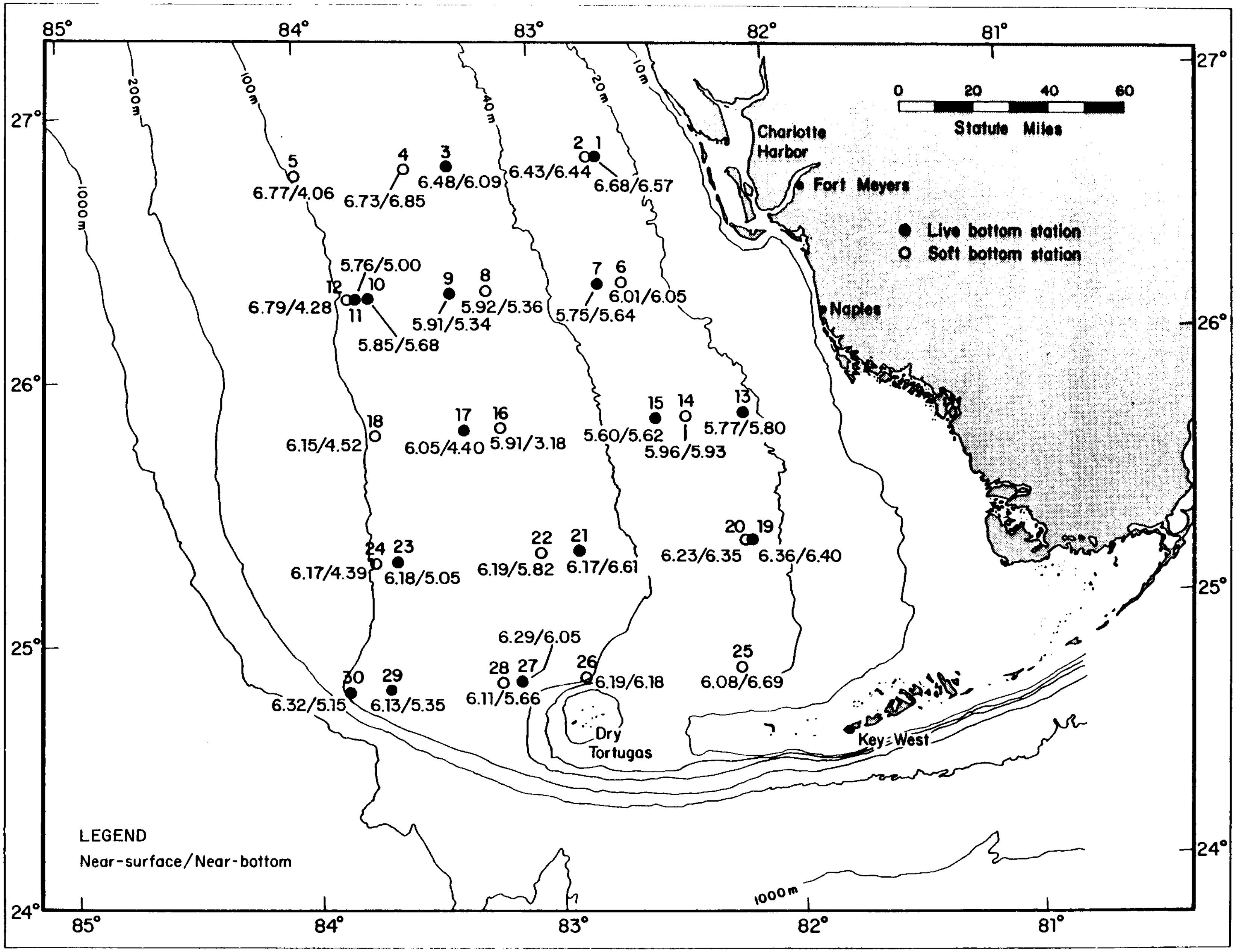

Figure 6-7. October-November 1980 near-surface and near-bottom dissolved oxygen (ml/l) values.

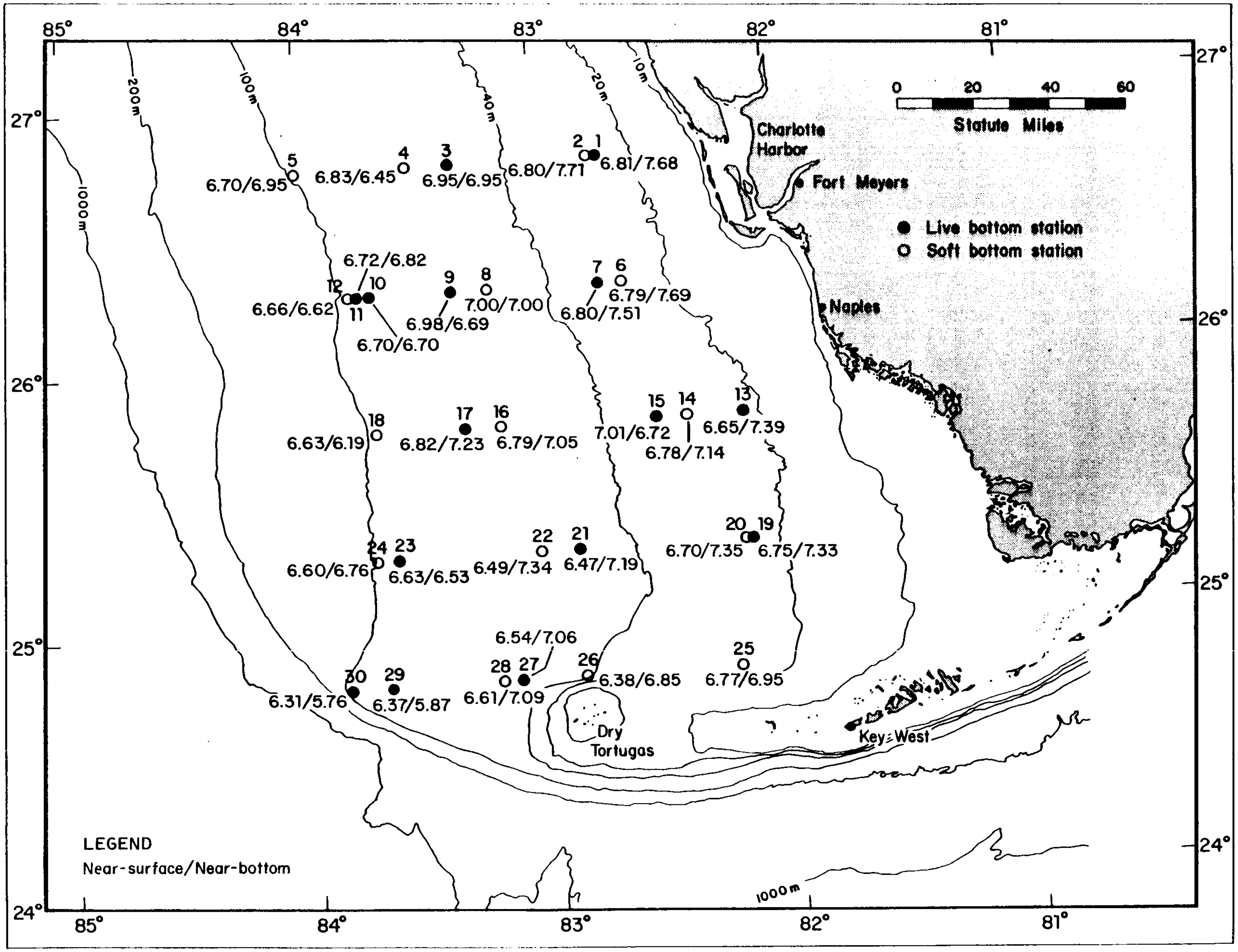

Figure 6-8. April-May 1981 near-surface and near-bottom dissolved oxygen (ml/l) values.

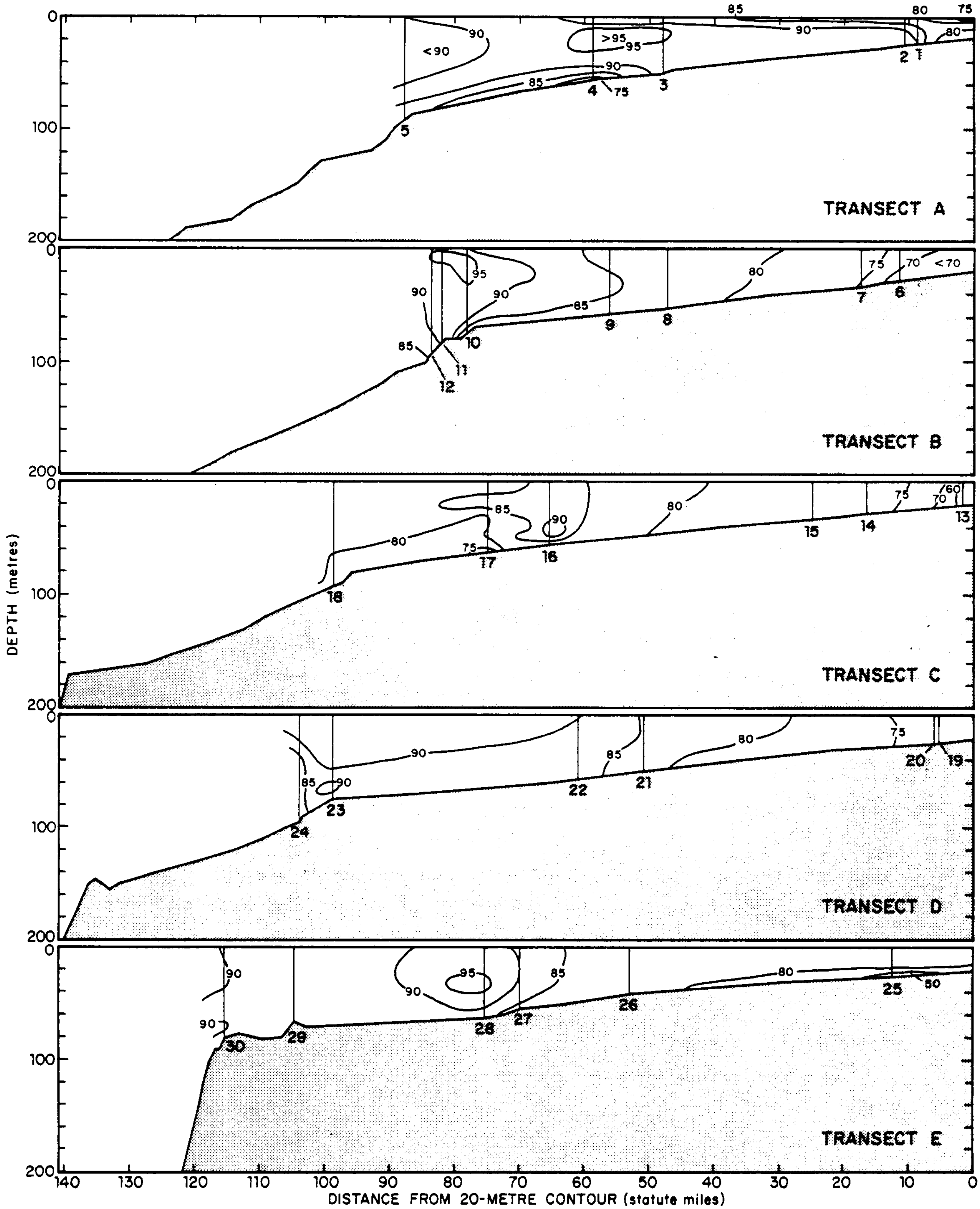

Figure 6-9. October-November 1980 transmissivity (%T) cross-sections.

which would increase shoreward as a function of depth. A near-bottom nepheloid layer at Station 17 (<75%T) suggests that a resuspension mechanism was also affecting Transect C. Likewise, a very strong bottom nepheloid layer (<45%T) was observed at Station 25.

Transmittance values on the Spring Cruise (Figure 6-10) ranged from a low of 40%T on Transect E to a high of 99%T on Transect C. As was observed in the salinity profiles, the transmissivity also reflected a vertically homogeneous water column. This was especially noticeable along Transects A and B, where there was a range of only 8%T for the entire water column. Transects A through D were all characterized by a near-bottom turbidity maximum at the nearshore and mid-shelf stations. An intense near-bottom nepheloid layer (40%T) was observed at Station 25, with the overlying water being greater than 90%T. Another nepheloid layer (69%T) was observed at Station 27. This one coincided with a temperature minimum and a disjunct salinity structure.

6.3.6 Light Penetration

The photometer data from the Fall Cruise (III) were not analyzed due to obvious inaccuracies in the top-side, illuminance cell data when compared to the underwater cell data. No photometer data were collected on the Spring Cruise due to equipment malfunction.

6.3.7 Yellow Substance

The amount of yellow substance (or "gelbstoff") is generally considered to be an assessment of the quantity of dissolved organics, particularly humic compounds, which are good indicators of terrigenous and fluvial input. Yellow substance values on both cruises, however, were so near the limits of detection that they could not be measured with any degree of accuracy.

6.3.8 Nutrients

During the Fall Cruise, concentrations of dissolved micronutrients, phosphate (PO_4-P), nitrite-nitrate (NO_2-NO_3-N), and dissolved silica (SiO_2), were

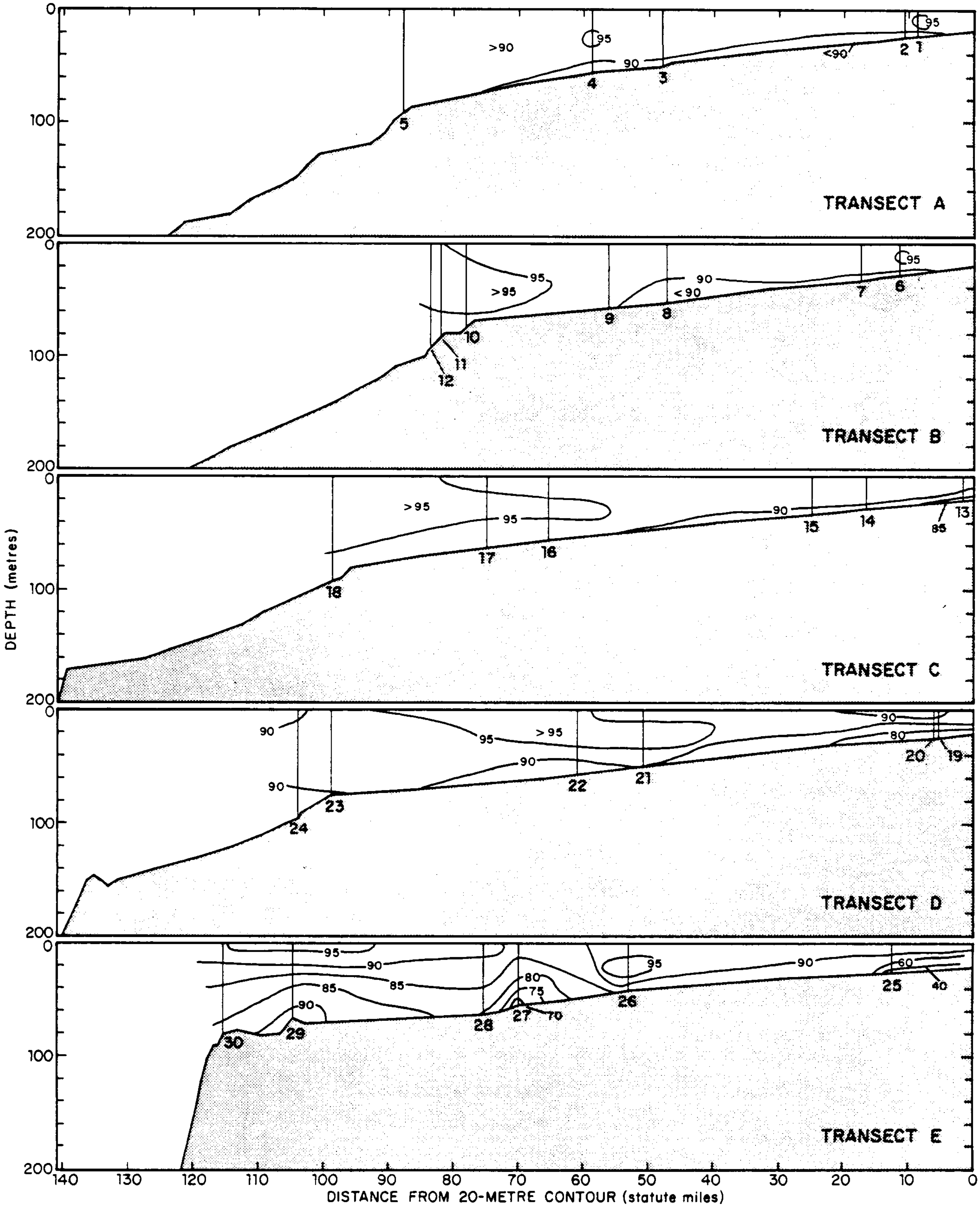

Figure 6-10. April-May 1981 transmissivity (%T) cross-sections.

minimally present in the surface mixed layer (Figures 6-11 through 6-13). Maximum values were generally observed below the pycnocline (see Section 6.1 for definition). Phosphate had a maximum value of only 1.10 μ_M_ near the bottom at Station 5 and a minimum value of 0.0 μ_M_ in the mixed layers of Transects B and C. The majority of the mixed layers on Transects B though E had phosphate values of <0.1 μ_M_, while Transect A had values predominantly between 0.1 and 0.2 μ_M_.

Below the pycnocline, PO_4-P concentrations gradually increased with depth. This trend was evident in all of the transects. Also noticeable was a trend in the offshore stations towards lower, near-bottom PO_4-P values in a southerly direction (e.g., Station 5 = 1.0 μ_M_; Station 30 = 0.48 μ_M_). This southerly progression was also reflected in the increasing salinity and temperature.

Nitrite values were generally so low that a separation of nitrite and nitrate was beyond the limit of the accuracy of the method. Isolines of NO_2-NO_3-N also followed a pattern similar to that of PO_4-P. At all stations, nitrite-nitrate levels of <0.1 μ_M_ predominated in the mixed layer. Below the pycnocline, a gradual increase in nitrates was observed at all offshore stations. A maximum occurred at Station 5 with 14.9 μ_M_, while the lowest near-bottom (below the pycnocline) concentration at the deepest sampling location was seen at Station 30 with 3.74 μ_M_.

Dissolved silica had the highest values of the micronutrients measured in the mixed layer. A minimum mixed layer concentration of 0.11 μ_M_ was observed at Station 19, but the majority of values ranged from 1.0 to 5.0 μ_M_ and increased in a shoreward direction. The highest mixed layer value (13.7 μ_M_) was seen near the bottom at Station 25. This corresponded to a strong nepheloid layer. The elevated values in the upper water column of Station 25 suggest that SiO_2 was advected towards the surface, although this was not observed in the transmissivity profile. Below the thermocline, in the offshore stations, an increase in SiO_2 concentration with depth was observed. There was also a decreasing near-bottom concentration that, like several other measured parameters, followed a southward progression. This trend was so pronounced that, by Transect E, the near-bottom dissolved silica value (2.0 μ_M_) was nearly indistinguishable from that of the overlying water column.

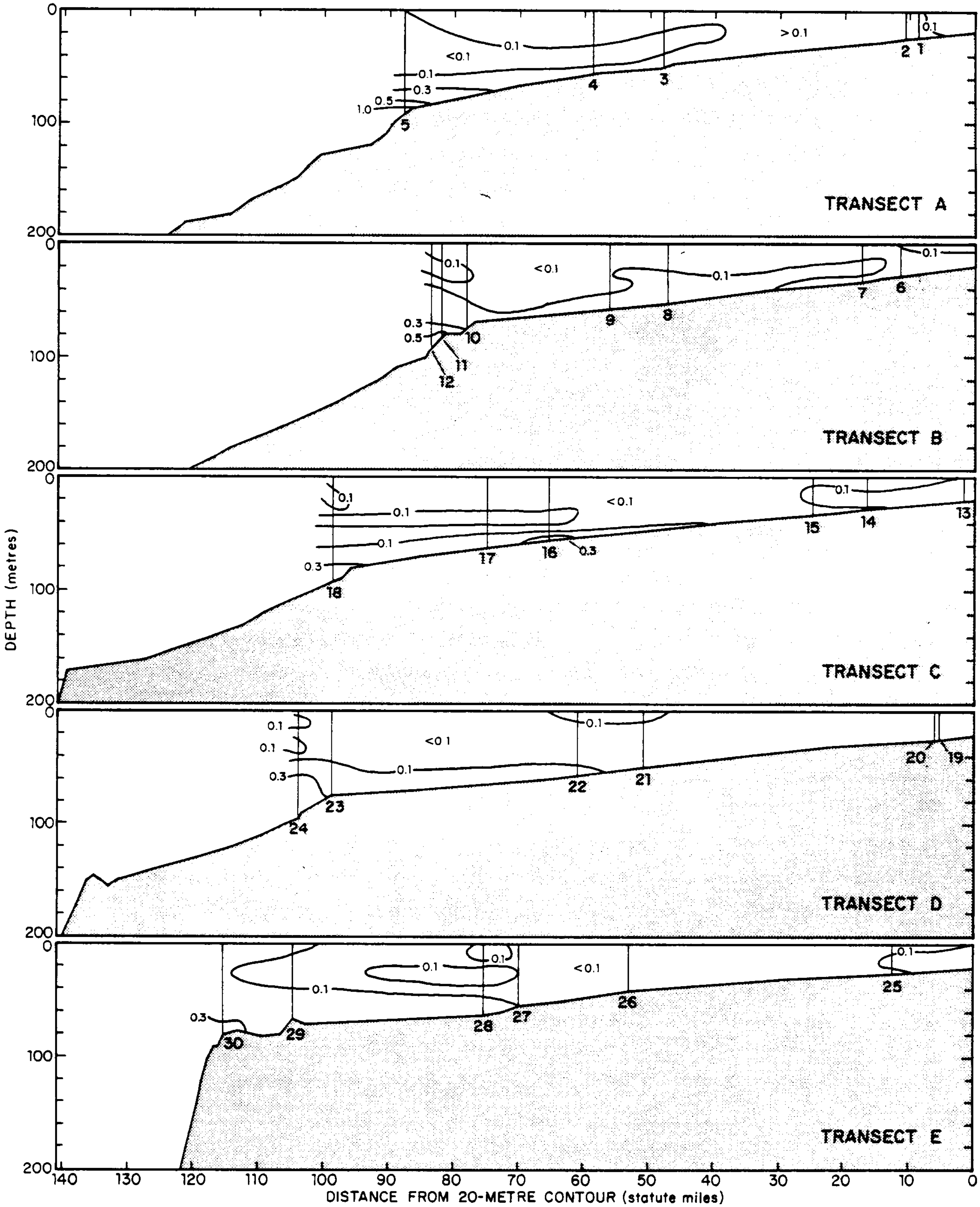

Figure 6-11. October-November 1980 phosphate ($\mu\underline{M}$) cross-sections.

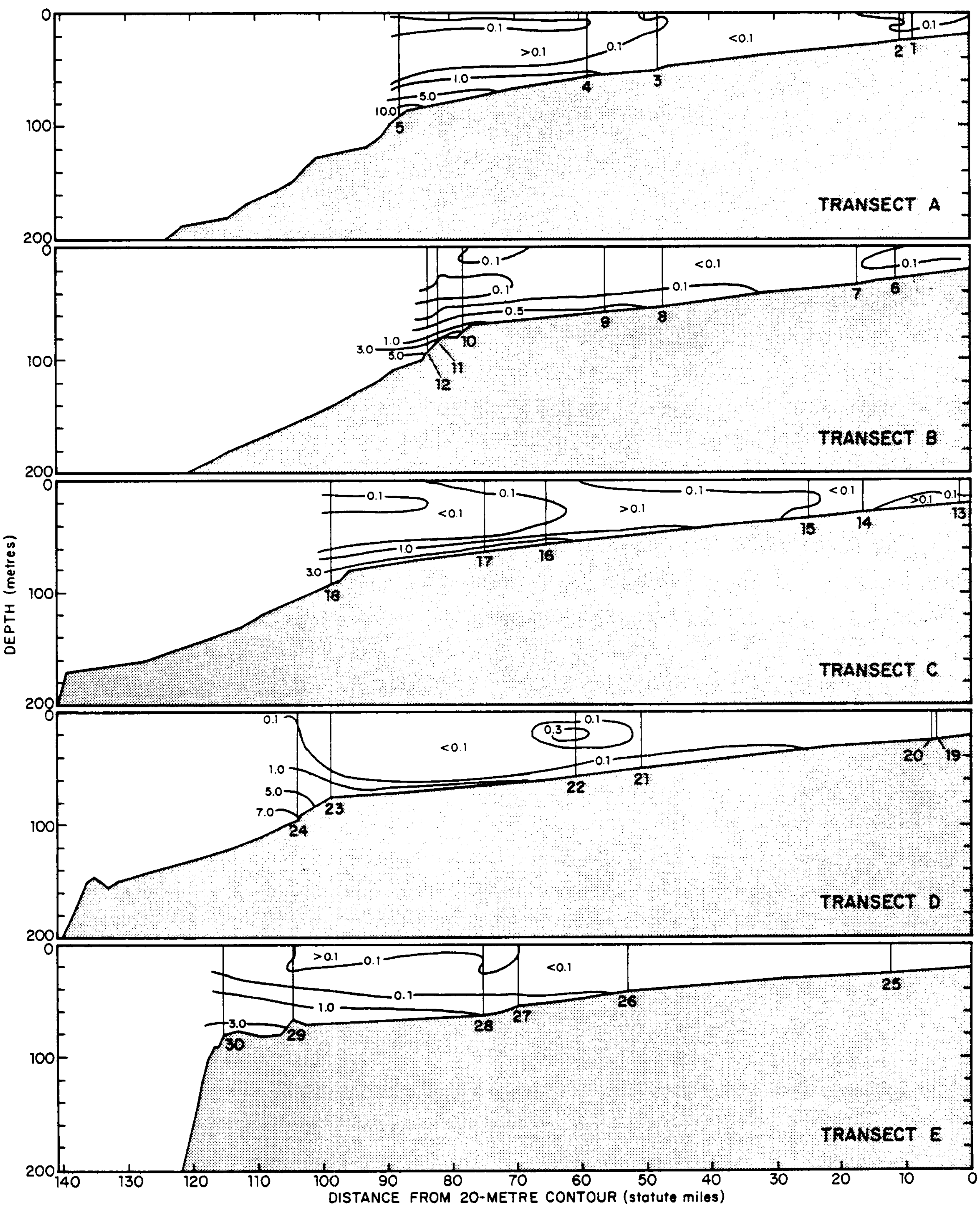

Figure 6-12. October-November 1980 nitrate-nitrite (µM) cross-sections.

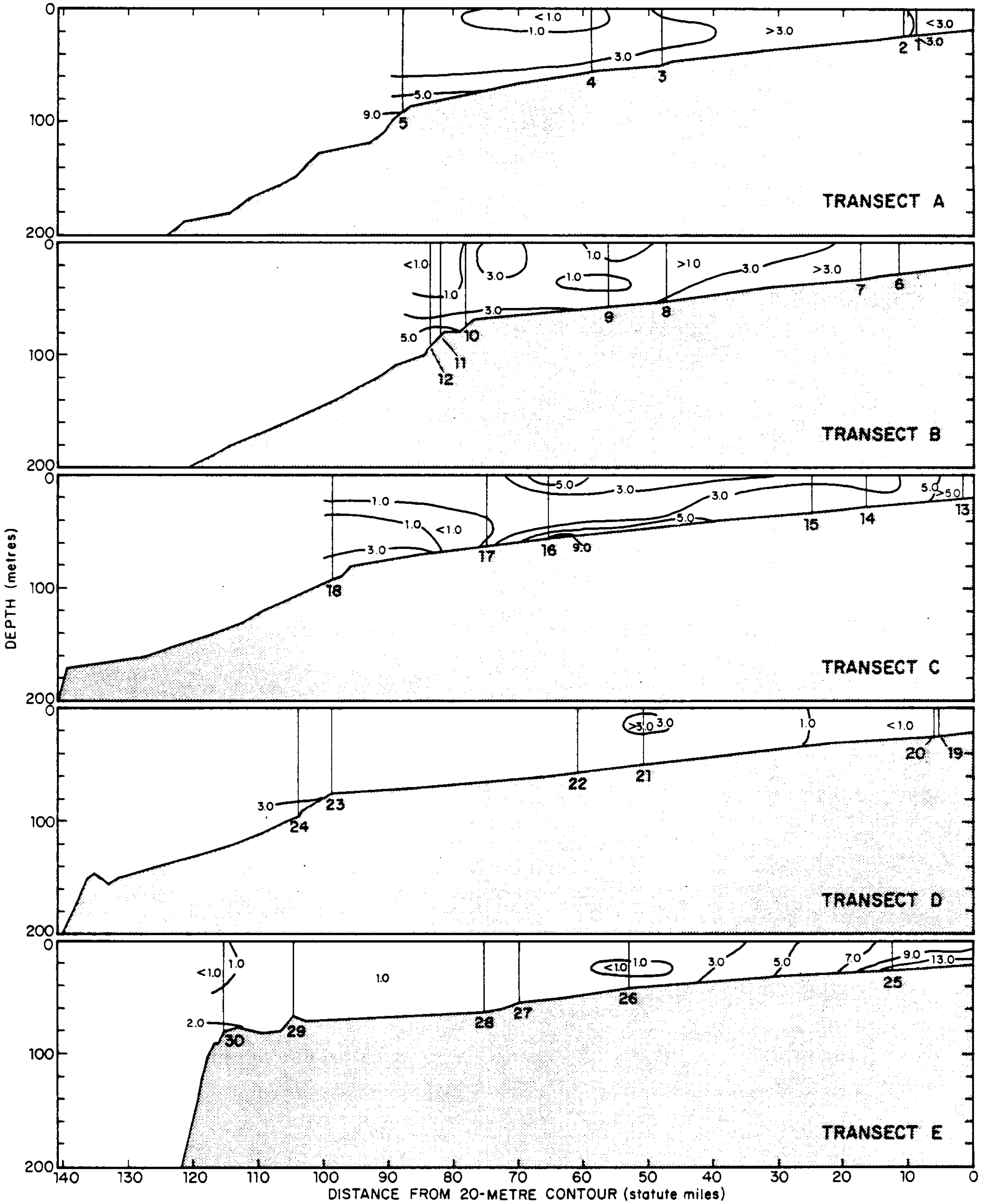

Figure 6-13. October-November 1980 dissolved silica (µM) cross-sections.

The data from the Spring Cruise showed that nutrients were low throughout the entire water column (Figures 6-14 through 6-16) as compared to the Fall Cruise. Phosphate ranged from <0.10 μM at some stations along all transects to a maximum of 0.6 μM at Station 9. There were distinct near-bottom increases at all of the offshore stations, but these values did not exceed 0.1 to 0.24 μM. Transect E had the highest mean PO_4-P levels with values of >0.01 μM found throughout the entire mid-to-bottom water column. In general, PO_4-P was homogeneous throughout the study area during the Spring Cruise.

Nitrite-nitrate concentrations ranged from 0.0 μM observed on Transects A, D, and E to 3.7 μM on Transect E. The most defined isoline structure was found in the near-bottom, outermost stations, where the NO_2-NO_3-N levels increased substantially. An upwelling of these nutrients toward the surface was observed at Station 29. This feature was observed in other measured parameters.

Dissolved silica was also characterized by near-bottom maxima that ranged from 1.0 to 3.4 μM. Except for isolated pockets, the mid-to-surface values were all <2.0 μM. A marked increase to 3.9 μM was observed at a depth of about 25 m at Station 30.

6.3.9 Chlorophyll a

Although three methods (fluorometer, spectrophotometer trichlorometric, and spectrophotometer acid methods) were used for chlorophyll analysis, the spectrophotometer acid method was used primarily in the Fall Cruise (III) analysis. Chlorophyll a data from the Spring Cruise (IV) were primarily contoured with the fluorometrically quantified values rather than the spectrophotometer values. This was due to a more consistent availability of fluorometer data since in many cases concentrations were lower than the accuracy of the spectrophotometer. Spectrophotometer values were used, however, when fluorometer values were not available (generally when chlorophyll a was >0.3 mg m^{-3}). The differences in methods may result in a slight error in absolute values, but this has no bearing on relative concentrations and general comparisons. The raw data from each method are included in the computer data base for those wishing to compare data.

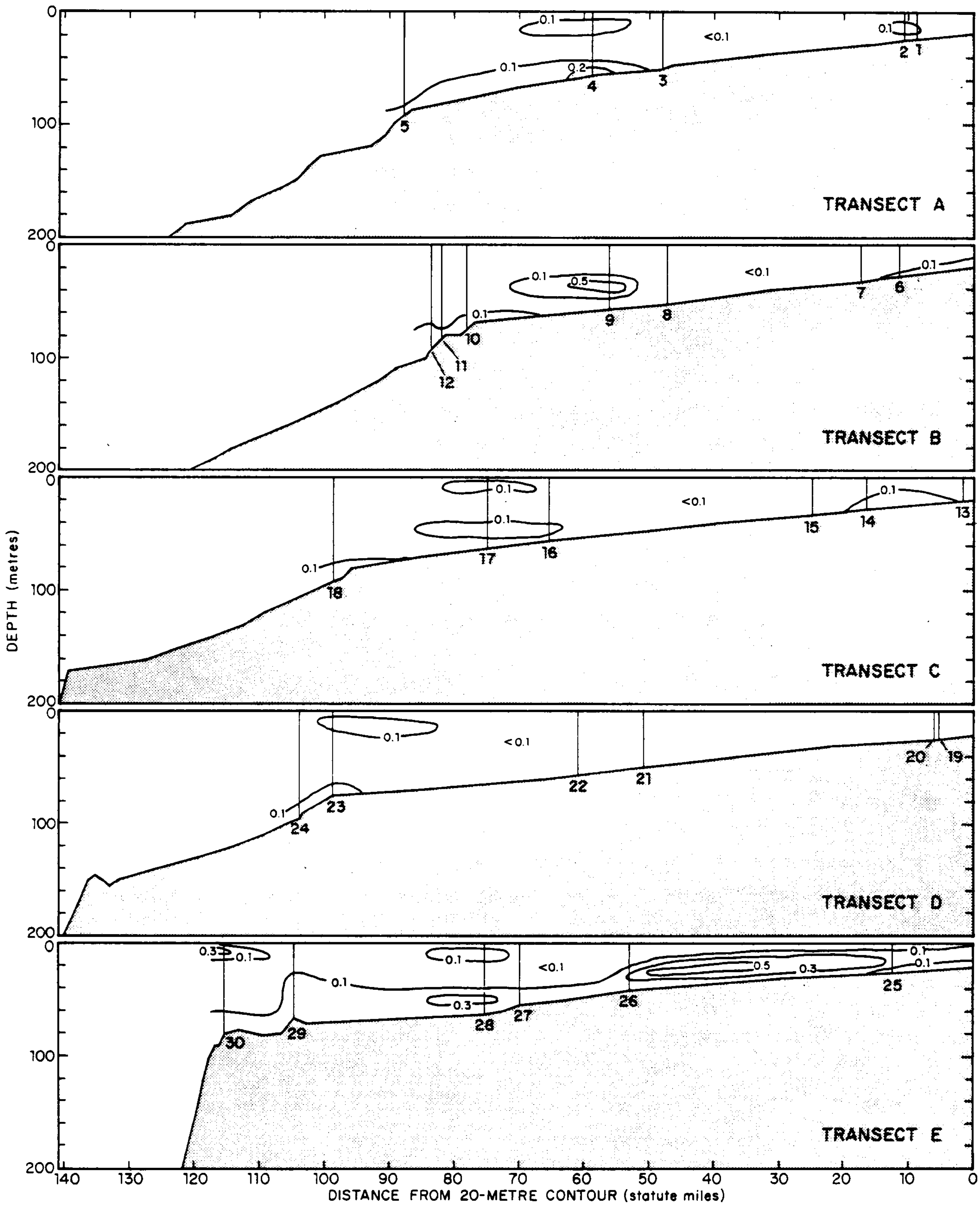

Figure 6-14. April-May 1981 phosphate (µM) cross-sections.

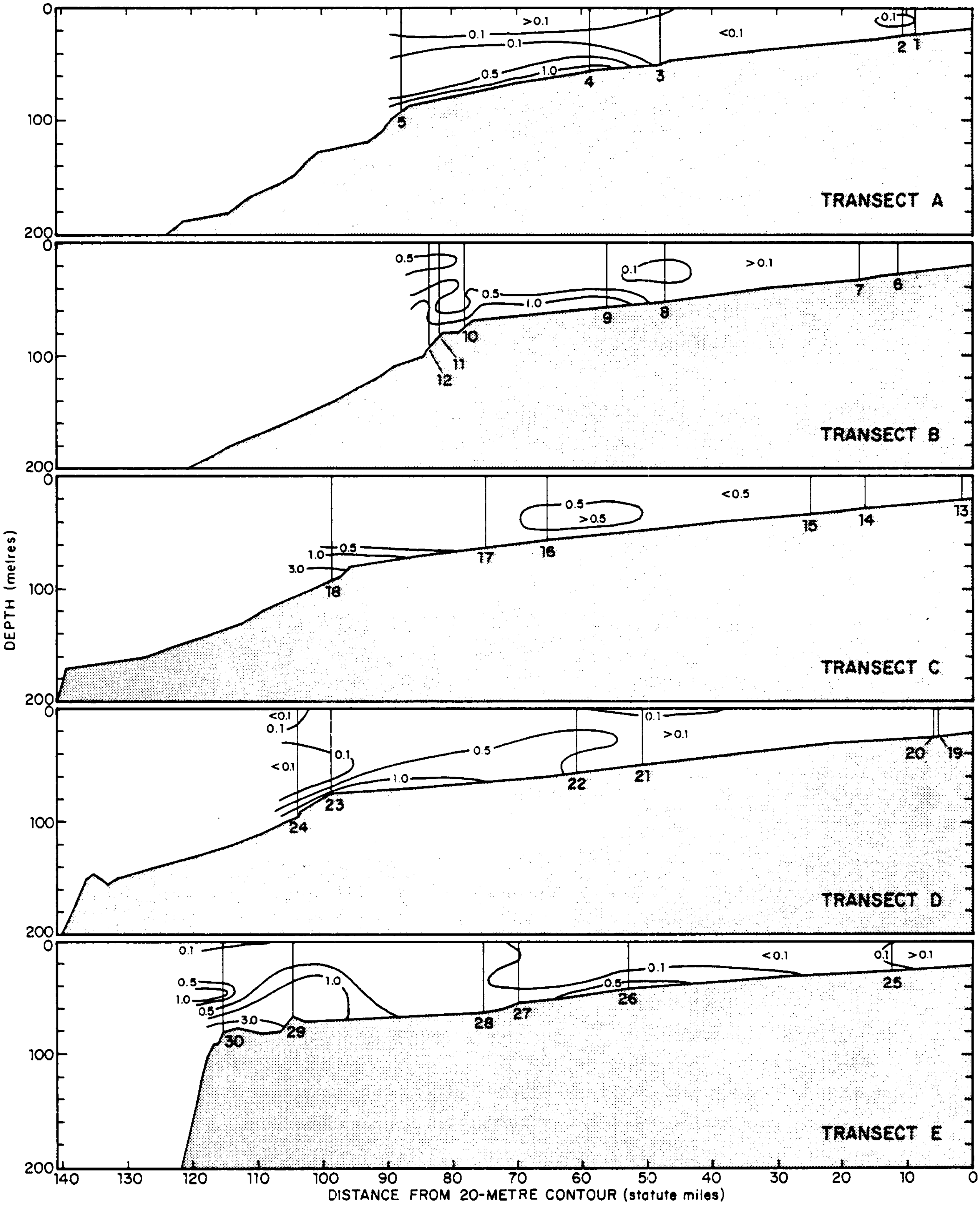

Figure 6-15. April-May 1981 nitrate-nitrite (μM) cross-sections.

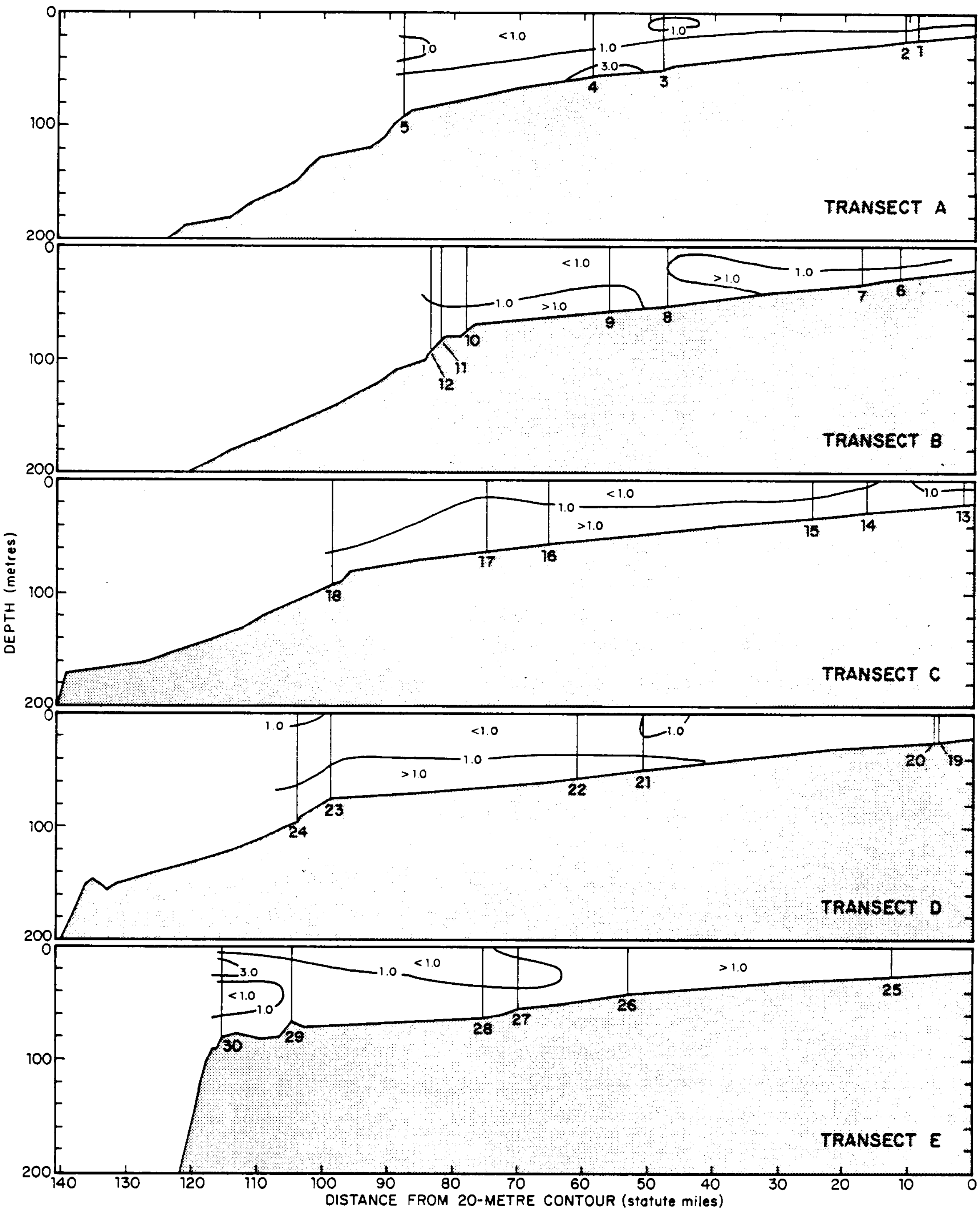

Figure 6-16. April-May 1981 dissolved silica (µM) cross-sections.

The Fall Cruise chlorophyll a (Chl a) measurements showed the study area to be characterized by low values (Figure 6-17). The highest value of Chl a was only 1.9 mg m^{-3} at Station 14, and the lowest values were all <0.1 mg m^{-3}. These low values were found on all transects. Transect A had a large area of <0.1 mg m^{-3} Chl a, which coincided with high transmissivity values and a temperature maximum. The Chl a concentrations on Transect A increased to >1.0 mg m^{-3} at both the surface and bottom in the nearshore area and coincided with increasing turbidity. Transects B and C also showed this shoreward trend.

Transects D and E had Chl a values of <0.1 mg m^{-3}, and these showed a general correlation with the location of the salinity minimums. Both transects showed a trend of increasing Chl a at the innermost stations, but decreased values relative to the other transects. This was probably due to the increasing distance from the coast, eliminating normal sources of nutrients for standing crops. As in the case of the other measured variables, Station 25 had an increased Chl a level near bottom (0.51 mg m^{-3}), but this level of Chl a would not explain the extreme turbidity values observed at this station.

During the Spring Cruise, Chl a was low throughout the study area, with values of <0.05 mg m^{-3} on all transects and a maximum of only 0.8 mg m^{-3} on Transect E (Figure 6-18). Chl a levels were also seen, for all transects, to increase both in shoreward direction and demonstrate an apparent increase with depth. Each transect had the Chl a maximum within the 40 to 65-m isobath. The Chl a maximum also appeared to correspond to low temperature pockets, i.e., with the exception of Transect E. Concentrations of Chl a at Station 29 showed an upwelled isopleth structure analogous to other observed variables at this station. Note how the gradually decreasing values from bottom to surface are interrupted by a distinct but higher concentration at about mid-depth.

6.4 Discussion

6.4.1 Circulation Patterns

6.4.1.1 Loop Current

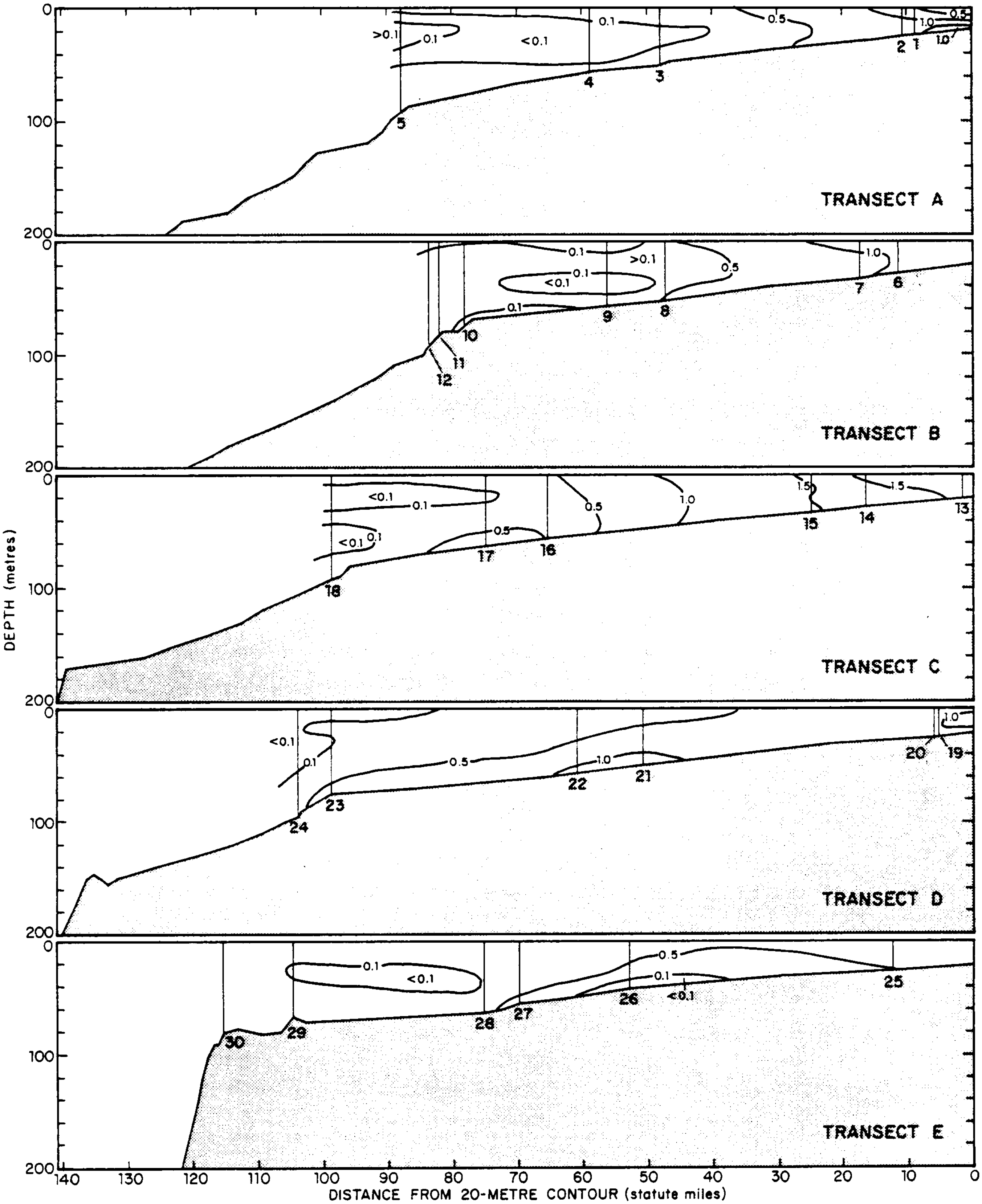

Figure 6-17. October-November 1980 chlorophyll a (mg/m^3) cross-sections.

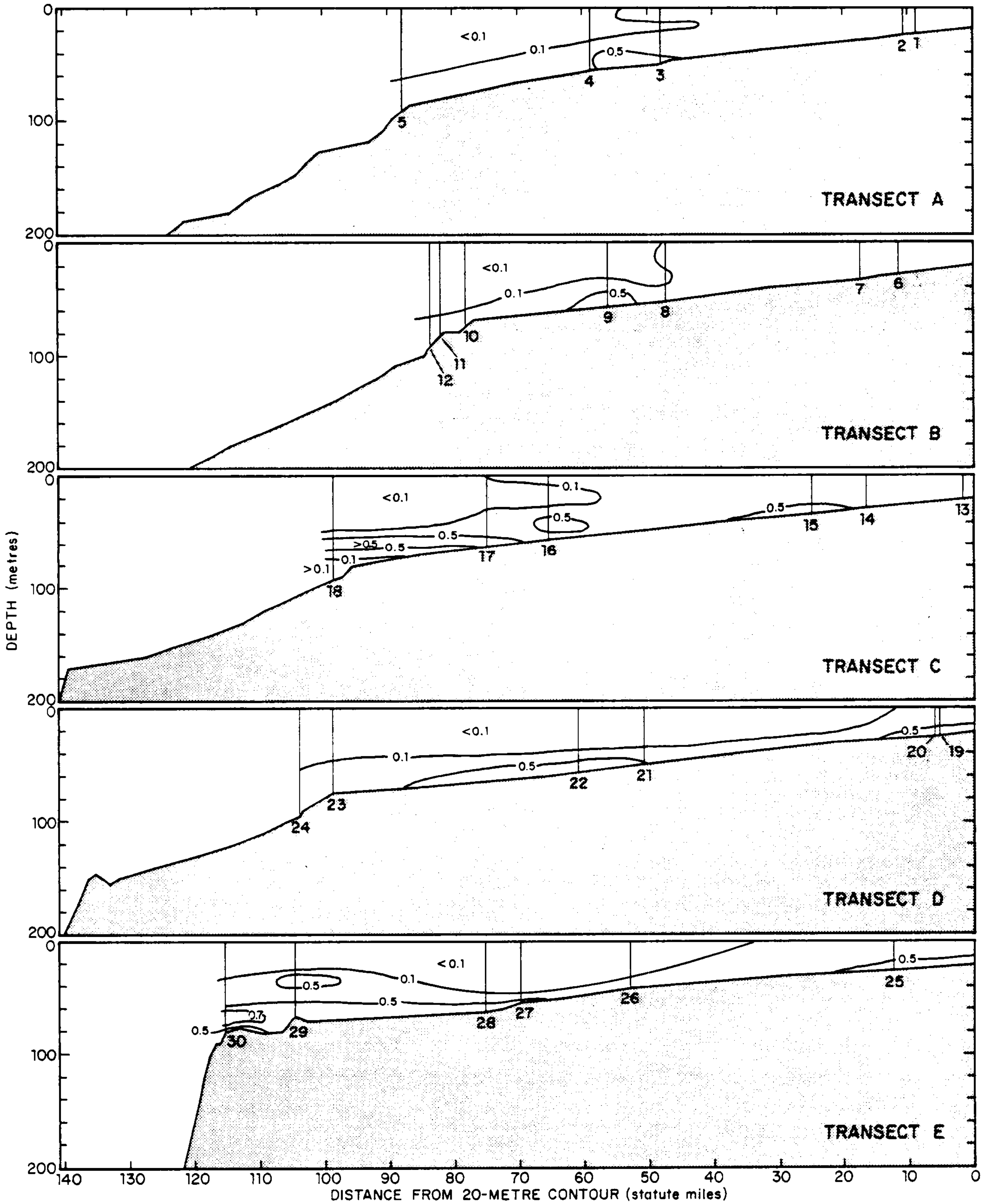

Figure 6-18. April-May 1981 chlorophyll a (mg/m^3) cross-sections.

6.4.1.1.1 Historical Data

When assessing hydrographic regimes within the Gulf of Mexico, the potential influence of the Loop Current must be considered. The Loop Current is the most striking feature of the circulation within the Gulf of Mexico (Chew, 1955; Leipper, 1954, 1970). The Loop Current is an extension of the Yucatan Current which enters the Gulf of Mexico basin through the Yucatan Straits, turns anticyclonically within the basin, and exits through the Florida Straits as the Florida Current. The Loop Current then becomes part of the Gulf Stream system flowing along the eastern seaboard. It has been suggested that the Loop Current has a seasonal flow into the northern latitudes with a spring intrusion, summer maximum, and fall retreat (Leipper, 1970). This classical development pattern, however, is not necessarily accurate. Maul (1977) confirmed a seasonal growth and decay but also found significant year to year variability. Molinari et al. (1977), using satellite data, have found the current to extend well into the Gulf (above 26° latitude) during the winters of 1974-1977, further documenting variability.

Molinari et al. (1975) defined the Loop Current and Loop Current waters as those having a salinity maximum of >36.5°/oo. These higher salinities are generally associated with the Subtropical Underwater (SUW) which is found normally below the 100-m depth within the Loop Current structure. Leipper (1970) has used the depth of the 22°C isotherm (150-220 m) to define the Loop Current. Austin (1971) has used selected indicator organisms to identify Loop Current waters.

In addition to the Loop Current proper, large and small scale eddies are known to develop as a result of Loop penetration into the Gulf (Cochrane, 1972; Leipper et al., 1972; Nowlin et al., 1968; Jones, 1973; Maul, 1977).

The relationship of the Loop Current and other physical variables to the west Florida shelf dynamics is poorly documented. Trade winds, frontal passages, tides and inertial motions, Loop Current, and river runoff are all forces driving both local and mesoscale shelf circulation (Maul and Molinari, 1975). Vukovich et al. (1979) have identified large Loop-associated meanders off the southwest Florida shelf prior to development of warm water gyres in the northern latitudes. This certainly has an effect on the shelf circulation. Maul (1977), Haddad and Carder (1979), Williams et al, (1977), Jones et al. (1973), and others have observed the impingement of Loop Current waters well onto the shelf. Carder and Haddad (1979) have found extreme bottom turbidities associated with these impingements.

A seasonal surface flow has been grossly defined for the west Florida shelf (Williams et al., 1977). Using monthly surface drift bottles dropped between Tampa Bay and Charlotte Harbor over a three-year period, these authors found that winter releases had the majority of landings on the Florida east coast. Spring and summer releases had a high percentage of returns from the Florida west coast and the greatest number of returns from the western Gulf occurred from summer and fall releases. Approximately 60% of all returns were from the east coast of Florida, between Key West and Cape Canaveral, and 27% were from the Florida west coast within the bounds of the drops. The drift patterns appeared to follow seasonal wind patterns which were from a northerly direction in the winter and had a southeasterly to westerly component in the summer. During the fall of 1967, when the Loop Current and winds induced a southerly flow, several bottles were found on the east coast within 20 days, with one bottle achieving an average speed of >100 cm s^{-1}. There were no returns from the Florida Bay systems or on the Gulf of Mexico sides of the Keys and Tortugas chain.

The Loop Current is known to reach speeds of >200 cm s^{-1} (about 4 kn). For currents along the west Florida shelf, Mooers and Price (1975) and Niiler (1976) have found extreme velocities of 100 cm s^{-1} associated with storms, but flow was generally <20 cm s^{-1}. They found southerly, northerly, cross-shelf, and counter-currents, but the studies were not comprehensive enough to explain many of the forcing functions. Flow generally paralleled the isobaths and tidal oscillations produced negligible net flow. Rehrer et al. (1967) conducted bottom drift studies in the Tortugas shrimp grounds and found a predominant flow in a westerly-southwesterly direction.

Chew (1953, 1955) and Hela (1956) concluded that a permanent cyclonic eddy exists on the southwest Florida shelf. They suggested that the eddy was driven by the Loop Current. The existence of this circulation has not been studied in a comprehensive manner and has not been confirmed.

The effect that the Everglades may have on the study area is simply not known. Schmidt and Davis (1978) summarized water quality data from the Everglades National Park from 1879-1977. A salinity range of 26.7°/oo to 39.2°/oo was observed along the Florida Bay mainland in the 1930's while hypersaline conditions (41-66°/oo) were observed between 1973 and 1976. The effect of these high-salinity waters is unknown. Hela (1956) suggested that these waters, at times, may be incorporated into the cyclonic eddy at the shoreward stage. The existence of these hypersaline barriers within the inner Florida Bay area has increased as a function of drainage rerouting in conjunction with development (Thomas, 1974). Ziemen (1982) has found surface concentrations of seagrass blades in the study area and has determined their source to be the extensive seagrass beds within the shallow waters of Florida Bay. He has indicated that the exchange of material between the inshore grass beds and the coastal shelf region is governed mainly by winds with the predominant transport westward from Florida Bay and the lower keys. Ziemen suggested the annual input of seagrass to the offshore sediments ranges from 0.009 to greater than 0.9 g m^{-2}.

This finding has several implications relative to the study area. Seagrass decomposition at the benthic level may provide a substantial nutrient source to the area and, although neither the Fall nor Spring Cruise sampling indicated an Everglades input, transport (at least surface) from the shallow Florida Bay areas to the westward offshore zones is quite possible. If these inner bay areas receive an Everglades input it would be possible for Everglades waters to penetrate the study area.

6.4.1.1.2 Shipboard and Satellite Imagery Data

The position of the Loop Current during the Fall Cruise (III) is shown in Figure 6-19. The Loop Current was present north of 27°N latitude with the eastern edge approaching the west Florida shelf on October 28, 1980. This general flow pattern was maintained at least through November 28th. The position of the Loop Current, in relation to the study area, suggests that the

WE = Warm Eddy LC = Loop Current

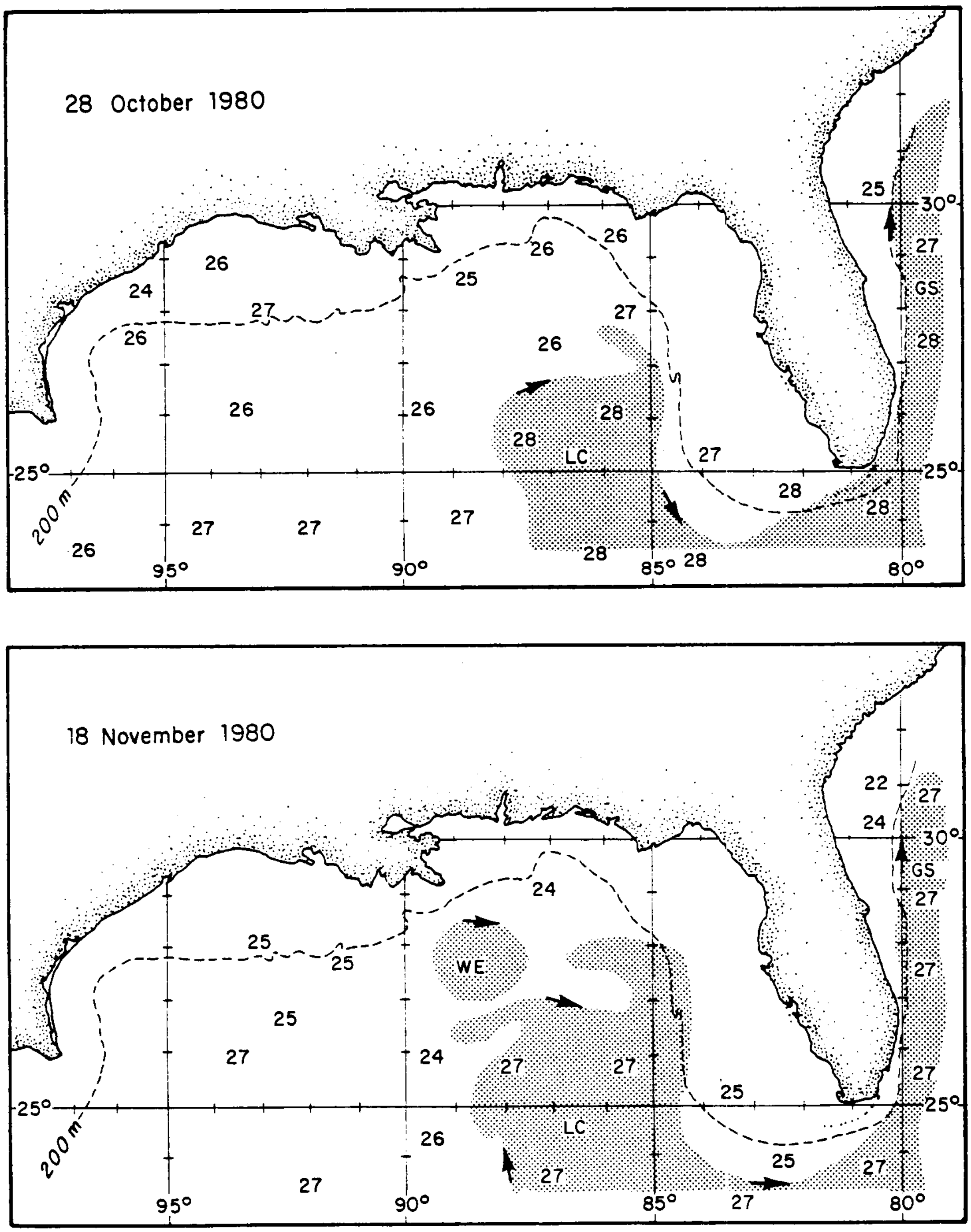

Figure 6-19. Loop current positions and sea surface temperatures (°C) during the Fall Cruise as depicted by thermal imagery from the National Earth Satellite Service GOES satellite.

current was not directly affecting the shelf environment during the Fall Cruise.

This lack of direct influence of the Loop Current is apparent in the salinity data for Transects A through D. There were no salinities in excess of 36.38°/oo, suggesting that the study area was covered by outer shelf water. Transect E had a salinity maximum (36.5°/oo) which is more characteristic of Subtropical Underwater (Figure 6-20), indicating that there was some contact with the outer (eastern) edge of the current. Transmissometer data indicates that this contact may not have been within the velocity field of the current since no near bottom turbidity was observed. However, very little soft substrate was present at Station 30 (Section 7.0). Geographically, Transect E is nearest the Florida Straits and its outermost station is located on the steepest topography leading off the shelf. Thus, this area may be more susceptible to the influence of the Loop and Florida Current waters than are the other transects, particularly subsurface.

Figure 6-21, which depicts the position of the Loop Current prior to and during the Spring Cruise, shows that on March 5, 1981 the Loop Current had penetrated far into the Gulf and a large warm water eddy was separating north of 26.0°N and to the west of 85.0°W. In addition, a portion of the Loop Current appeared to extend well into the study area near 83°W.

A similar pattern was observed on April 9th, except that the Loop Current had retreated to 84°W and was westward of the study area. By April 30th, the Loop Current was west of the shelf (84°W) near the study area and a warm intrusion was evident along the shelf break. This was still evident on May 14th when the warm waters had again impinged eastward into the study area. From this, it may be concluded that the Loop Current was not directly impacting the study area during the Spring Cruise but may have had some impact in early April prior to the cruise and again after the cruise. This conclusion is supported by the temperature and salinity data which do not indicate a shoreward intrusion nor a strong penetration of Subtropical Underwater (SUW). Several offshore stations had salinities >36.5°/oo at temperatures within the confines of the SUW. The salinities appeared to be passive or remnant components of the Loop Current

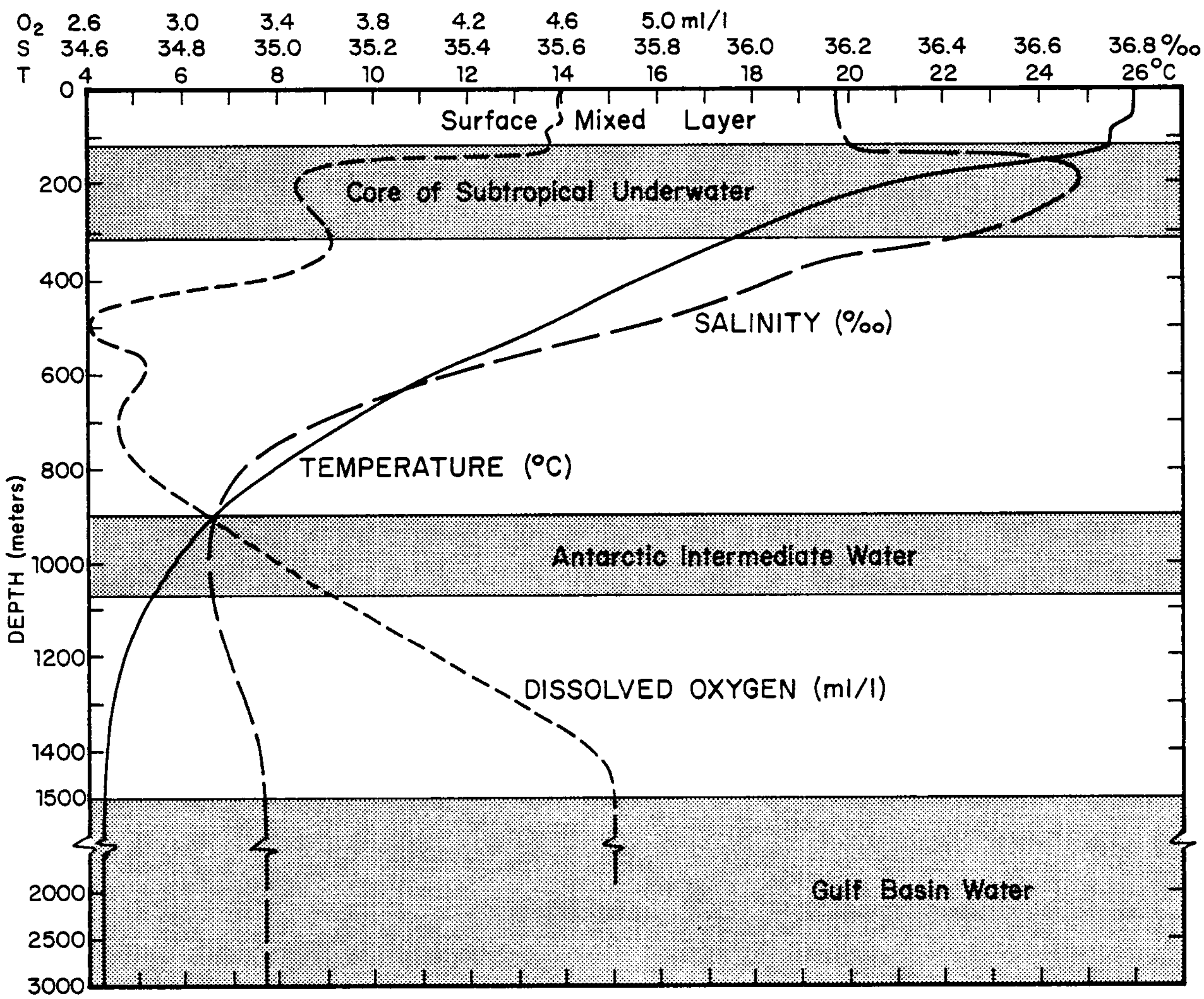

Figure 6-20. A "characteristic" hydrographic station in the central eastern Gulf of Mexico explaining the vertical layering of waters (from Nowlin, 1971).

WE = Warm Eddy LC = Loop Current GS = Gulf Stream

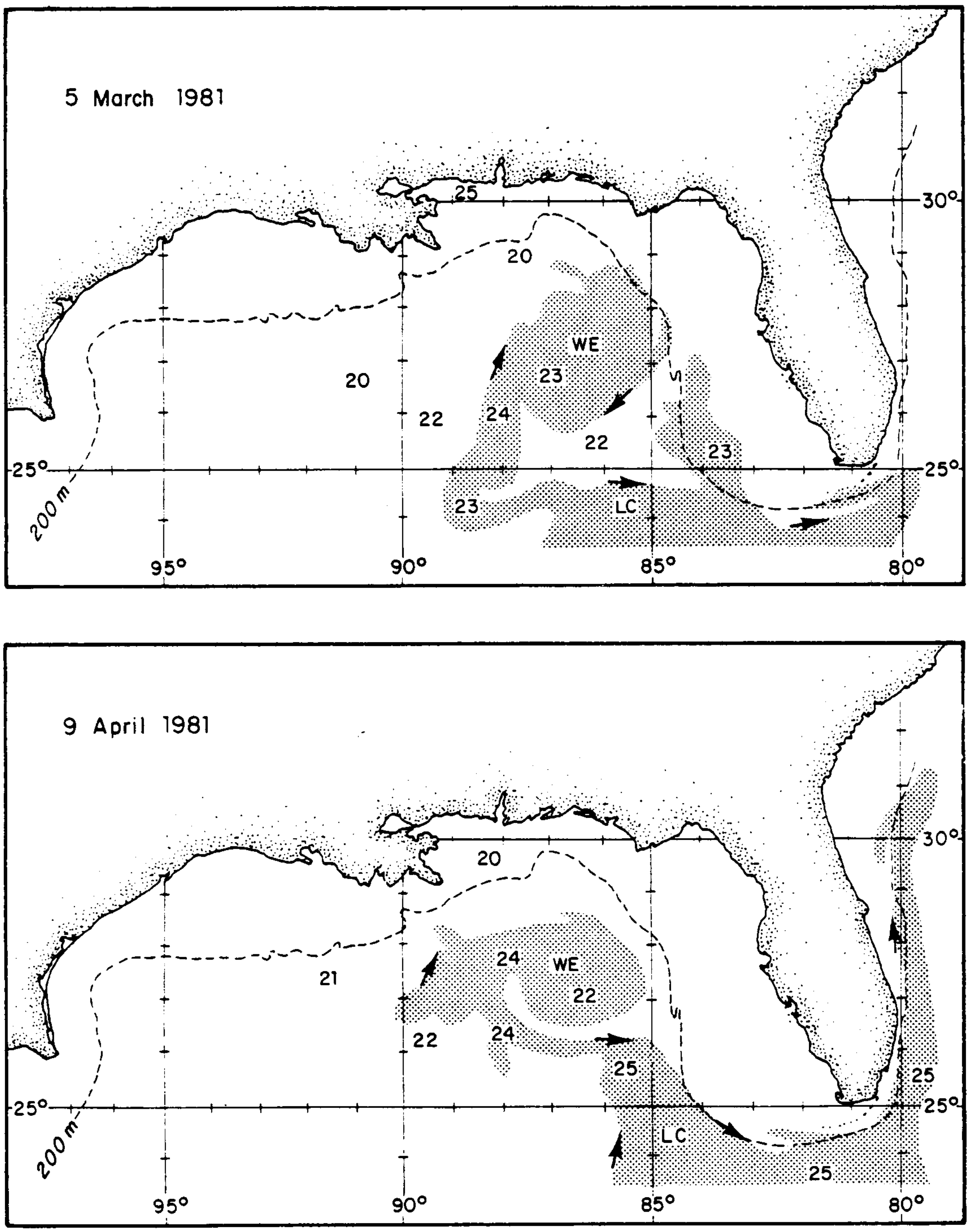

Figure 6-21. Loop Current positions and sea surface temperatures (°C) during the Spring Cruise as depicted by thermal imagery from the National Earth Satellite Service GOES satellite.

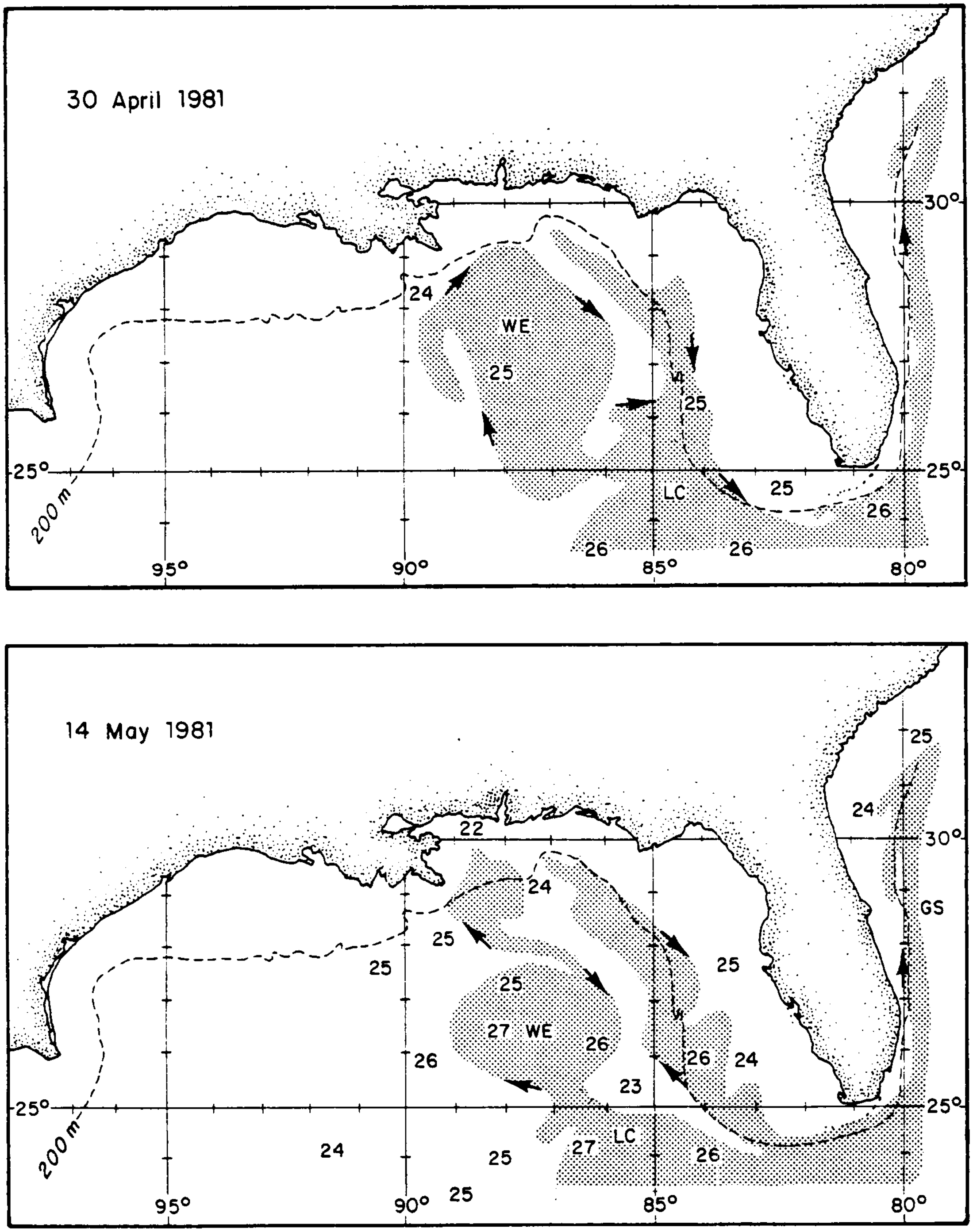

Figure 6-21. (continued).

since near bottom turbidity was not observed, although a lack of surficial sediment could have precluded any resuspension.

6.4.1.2 Continental Shelf Currents

Circulation patterns during the Fall and Spring Cruises may only be inferred. Seasonally, both the wind and the Loop Current influence surface circulation in the study area. By late fall, surface flow generally has a southern component (Williams et al., 1977). This southerly circulation pattern was the cause for the transplantation of a portion of a west Florida red tide bloom to the east Florida coast within the time frame of the Fall Cruise (III). This type of pattern has also been reported by Murphy et al. (1975) for a red tide bloom in the fall of 1972. The most likely avenue for flow would be around the western edge of the Tortugas Bank and also between Rebecca Shoal (west of the Marquesas) and the Tortugas. This same surface flow pattern would also be expected in April and May (Spring Cruise), although northward transport at some of the nearshore stations may occur.

Subsurface flow is, at present, not well documented and potential flow patterns cannot be inferred from the fall and spring data (see Section 6.4.1.1.1).

6.4.2 Temperature

The Fall and Spring Cruises both encompassed a seasonal transition of the water column environment. The Fall Cruise (October-November) typified the summer/winter transition, when atmospheric cold fronts begin to penetrate into south Florida. At this time, the water column undergoes a mixing process induced by winds and water surface cooling. The bottom thermocline is mixed out to deeper isobaths as the winter environment intrudes onto the west Florida shelf. These effects may have been enhanced by the passage of Hurricane "Jean" which had a minor mixing influence on the study area.

The surface mixed layer, at the time of the Fall Cruise, extended to 40 to 60-m depths and decreased by approximately 1.5°C in a southerly direction. Seasonal cooling in relationship to the north to south sampling schedule possibly accounted for the decrease. The thermocline was mixed or had retreated to the

40 to 60-m isobaths. Temperatures below the thermocline at the offshore stations generally increased in a southerly direction. This latitudinal change was observed in most of the measured variables (either increases or decreases) during the Fall Cruise. It was not likely that a different input source existed between Transects A and E. This was evident in that the 23°C location at all the outermost stations was at the 50-m isopleth. The latitudinal differences in temperature observed below the thermocline were related to outer station sampling isobaths in conjunction with other forcing factors (e.g., wind and currents). The results of this would be the observation of different isopycnal lines which reflect a variability in the waters measured below the thermocline.

The Spring Cruise (April-May) was made during a period of restratification of the water column. During this time, a decrease in turbulent forces was seen and a gradually warming surface water began to mix into the water column. It was apparent that the summer thermocline was in the process of forming during the Spring Cruise. The thermal isolines were spread vertically over the water column and became more compacted, forming a sharp thermocline only at the nearshore stations. This was due to the shallow water heating and mixing, which would tend to form a bottom thermocline as the vertical temperature gradation was mixed. The near-bottom, mid-shelf temperature minima were also a prominent feature during the Spring Cruise. This was also a result of the stratification process taking place on the shelf. Mixing of the mid-shelf surface waters (23-26°C) was not as predominant as that which had taken place in the shallower depths. It was also apparent that warmer oceanic waters were affecting the offshore stations, thus contributing to the location of the mid-shelf, near-bottom temperature minimum. This minimum was most pronounced on Transect E where the warmest offshore waters (26°C) were observed. It was possible that the Loop Current water, as observed by satellite (Figure 6-21), was affecting the outer stations of this transect. A second possibility was that the transect was continuously affected by the Loop and Florida Currents and the shallow barrier waters to the south.

6.4.3 Salinity

During the Fall Cruise, salinity corresponded well with the temperature isopleths. The bottom halocline corresponded with the thermocline and the mixed layer salinities were partitioned in a cross-shelf direction. Salinity minima over the cruise area are depicted in Figure 6-22. The data indicate what may be an eddy, but no conclusion can be drawn due to a lack of synopticity, or simultaneity, in the data. This eddy-like feature was defined by a lower salinity lens that penetrated to a depth of 20 m in the offshore direction. The higher to lower salinity progression was analogous to patterns encountered on the shelf during May, June, and July, 1980 (Haddad, 1980a; Milliken, 1980).

During these months, north of 26°N, a near-bottom, high-salinity (36.3 to 36.6°/oo) upwelling occurred to within the 20-m isobath. This near-bottom water was 22°C and was considered to be of SUW and Loop Current origin. Overlying the near-bottom feature was a low-salinity lens (decreasing in an offshore direction) which extended to the shelf break. Minimum salinities were <34.0°/oo and were within a 20-m surface lens. Alexander et al. (1977) suggested that this type of phenomenon is a result of Loop Current eddy development and impingement with the low-salinity lens being Mississippi water. During the Fall Cruise, this analogous pattern was either the result of a similar small scale process occurring in the study area with the lower salinity lens, a result of an eddy impingement, or this was a remnant of the massive impingement which occurred during the summer. The lower salinity was not associated with Hurricane "Jean" rainfall since the offshore patterns were evident on Transects A and B prior to the storm. Since turbidities associated with the lens were low, the input source, if riverine, was not recent. This type of hydrographic regime is not known to be common. Fausak (1979) found that in all cases during sampling on the shelf in 1977, the salinities decreased in a shoreward direction.

The nearshore water mass, characterized by higher salinities, may have also been a remnant of the summer impingement or reflected a nearshore forcing and partitioning of the mid-shelf environment by the low-salinity input. Increases

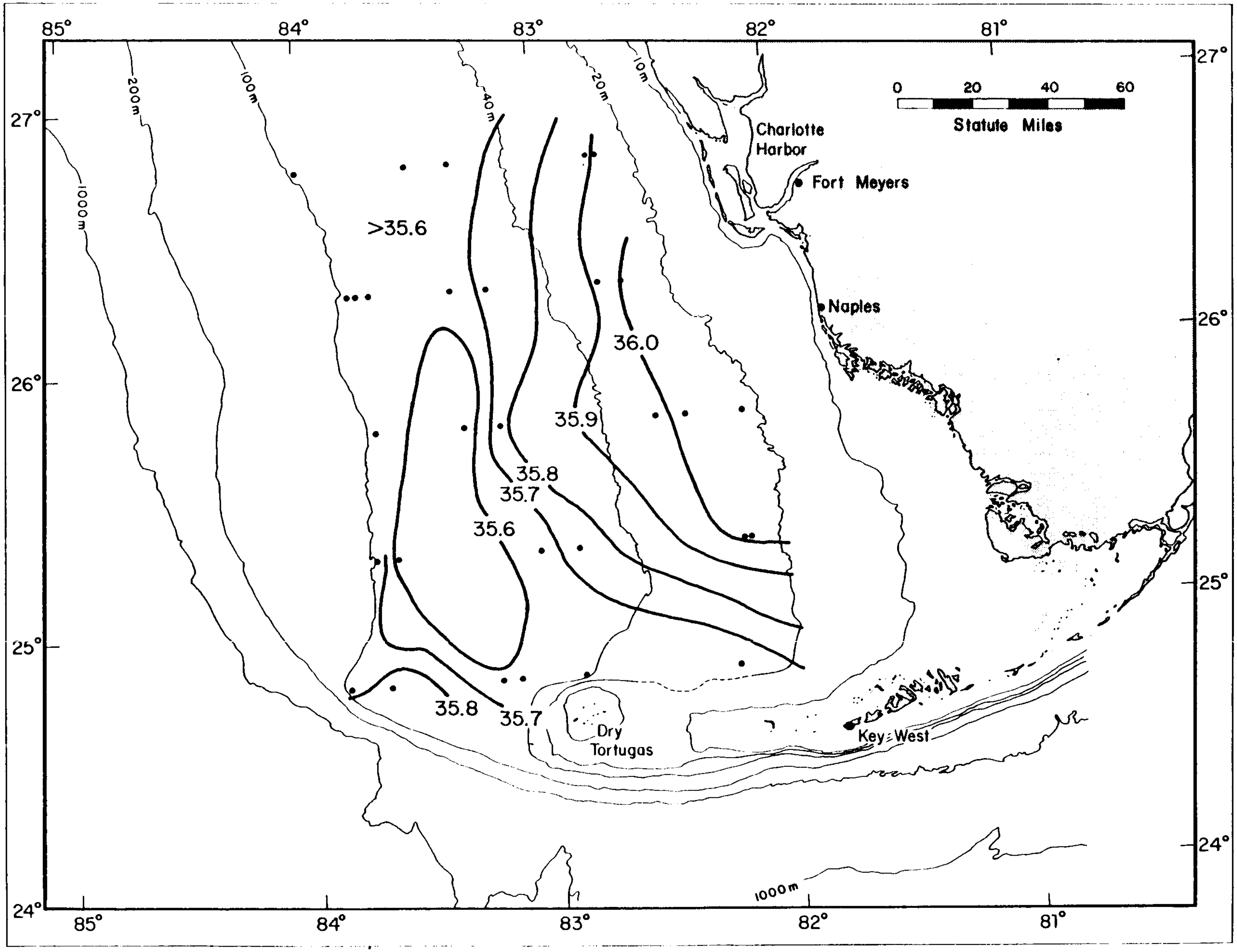

Figure 6-22. October-November 1980 near-surface salinities (°/00).

in Chl a at the nearshore stations suggest an influence by nearshore coastal waters.

During the Spring Cruise, no true haloclinic development was seen and salinities were generally mixed from surface to bottom with only isolated high salinity pockets. The existence of an exceptionally high salinity pocket (>36.8°/oo) was observed at Station 17.

When first observing these anomalous salinities, it is natural to consider them as artifacts of sampling and/or techniques, but in most cases more than one data point was high. Also, in the literature, many researchers have reported these salinities in the Gulf of Mexico and shelf areas (e.g., Chew, 1955; Collier et al., 1958; Maul et al., 1979; Morrison and Nowlin, 1977; Nowlin, 1971; and Wennekens, 1959). Assuming these values as valid, several sources are possible: (1) the shallow water of Florida Bay often reaches high salinities capable of producing this effect, (2) localized extreme surface evaporation and subsequent sinking to stabilize, and (3) intrusion of Loop Current Subtropical Underwater (SUW) which is created by evaporation in the Sargasso Sea, and possible enhancement of these high salinities by evaporation in the Gulf of Mexico.

In this case, the SUW would again be the suspect due to its continual proximity to the Loop Current and constant meandering into the study area. The reason that the salinities are so high is debatable. Although they do affect the shelf, these anomalous salinities should generally be considered transient in nature. Other than these characterized pockets, the salinities were vertically mixed and decreased shoreward (>36.3°/oo offshore to <35.8°/oo nearshore).

6.4.4 Dissolved Oxygen

Dissolved oxygen values were mixed throughout the water column during the Fall Cruise. They had no definitive features except the low values near the bottom at the offshore stations. El Sayed et al. (1972) depicted the dissolved oxygen values (O_2) in the upper layers of the Gulf to range from 4.5 to 4.8 ml l^{-1} in the mixed layer and decline to 3.3 to 4.5 ml l^{-1} below 100 m. When compared to the Fall Cruise data, it would appear that higher O_2 shelf water was overlying a parcel of open Gulf water representative of the first 100 m and in some cases below 100 m. Sufficient data do not exist to explain the mid-shelf low of 3.18 ml l^{-1} at Station 16.

The dissolved oxygen values were high throughout the study area during the Spring Cruise. This was most likely due to the intense mixing which took place during the winter and early spring months.

6.4.5 Transmissivity

Turbidity of the water column during both fall and spring was attributable to both bottom sediment resuspension and plankton activity. An abrupt change in the turbidity structure occurred from Transects A to B through E during the Fall Cruise. Transect A had water of >80%T at the nearshore stations while at Transects B through E this clear water did not exist beyond the mid-shelf stations. When comparing this change to Chl a concentrations, it becomes apparent that the overall water column turbidity increases were not the result of phytoplankton growth but, rather, the passage of a weather front which occurred after the sampling of Transect A and homogenized the water column as well as increased the particulate suspended load. Temperature also reflected this frontal passage with a slight decrease in the mid-shelf to nearshore stations. This exemplifies the abrupt changes which can take place as cold fronts begin to penetrate a study area. The fact that the overall turbidity increase did not reflect a major phytoplankton contribution does not preclude a potential contribution to turbidity in a nearshore direction (see Section 6.4.8). The Fall Cruise data also suggested a small localized influence of bottom currents at several of the mid-outer shelf stations. Those increases were not indicative of a strong bottom flow.

The near-bottom increases in turbidity (Fall and Spring Cruises) were consistent with Steward (1981), but the relatively clear water indicates that strong currents were not affecting the area. Carder and Haddad (1979) have found bottom currents on the west Florida shelf capable of developing nepheloid layers of <30% transmittance. Station 25 had the sharpest nepheloid layers during both cruises (<50%T). The sediments at this station had a high silt/clay content (Section 7.0) and strong tidal currents could account for resuspension. The Spring Cruise showed that the water column had less particulate matter than in the fall, and that there was no evidence of bottom currents offshore. There was, however, an increased phytoplankton and particulate resuspension contribution nearshore. Transects C through E on the Spring Cruise (IV) developed nepheloid layers at the nearshore stations. The exceptionally high values (97-99%T) on Transects D and E suggest waters as clear as those of the Sargasso Sea. These pockets of exceptionally clear water were adjacent to high salinity pockets on the shelf. The near-bottom increases, in most cases, were the result of accumulations of organic matter and phytoplankton at increasing water density levels. This concept is supported by the fact that Chl *a* values generally increased with depth.

6.4.6 Yellow Substance

There was no obvious influence on the study area by the Everglades. Yellow substance concentrations were extremely low and there were no salinity configurations or fluctuations that were indicative of inputs of Everglades water either as surface runoff or hypersaline input. In agreement with these findings, there are no data in the literature that suggest that the Everglades system has a major influence on the study area. Although there is a general lack of literature on this subject (Section 6.4.1.1.1), it is possible that under extreme conditions, Everglades runoff could affect the study area, but the environmental impact is unknown.

6.4.7 Nutrients

Generally, there is a substantial lack of systematic information concerning nutrient fluxes on the west Florida shelf. To date, the most pertinent literature has involved red tide and large scale Gulf of Mexico research. Little recent research data are available. Dragovich et al. (1963) found PO_4-P (phosphate and biologically available phosphorus) concentrations in lower Charlotte Harbor to range from 5.8 to 10.4 µM. At a distance of only 9.3 km to 37.1 km offshore of Boca Grande, the values were found to have ranged from 1.1 to 1.6 and 0.6 to 0.7 µM, respectively. Likewise, Finucane and Dragovich (1959) also found low phosphate concentrations offshore of Florida Bay.

Nutrient concentrations in the open Gulf of Mexico were found by Morrison and Nowlin (1977) to increase below the euphotic zone. Phosphates ranged from negligible at the surface to approximately 1.2 $\mu\underline{M}$ at 200 m. Waters of the Loop Current had phosphate concentrations that were negligible at the surface and only 0.3 $\mu\underline{M}$ at 200 m. Haddad and Carder (1979) showed that the waters of the Loop Current may intrude onto the shelf, penetrating below the summer thermocline. In conjunction with this, Freeberg and Hyle (1978) showed that when a 1977 Loop Current intrusion came within two nautical miles of shore the orthophosphate levels increased by 88% and SiO_4-Si (dissolved silica) increased by 129%.

El Sayed et al. (1972) reported the upper 100 m of water in the Gulf of Mexico to be nutrient poor. Values for PO_4, NO_3, and SiO_2 generally did not exceed 0.4, 2.0, and 2.0 $\mu\underline{M}$, respectively.

With several exceptions, the spring and fall nutrient concentrations were low throughout the study area, with small increases observed with depth. This was consistent with previous research on the shelf. One exception to this observation was the substantial increase in concentrations of the nutrients below the pycnocline during the Fall Cruise. Some of the observed values were 10 to 100 times those found near the surface. Many of the values exceeded those found in the upper 100 m in the Gulf (El Sayed et al., 1972; Collier et al., 1958). Nutrient pore water release is a possible source for higher nutrients (Barnard and Froelich, 1981), but this would normally accompany a bottom turbulence which was not observed by the transmissometer. The most likely source of the high nutrient water was intrusion of water seaward of the shelf from depths below the subsurface salinity maximum. Yentsch (1974) described a mechanism based upon the Rossby jet characteristics of the Gulf Stream whereby nutrients may be transported and updrafted from below the euphotic zone as a geostrophic flow to the left side of the direction of flow of the current. This is a separate mechanism when compared to wind-driven upwelling but the two mechanisms may act to enhance the upwelling process. The flow of the Loop Current would be an analogous situation. Bogdanov et al. (1969) described an area of upwelling and high productivity off the southwest Florida shelf and a geostrophic upwelling would explain this phenomenon.

The high nutrients and the general proximity of the Loop Current to the study area suggest that the Loop Current and/or winds had directly or indirectly induced an upwelling of deeper waters into the near-bottom environment during the Fall Cruise. This possible mechanism should be investigated in greater detail in future study efforts.

Another exception to the low nutrient values found throughout the study area was a substantial increase in dissolved silica (<13 μM) at Station 25 during the Fall Cruise. This correlated with the strong nepheloid layer at this station. There was a high silt/clay sediment content at this station which may have contributed to the elevated levels through pore water release or *in situ* dissolution if resuspension was continuous. On the Spring Cruise, an equally turbid nepheloid layer was observed but dissolved silica was <3.0 μM. An explanation for this change cannot be discerned from the available data. It is possible that there is an inherent variability in dissolved silica within the area. It is difficult to apply seasonality differences. Since Chl *a* concentrations remained similar, it would not be likely that phytoplankton growth accounted for the lower dissolved silica values unless the phytoplankton assemblage (i.e., increased diatoms) favored greater utilization in the spring.

6.4.8 Chlorophyll a

Previous workers, such as El Sayed et al. (1972), found the average depth of the euphotic zone (1% level) in the Gulf of Mexico to be 74 m. Chlorophyll *a* (Chl *a*) concentrations at the surface averaged 0.2 mg m^{-3}, but ranged from 0.05 to 0.3 mg m^{-3}. El Sayed et al. also determined that maximum Chl *a* concentrations were subsurface and many maxima coincided with the depths of the euphotic zone.

The euphotic zone on the shelf often penetrates to the bottom, with the highest Chl *a* concentrations found in the bottom samples (Haddad, 1980a). This is not the case during phytoplankton bloom conditions, when values at the surface may exceed 100 mg m^{-3} in extreme cases. Under normal conditions, values range from 1 mg m^{-3} nearshore to 0 mg m^{-3} (three litres filtered) offshore, both at the surface and on the bottom. Gordon et al. (1980) used Nimbus 7 Coastal Zone Color Scanner satellite imagery to map the distribution and concentration of Chl a on the Florida continental shelf on 14 November, 1978. Their results showed that the concentrations of Chl a and phaeopigment a ranged from about 0.2 to 2.20 mg m^{-3}. Haddad (1980b) was able to show that some of the higher values on the southwest shelf were attributable to a red tide bloom in the area at the time.

The data indicated there may have been a general relationship between nutrients and Chl a during the Fall and Spring Cruises. Above the pycnocline, increased PO_4 on occasion coincided with increases in Chl a concentrations. This was observed at Stations 1, 6, and 13 on the Fall Cruise where >0.1 µM PO_4 corresponded to >1.0 mg m^{-3} Chl a. A general lack of nutrient availability was reflected in the Chl a data. As described in Section 6.3.9, the fall samples were the only ones to have encountered Chl a values >1.0 mg m^{-3}. These higher values were nearshore in the northern transects (e.g., Station 1) and probably reflected the influence of nearshore nutrients and increased phytoplankton growth. A red tide bloom in the area at the time may also have had an impact on these values. The remainder of the water column was characteristic of oligotrophic conditions. During the Spring Cruise, the greatest nutrient availability was in the near-bottom water of the offshore stations where light availability limits phytoplankton growth. Station 29 on Transect E provides an example of how this bottom water can interact with the remainder of the water column. An upwelling of water, which was observed in all the measured variables, had extended from the bottom to a depth of approximately 30 m, introducing a higher nutrient load into the upper water column. Accompanying an increase in nutrients was a marked increase in Chl a (0.5 mg m^{-3}), thus indicating a higher phytoplankton standing crop. This would be expected when the nutrient rich waters are upwelled towards the surface at any place over the study area. The low Chl a values imply that the phytoplankton standing crop was generally low throughout the study area with a small potential for increases due to terrigenous and nearshore sources and more so from upwelling. In either case, the effect would be transient in nature.

6.4.9 Transect E

Transect E consistently deviated from the structural patterns of the other transects recorded during both cruises. The measured parameters were usually at one extreme or the other and occasionally at both. This may be attributable to this transect's southerly location at the edge of the continental shelf. During the fall, for instance, this would have been the last part of the study area to receive the effects of storm fronts. Transect E was also the greatest distance from a mainland terrigenous influence, and was bounded on the south by a shallow water barrier. This transect was also the most proximal to the influence of the Florida Current and Loop Current system, being in closest proximity, in the west and south, to the Straits of Florida.

6.5 Summary

The study area during the Fall and Spring Cruises was found to be oceanic in nature. Generally, low nutrients, turbidity, phytoplankton standing crop (Chl *a*), high salinities and temperatures contributed to producing a classical tropical-subtropical marine environment. Data were collected at a series of 30 stations aligned on five east-west shelf transects. These data provide an initial assessment of water column variability and major trends within the area during the two transitional seasons. During the upcoming Year II study program, additional data will be collected during the summer and winter seasons. At that time an effort will be made to investigate possible relationships between observed water quality data patterns and the benthic communities present along the southwest Florida shelf.

In the October-November time frame which typifies the fall transition, atmospheric cold fronts begin to penetrate into south Florida. At this time, the water column undergoes a mixing process induced by winds and water surface cooling. The remnant summer bottom thermocline is mixed out to deeper depths as the winter environment intrudes onto the west Florida shelf. The thermocline is mixed or has retreated to the 40 to 60-m isobaths. Temperatures below the thermocline at the offshore stations generally increase in a southerly direction.

Concurrent salinity changes correspond well to the temperature isolines. The bottom halocline corresponds to the thermocline and the mixed-layer salinities are partitioned in a cross-shelf direction.

Dissolved oxygen values are generally mixed throughout the water column. They have no definitive features except the low values near the bottom at the offshore stations.

The Everglades appear to show no obvious infuence in the outer continental shelf waters. Yellow substance concentration is extremely low and there are no salinity configurations or fluctuations that are indicative of inputs of Everglades water either as surface runoff or hypersaline input.

The high nutrients observed below the pycnocline during the fall and the general proximity of the Loop Current to the study area suggest that the Loop Current and/or winds have directly or indirectly induced an upwelling of deeper waters into the near-bottom environment. Generally, however, the spring and fall nutrient concentrations were low throughout the study area, with small increases observed with depth. The photic zone on the shelf often penetrates to the bottom, with the highest Chl a concentrations found in the bottom samples.

During the spring transition (April-May) or period of thermal restratification of the water column, a decrease in turbulent forces is apparent and a gradual warming of surface waters begins to mix into the water column. The isotherms are spread vertically over the water column and became more compacted, forming a true thermocline barrier only in the nearshore regions. This is, of course, due to shallow water heating and mixing which tends to form a sharper thermocline as the vertical temperature gradation is mixed.

Near-bottom mid-shelf temperature minima are also a prominent feature of this seasonal transition. This is also a feature of the stratification process taking place on the shelf. Vertical mixing of the warming surface waters (23°-26°C) is not as predominant as that which takes place in the shallower depths. Salinities are generally mixed from surface to bottom with only isolated pockets of highly saline water. The existence of several pockets of exceptionally high salinities (>36.8°/oo) was observed in the study area.

Dissolved oxygen values are generally high throughout the study area during this season. This was most likely due to the intense mixing which took place during the winter and early spring months.

The spring data showed that the water column had less particulate matter than in the fall, and that there was no evidence of strong bottom currents offshore. There was, however, an increased phytoplankton and particulate resuspension contribution nearshore. The near-bottom increases, in most cases, were the result of accumulations of organic matter and phytoplankton at increasing water density levels. This concept is supported by the fact that Chl a values generally increased with depth.

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7.0 SUBSTRATE CHARACTERISTICS

7.1 Introduction

Characterization of sea floor substrate types is one of the more important aspects of benthic surveys. Substrate plays an important role in determining the benthic biological assemblage present at a particular location. Since the type of substrate is a major factor in the settling and success of larvae of benthic organisms, the structure of a marine benthic community is strongly related to the structure and type of sea floor at a particular location. Classically, substrate type has been utilized as one of the principal physical parameters to delineate discrete benthic systems.

Sea floor substrate surveys at stations on the southwest Florida continental shelf were performed during the Fall (25 October to 23 November 1980) and Spring (22 April to 5 May 1981) Cruises. Data and samples were collected using a variety of methods. Analysis of these data revealed several distinct, often intergradational, bottom types. These bottom types and some aspects of their interrelated benthic communities are discussed in this section.

7.2 Materials and Methods

As shown in Figure 7-1, 30 stations were sampled during both the Fall and Spring Cruises. The stations were designated as either soft bottom or live bottom stations as described in Section 5.0. The types of data collected at each station were dependent upon the station type. General shipboard collection methods are also described in Section 5.0. The data/sample sets at soft bottom stations consisted of television videotapes, still camera photographs, and samples of surficial sediment collected by subsampling a box core. The box core was subsampled with a 7.5-cm diameter stainless steel core tube that was inserted to a depth of 5 cm into the sediment of each box core sample (five box cores per station). Samples were stored in plastic jars and frozen for later analysis in the laboratory. The surficial sediment samples were analyzed for grain size and percent carbonate. Data sets at live bottom stations consisted of television videotapes and still camera photographs.

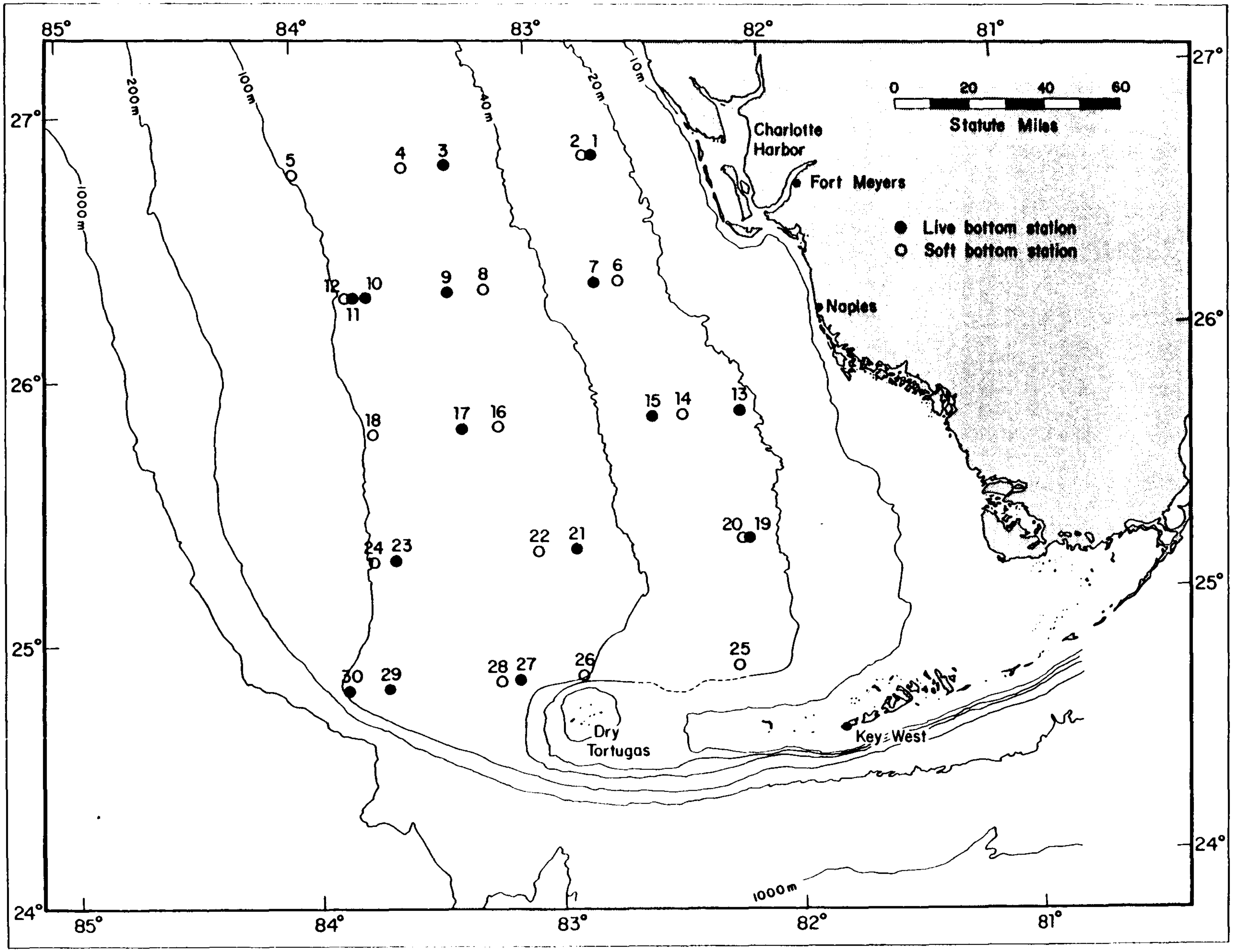

Figure 7-1. Geographic locations of live and soft bottom stations.

7.2.1 Laboratory Analyses of Data and Samples from Soft Bottom Stations

Sediment analysis methodology is outlined in the flow diagram presented in Figure 7-2. For the samples collected during the Fall Cruise, the sand fraction was sieved through a nest of 1-phi (Φ) size intervals; a nest of 0.5-phi intervals was used to sieve the samples collected on the Spring Cruise. The silt-clay fraction was analyzed using pipette methods similar to those described by Rittenhouse (1933). Statistical measures of grain size used in the data analyses are presented in Appendix A-2.

Subsamples (1 to 3 g) of the sediment samples were analyzed for percent carbonate. Differences in weights before and after acidification were used to determine the percentage of carbonate.

Videotapes recorded at the soft bottom stations were analyzed to obtain detailed descriptions of sediment bedforms, such as sand waves when present. Still photographs were used to make more exact estimates of sand wave characteristics and other features such as bioturbation.

7.2.2 Laboratory Analyses of Data from Live Bottom Stations

All videotapes were analyzed to describe substrate types at each station; substrate types were classified according to a bottom type characterization scheme. These analyses were performed using the television/still camera sled tow track navigational maps for each station that were described in Section 5.0. Each of the 60-second intervals was divided into four 15-second intervals. The bottom type for each of these intervals was recorded on track maps while the videotape of the television tow was reviewed. Where present, sand waves, their estimated size and direction, and a brief description of trough accumulations were recorded. Areas of bioturbation were also noted.

After analysis, the time intervals were converted to distances. The approximate percentage of each observed bottom type was calculated for each live bottom station.

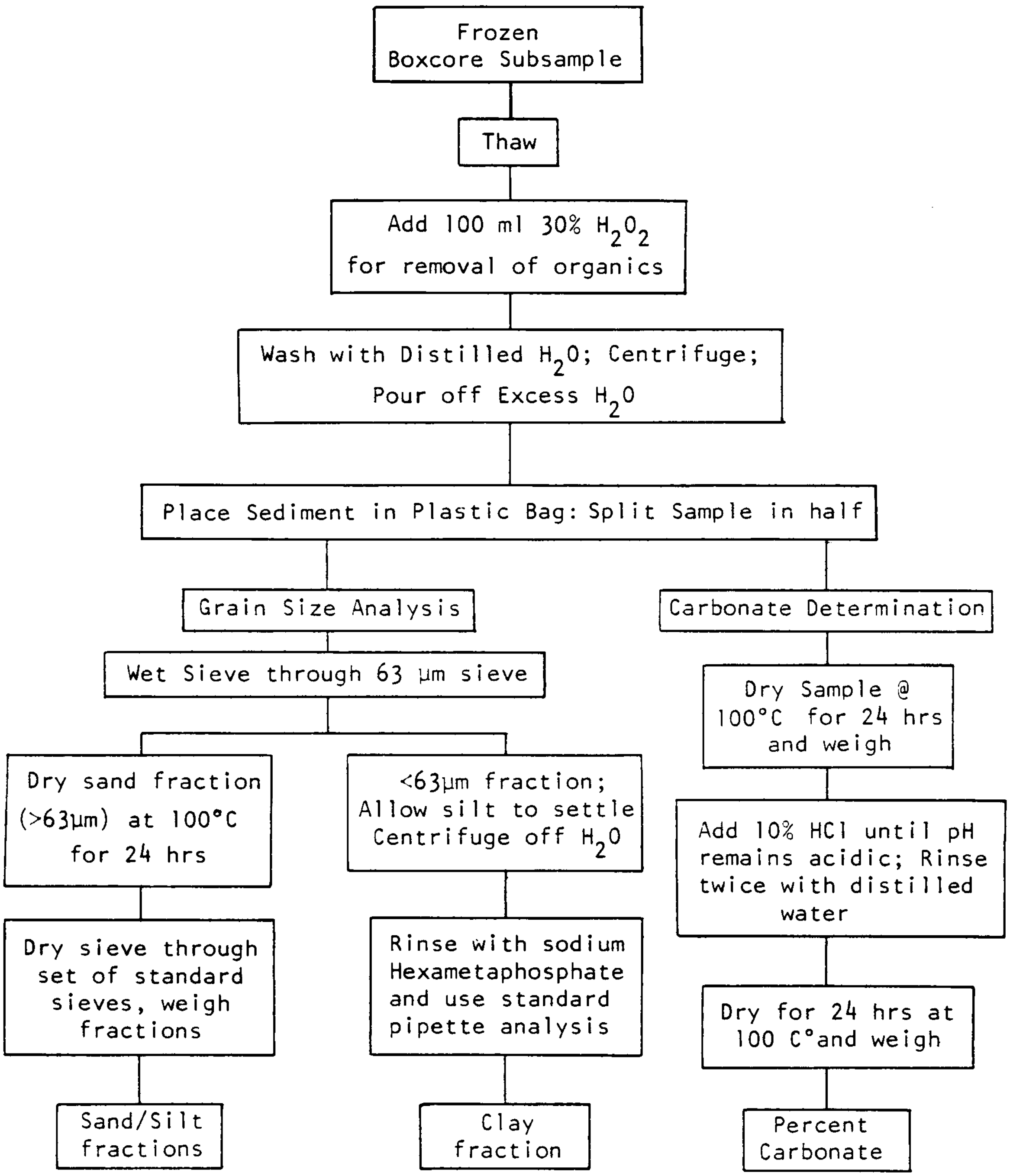

Figure 7-2. Sediment analysis methodology.

Still camera photographs were viewed in conjunction with the videotapes to further document bottom characteristics. The detailed methodology for the quantitative viewing of the photographs is presented in Section 5.0.

7.3 Results

Substrate data from the television videotapes and still camera photographs from the 30 stations conformed to the previously described (Section 3.0) bottom type classification. Five main bottom types were observed; these were rock outcrops/hard bottom, thin sand over hard substrate (suspected hard bottom), sand bottom/soft bottom areas composed of varying mixtures of quartz and carbonate sands, soft bottom areas overlain by a veneer of coralline algal nodules, and soft bottom areas overlain with an algal nodule pavement with *Agaricia* accumulations. A schematic of this classification scheme has previously been presented as Figure 3-3.

Television Videotapes

Station tract plots showing habitat types and associated biological data recorded from the television videotapes and still camera photographs taken during the Fall and Spring Cruises are presented in Appendix B-3. Substrate types associated with soft bottom stations were not mapped. Substrate types recorded from the television videotapes as percent coverage at each station are listed in Tables 7-1 and 7-2 for the Fall and Spring Cruises, respectively. Considering that the television observes only about 0.4% of the total area (one million square metres) that comprises each station, there is generally good agreement between observations during both cruises.

Quantitative Slide Analysis

Tables 7-3 and 7-4 list the average percent coverage of substrate components derived from quantitative slide analysis of the Fall and Spring Cruise data, respectively. As explained in Section 5.0, still camera photographs were only analyzed from live bottom areas. These areas correspond to Rock Outcrops/Hard Bottom, Thin Sand over Hard Substrate, Coralline Algal Nodule Layer over Sand, and Algal Nodule Pavement with *Agaricia* Accumulations bottom types.

Table 7-1. Substrate types observed on videotape at live bottom sample stations during the Fall Cruise (values represent percent of the total station transect).

Stations	Transect	Rock Outcrops/ Hard Bottom	Thin Sand over Hard Substrate	Sand Bottom/ Soft Bottom	Coralline Algal Nodule Layer over Sand	Algal Nodule Pavement with *Agaricia* Accumulations
1	A	0.0	27.2	72.8	0.0	0.0
3	A	0.0	19.8	80.2	0.0	0.0
7	B	0.0	10.2	89.8	0.0	0.0
9	B	0.0	45.3	54.7	0.0	0.0
10	B	0.0	0.0	49.3	50.7	0.0
11	B	0.8	0.0	57.1	42.1	0.0
13	C	0.0	42.0	58.0	0.0	0.0
15	C	3.3	47.5	49.2	0.0	0.0
17	C	0.0	20.6	79.4	0.0	0.0
19	D	0.0	34.0	66.0	0.0	0.0
21	D	0.0	71.4	28.6	0.0	0.0
23	D	0.0	0.0	0.0	100.0	0.0
27	E	0.0	14.2	85.8	0.0	0.0
29	E	0.0	0.0	0.0	0.0	100.0
30	E	0.0	0.0	0.0	0.0	100.0

Table 7-2. Substrate types observed on videotape at live bottom sample stations during the Spring Cruise (values represent percent of total station transect).

Stations	Transect	Rock Outcrops/ Hard Bottom	Thin Sand over Hard Substrate	Sand Bottom/ Soft Bottom	Coralline Algal Nodule Layer over Sand	Algal Nodule Pavement with *Agaricia* Accumulations
1	A	0.7	77.5	21.8	0.0	0.0
3	A	0.0	16.5	83.5	0.0	0.0
7	B	0.0	33.4	66.6	0.0	0.0
9	B	0.0	76.6	23.4	0.0	0.0
10	B	3.2	0.0	41.4	55.4	0.0
11	B	0.3	0.0	19.6	80.1	0.0
13	C	0.0	46.8	53.2	0.0	0.0
15	C	0.0	50.0	50.0	0.0	0.0
17	C	0.0	28.0	72.0	0.0	0.0
19	D	0.0	35.7	64.3	0.0	0.0
21	D	0.0	81.5	13.5	0.0	0.0
23	D	0.0	0.0	3.8	96.2	0.0
27	E	0.0	13.6	86.4	0.0	0.0
29	E	0.0	0.0	0.0	0.0	100.0
30	E	0.0	0.0	0.0	0.0	100.0

Table 7-3. Average percent of the bottom covered by exposed substrates at live bottom stations as determined from Fall Cruise quantitative slide analyses.[a]

		Substrate Composition			
Station	Transect	Rock Outcrops	Sand	Rock, Shell, and Dead Algal Rubble	Algal Nodule Pavement with *Agaricia* Accumulations
1	A	0.0	68.0	16.5	0.0
3	A	0.1	86.1	6.3	0.0
7	B	7.5	58.8	18.8	0.0
9	B	0.0	23.3	60.4	0.0
10	B	4.6	16.1	68.0	0.0
11	B	2.8	33.7	22.3	0.0
13	C	1.8	70.8	8.7	0.0
15	C	1.9	65.4	13.6	0.0
17	C	0.0	79.8	4.1	0.0
19	D	0.0	74.8	5.8	0.0
21	D	0.0	77.0	5.1	0.0
23	D	0.0	17.0	48.3	0.0
27	E	0.0	90.5	2.0	0.0
29	E	0.0	0.0	0.2	35.3
30	E	0.0	10.2	0.0	42.0

[a] Remaining coverage at each station was epibiota.

Table 7-4. Average percent of the bottom covered by exposed substrates at live bottom stations as determined from Spring Cruise quantitative slide analyses.[a]

		Substrate Composition			
Station	Transect	Rock Outcrops	Sand	Rock, Shell, and Dead Algal Rubble	Algal Nodule Pavement with *Agaricia* Accumulations
1	A	0.0	72.7	7.3	0.0
3	A	0.0	66.6	16.8	0.0
7	B	1.3	70.8	12.3	0.0
9	B	0.0	66.8	18.6	0.0
10	B	1.8	45.9	30.1	0.0
11	B	0.5	45.7	46.7	0.0
13	C	0.0	73.9	4.1	0.0
15	C	0.0	67.6	12.6	0.0
17	C	0.0	82.0	9.5	0.0
19	D	0.0	82.8	3.5	0.0
21	D	0.0	74.7	5.4	0.0
23	D	0.0	26.1	36.8	0.0
27	E	0.0	77.8	10.7	0.0
29	E	0.0	0.7	0.0	19.7
30	E	0.0	11.7	0.0	37.9

[a] Remaining coverage at each station was epibiota.

The following paragraphs summarize some of the principal distributional characteristics of the sea floor bottom types observed.

7.3.1 Rock Outcrops/Hard Bottom

The hard bottom areas that occurred at Stations 1, 10, 11, and 15 were rock outcrops of underlying geological formations. Rock outcrops were observed during both the Fall and Spring Cruises at Station 11 only (0.8 and 0.3% coverage, respectively) and in very low percentages at Stations 1 (0.7%, Spring Cruise), 10 (3.2%, Spring Cruise), and 15 (3.3%, Fall Cruise). These rock outcrops generally took the form of ledges or exposed, low-relief rock areas.

The rock outcrop areas that were observed at Stations 10 and 11, at a depth of approximately 70 m, are associated with the innermost edge of the outer shelf. These areas, as noted by Holmes (1981), may represent remnants of a buried Miocene (?) karst topography which was eroded during the Pleistocene into a series of wave-cut terraces. The areas exposed at Stations 1 and 15 may represent a continuation of a Miocene formation (Tamiami formation?) which outcrops along the southwest Florida coast from Tampa to Port Charlotte.

Quantitative slide analysis identified barren rock (no epibiota) at six stations (3, 7, 10, 11, 13, and 15) during the Fall Cruise and at three stations (7, 10, and 11) during the Spring Cruise. Stations 7 (7.5%), 10 (4.6%), and 11 (2.8%) had the highest percent of barren rock coverage during the Fall Cruise; Stations 10 (1.8%) and 7 (1.3%) had the highest percents during the Spring Cruise. Those stations that had rock outcrops identified from the videotapes were also observed to have bare rock present in the slide analysis (one exception was Station 1 which only had 0.7% coverage of rock outcrops). Differences in percentage of rock outcrops between the videotapes and slide analysis are not unexpected because of the greater areal coverage but lower resolution of the television and better resolution but lesser coverage of the photographs.

7.3.2 Thin Sand over Hard Substrate

This complex bottom type was visually identifiable as a Sand Bottom/Soft Bottom. The subbottom profile records from the Geophysics Cruise showed that the sand layer was relatively thin (<1 m), however, and covered a hard substrate. In addition, this bottom type was characterized by large attached epibiota (sponges, sea whips, etc.) which appeared to be living in a Sand Bottom/Soft Bottom substrate, but in fact must have been attached to an underlying hard substrate.

This bottom type was observed on the videotapes at all live bottom stations except those deeper than 63 m (i.e., Stations 10, 11, 23, 29, and 30). Additionally, this bottom type covered an average of 33.2% (Fall Cruise) and 46.0% (Spring Cruise) of the sea floor at the stations shallower than 63 m (Tables 7-1 and 7-2). The highest average coverage of this bottom type for both cruises occurred at Stations 21 (76.5%), 9 (61.0%), and 1 (52.3%).

Quantitative slide analysis showed that sand was a distinguishable substrate component within live bottom patches at all live bottom stations. The mean percent coverage of sand within the live bottom areas was 51.4% for the Fall Cruise and 57.7% for the Spring Cruise. During the Fall Cruise, Stations 27 (90.5%), 3 (86.1%), and 17 (79.8%) had the highest percent of sand coverage within the live bottom patches. Stations 19 (82.8%), 17 (82.0%), and 27 (77.8%) had the highest percent coverage during the Spring Cruise. Stations 27 (84.2%), 17 (80.9%), and 19 (78.8%) had the highest average percent coverage of sand for the combined cruises. Since photographs were only taken in live bottom areas, this sand probably represented a sand veneer rather than a Sand Bottom/Soft Bottom *per se*.

7.3.3 Sand Bottom/Soft Bottom

Sand Bottom/Soft Bottom areas were encountered not only at the areas that encompassed soft bottom stations, but also at 13 of the 15 live bottom stations. Tables 7-1 and 7-2 show that Sand Bottom/Soft Bottom was observed on the videotapes at all but three of the live bottom stations (23, 29, and 30) during the Fall Cruise and two stations (29 and 30) during the Spring Cruise.

Sand Bottom/Soft Bottom areas covered an average of 64.2% (Fall Cruise) and 46.1% (Spring Cruise) of the sea floor at the stations where they were present. Live bottom Stations 27 (86.1%), 3 (81.9%), 7 (78.2%), and 17 (75.7%) had the highest mean percentages of Sand Bottom/Soft Bottom coverage.

Significant visual changes in sediment characteristics were apparent at most soft bottom stations. Figure 7-3 summarizes the variation of sediment types at each soft bottom station as recorded by the still photographs. Sand, shell, and rubble substrates are recorded.

7.3.3.1 Sand Ripples

Sand ripples were observed during the Spring Cruise but none were seen on the Fall Cruise. Eleven (five live bottom and six soft bottom) of the 30 stations observed during the Spring Cruise had sand ripples present. Table 7-5 lists the stations, directions, estimated heights, and estimated wavelengths of the sand ripples. Nine of the stations were in water depths of less than 32 m, while Station 8 was in 48 m and Station 22 was in 52 m. The directions of the ripple axes were north-south, with the estimated heights ranging from 5-10 to 15-20 cm. The estimated ripple wavelengths ranged from 20 to 64 cm. Rubble was seen in the troughs of all of the ripples observed, with the exception of Stations 1, 7, and 13, where rubble occurred in 23, 51, and 56% of the sand ripple areas.

Sand ripples were observed principally at the shallower water depth stations with some occurrence at mid-depth stations. Since the sand ripples appear to be present in the winter but absent in the summer, their cause is probably closely related to regional storms.

7.3.3.2 Bioturbation

Evidence of bioturbation was prevalent throughout the study area, most commonly as mounds, burrows, and tracks. The percent of bioturbated Sand Bottom/Soft Bottom substrate at live bottom stations was recorded during both the Fall and Spring Cruises. Fall Cruise observations indicated that 8 of the 12 stations which recorded Sand Bottom/Soft Bottom also showed bioturbation between every

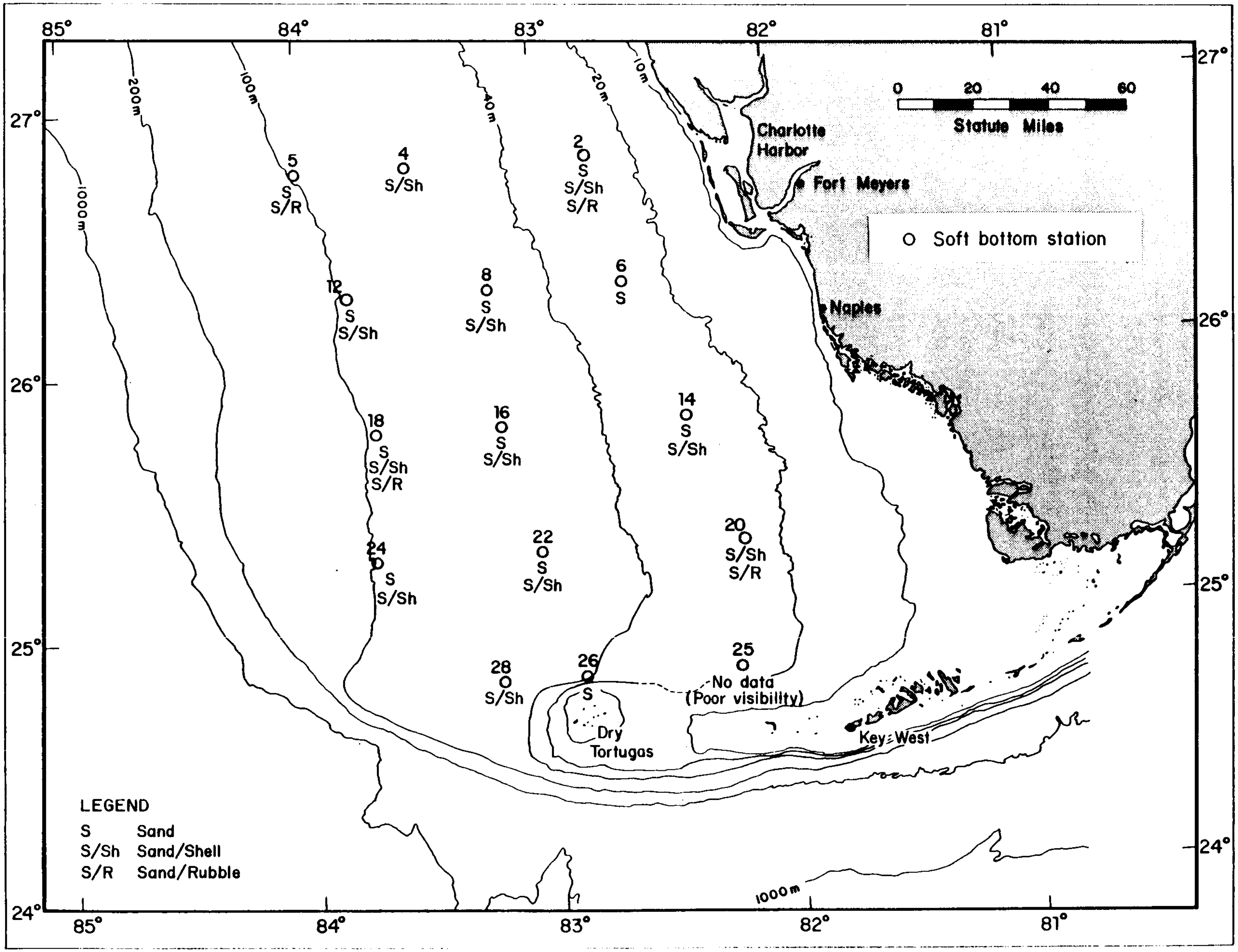

Figure 7-3. Sediment types recorded from still photographs during the Fall Cruise.

Table 7-5. Sand ripple characteristics.

Station	Station Type	Direction of Sand Ripple Axes[a]	Estimated Range of Sand Ripple Heights (cm)	Estimated Wavelength of Sand Ripples (cm)
1	Hard	North-South	5-10	20-36
2	Soft	North-South	8-18	15-46
6	Soft	North-South	10-15	25-36
7	Hard	North-South	5-10	15-46
8	Soft	North-South	10-18	25-36
13	Hard	North-South	8-10	30-46
14	Soft	North-South	15-20	38-46
15	Hard	North-South	10-15	30-61
19	Hard	North-South	5-15	30-64
20	Soft	North-South	8-15	30-61
22	Soft	North-South	8-12	51-61

[a] Ripple axes are parallel to crests and troughs.

set of fix marks. Stations 19 (90%), 15 (80%), 21 (20%), and 11 (4%) had lower percentages (corresponding to fewer fix mark areas) of recorded bioturbation. Bioturbation was recorded in 95 to 100% of all sand areas at 11 of the 13 Spring Cruise live bottom stations associated with recorded sand areas. The remaining two stations, 1 and 9, each had observed bioturbation between at least 50% of the fix marks.

The distribution and relative abundance of bioturbation forms observed at the soft bottom stations during the Fall Cruise are shown in Figure 7-4.

7.3.3.3 Sediment Grain Size Analysis

The results of the grain size analysis are presented in Appendix B-4. A 1.0-phi interval was used for the Fall Cruise samples; a 0.5-phi interval was used for the Spring Cruise samples. The mean, standard deviation, and coefficient of variation are provided for each phi interval for the five samples analyzed for each station. Statistical measures of median, mean, inclusive graphic standard deviation (sorting coefficient), inclusive graphic skewness, and graphic kurtosis are also presented in Appendix B-4. In addition, the mean, standard deviation, and coefficient of variation were calculated for the above tabular statistics for the five replicates at each station.

7.3.3.3.1 Mean Grain Size

For the Fall Cruise mean grain size ranged from -0.17 ϕ (very coarse sand) at Station 2 (Box Core D) to 4.44 ϕ (coarse silt) at Station 26 (Box Core B). The Spring Cruise data showed a range from 0.65 ϕ (coarse sand) at Station 4 (Box Core A) to 4.14 ϕ (coarse silt) at Stations 25 (Box Core C) and 26 (Box Core B). Little variation in mean grain size between box cores (mean coefficient of variation = 9.9) was recorded at most stations. Stations 2 (C.V. = 100.4), 16 (C.V. = 40.5), and 22 (C.V. = 34.2) from the Fall Cruise and Stations 4 (C.V. = 53.7), 22 (C.V. = 33.3), and 24 (C.V. = 36.0) from the Spring Cruise were exceptions.

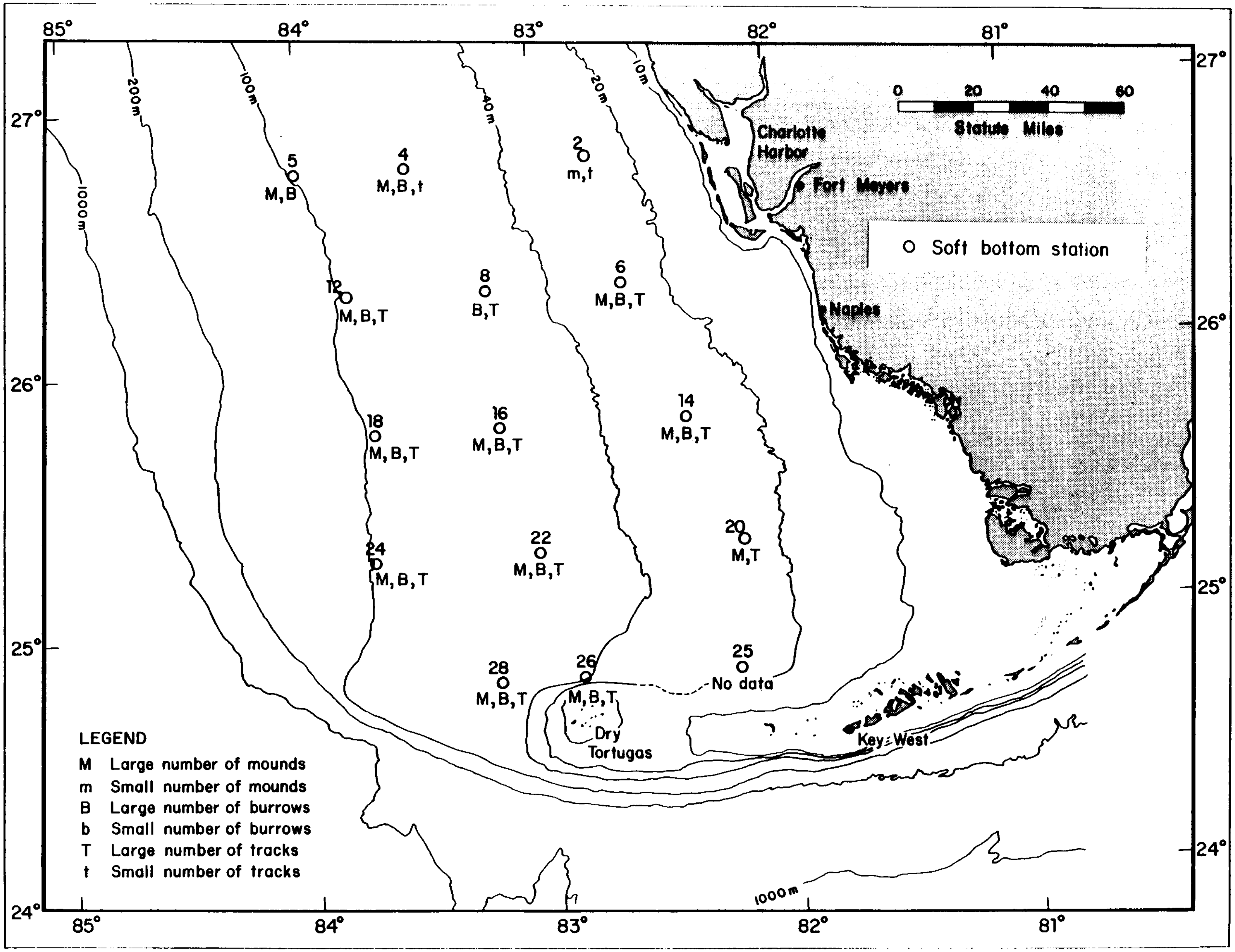

Figure 7-4. Distribution and relative abundance of bioturbation observed during the Fall Cruise.

The nearshore stations of the northern transects (A, B, and C) showed a general pattern of having fine to very fine sand (mean grain size) while the offshore stations were more variable. Stations 4 and 5 (Transect A) were found to have coarse to medium size sands. Stations 8 and 12 (Transect B) had fine sand. The offshore stations of transects (C, D, and E) showed a trend for having medium to fine sands. Stations 25 and 26 (Transect E) exhibited a very fine sand to a silt/clay sediment type.

7.3.3.3.2 Sorting, Skewness, and Kurtosis

In general, the grain size analysis for the nearshore stations of Transects A, B, and C (Stations 2, 6, and 14) and all of the stations deeper than 40 m showed a poor sorting of sediments. Nearshore Stations 20 and 25 (Transects D and E) showed a moderate degree of sorting. This was in marked contrast to the apparently well sorted sediments that were observed as sand waves during the Spring Cruise at Stations 2, 6, 8, 14, 20, and 22.

In terms of skewness (a measure of asymmetry within a sediment size-frequency distribution), Stations 2, 6, 14, 20, and 28 showed an almost symmetrical curve while stations deeper than 40 m on Transects A to D showed a near-symmetrical to a fine-skewed curve. Stations 25 and 26 (on Transect E) which had silt/clay mean grain sizes showed a strongly coarse-skewed curve.

Graphic kurtosis (a measure of the peakedness within a sediment size-frequency distribution) reflected less obvious trends than other statistics. Stations 2 and 4 (Transect A), 14 and 16 (Transect C), 24 (Transect D), and 28 (Transect E) exhibited a leptokurtic ratio (distinctly peaked; i.e., well sorted). Stations 25 and 26 (Transect E) showed a very leptokurtic ratio. The remaining stations exhibited a mesokurtic ratio (i.e., normal frequency distribution, neither peaked nor flat).

7.3.3.4 Sediment Textural Classifications

7.3.3.4.1 Ternary Diagram

The percentages of sand, silt, and clay were plotted on a triangle diagram (Shepard, 1954). Figures 7-5 and 7-6 present the plots for the Fall and Spring Cruises, respectively. All but two stations from both cruises had grain sizes that were classified as sand. Exceptions occurred at Stations 25 and 26; where grain sizes were classified as sandy-silts.

7.3.3.4.2 Percentage of Silt/Clay Fraction

The distribution of the silt/clay fraction (<63 μm) is shown in Figure 7-7. The data suggest a buildup (17-24%) of silt/clay in the center of the study area and a major accumulation (70-79%) of fine-grained sediments at Stations 25 and 26.

7.3.3.4.3 Principal Component Analysis

A principal component analysis was performed on the grain size data including the percent of total values for each phi size and the statistical measures developed for the Fall and Spring Cruises. The first three principal components explained 87% of the variance in the Fall Cruise data. As shown in Figure 7-8, three groups of stations were present in these data . Stations 25 and 26 were distinctly different from the other stations. This difference was related to the predominance of the silt-clay fraction. The second group of stations consisted of two nearshore stations on Transects B and C (Stations 6 and 14) and a mid-shelf station on Transect B (Station 8). This group of stations tended to have predominantly very fine to fine sands. The third group of stations was comprised of the offshore middle shelf stations on all transects (Stations 5, 12, 18, 24, and 28), the inshore middle shelf stations on Transects A, C, and D (Stations 4, 16, and 22, respectively) and the nearshore stations on Transects A and D (Stations 2 and 20, respectively). This group was dominated by larger grain sizes.

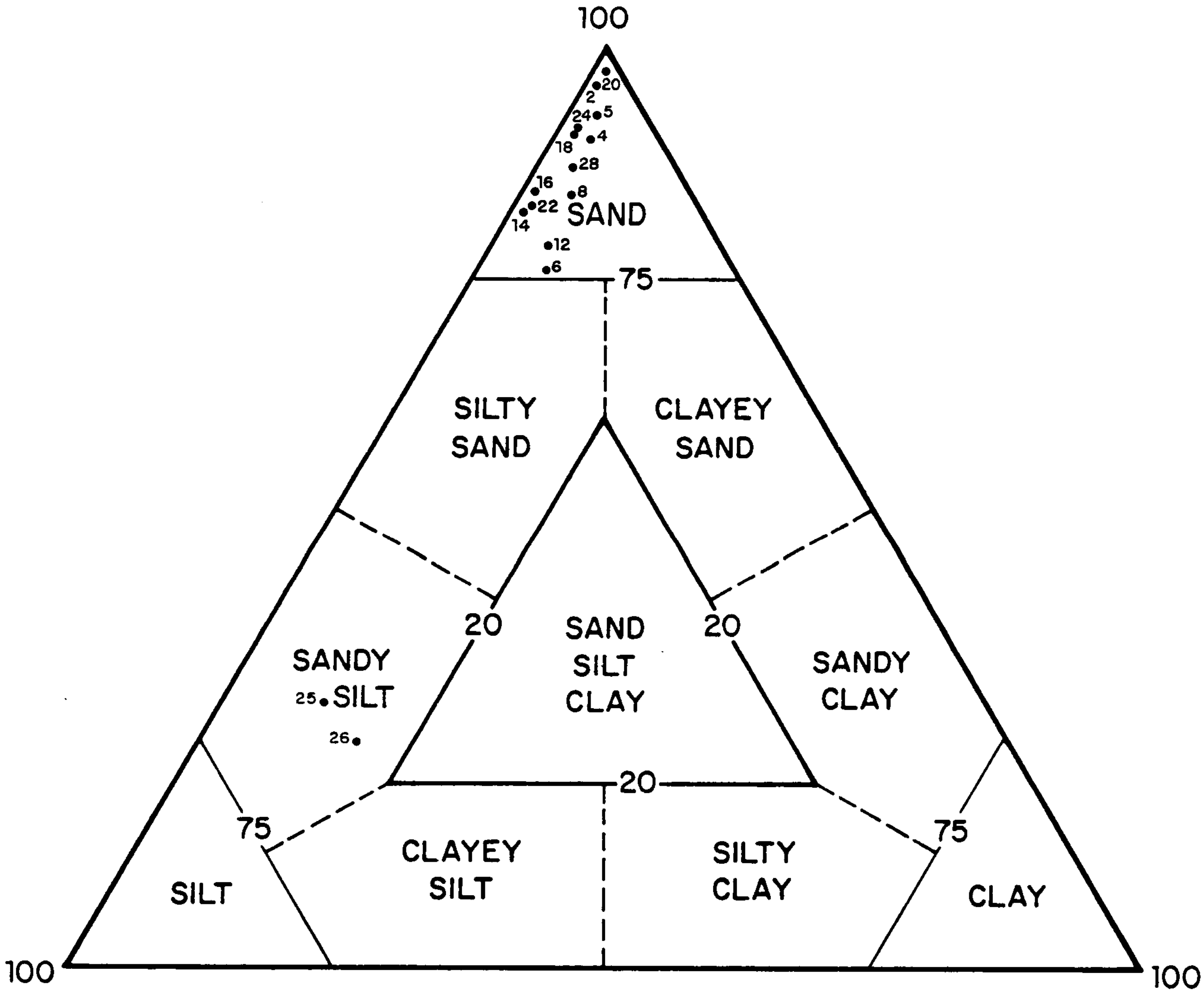

Figure 7-5. Textural triangle diagram for Fall Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpendicular distances from the respective apexes. Small numbers represent sampling stations.

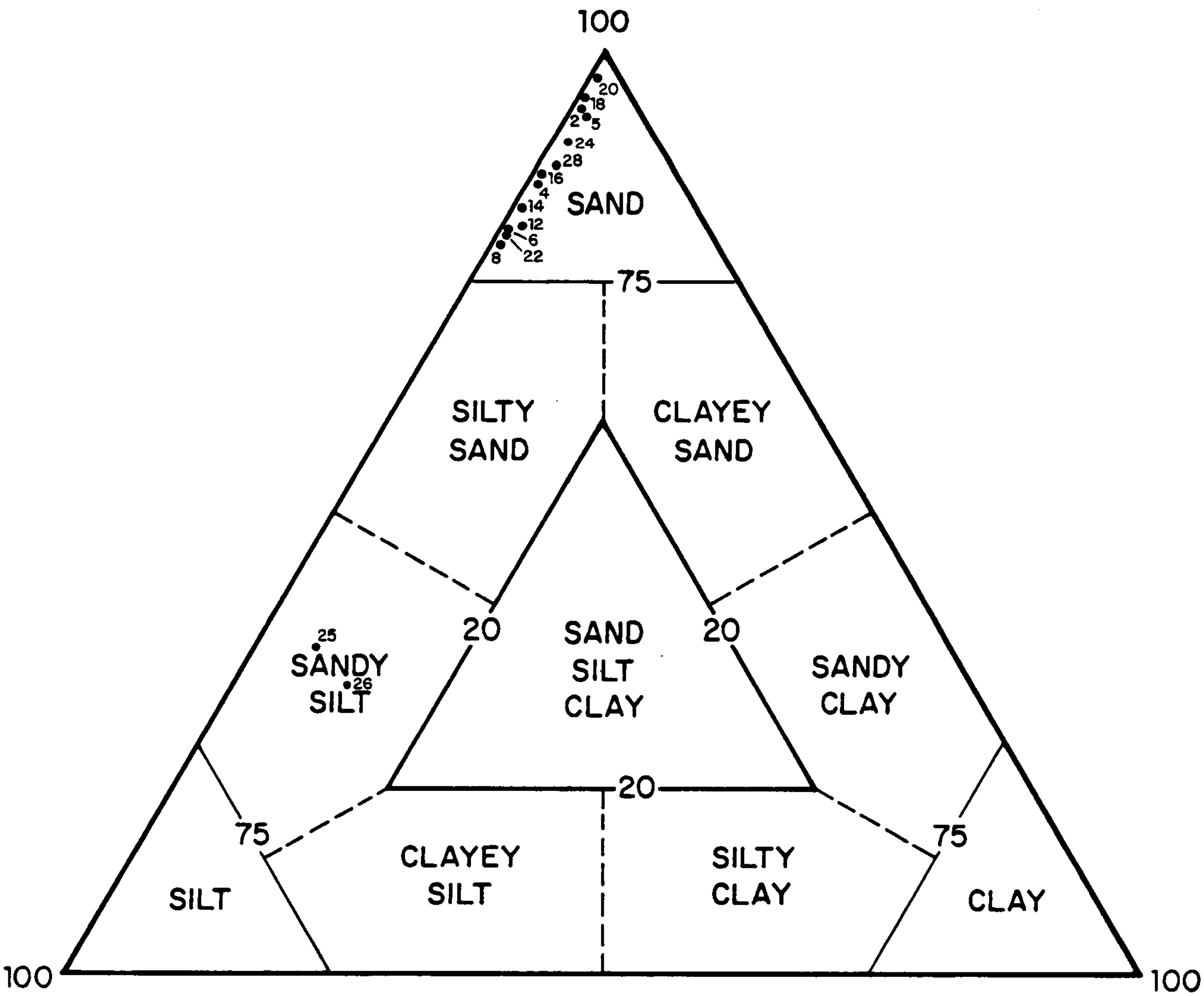

Figure 7-6. Textural triangle diagram for Spring Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpendicular distances from the respective apexes. Small numbers represent sampling stations.

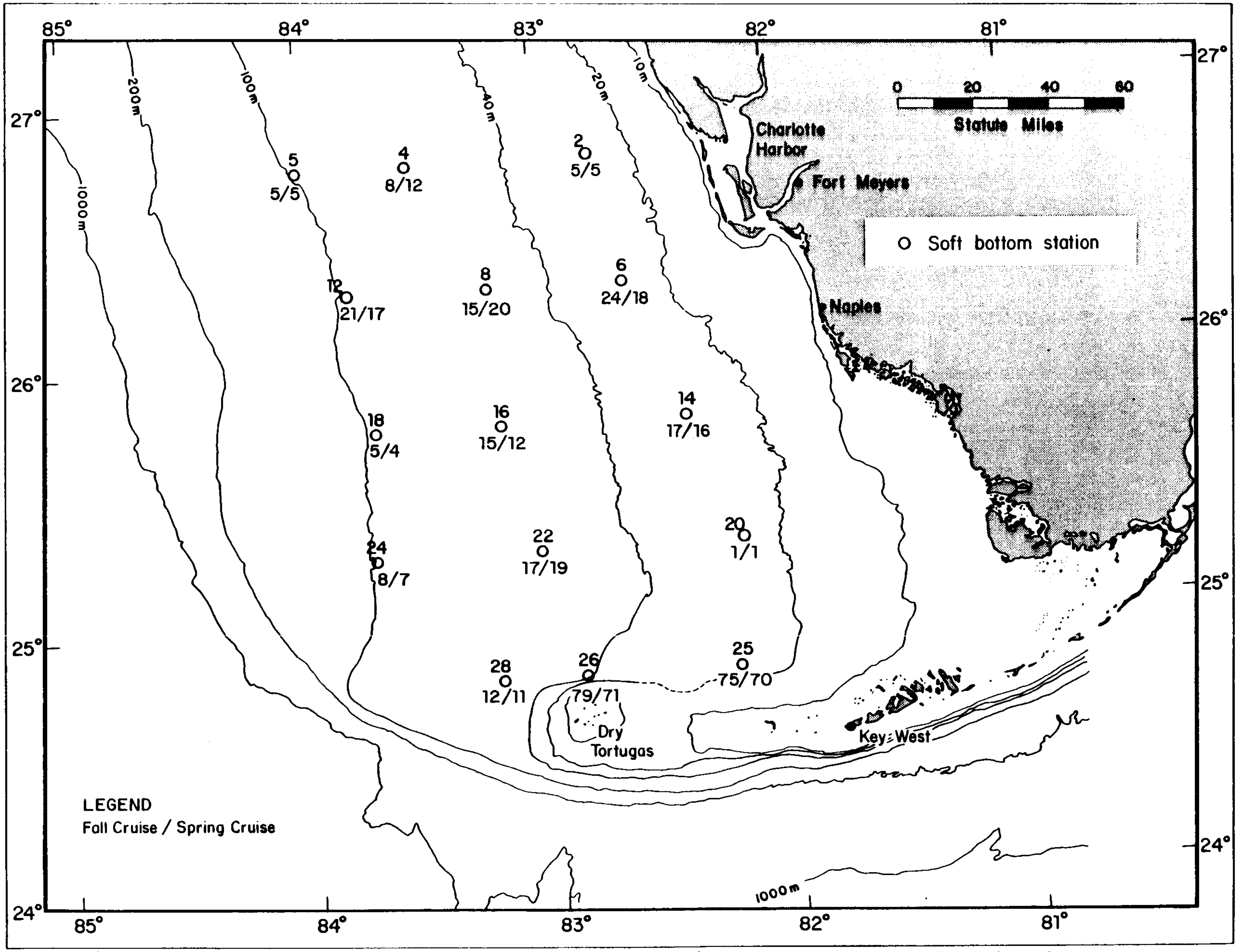

Figure 7-7. Mean percentage of silt/clay (<63μm) in soft bottom surficial sediments.

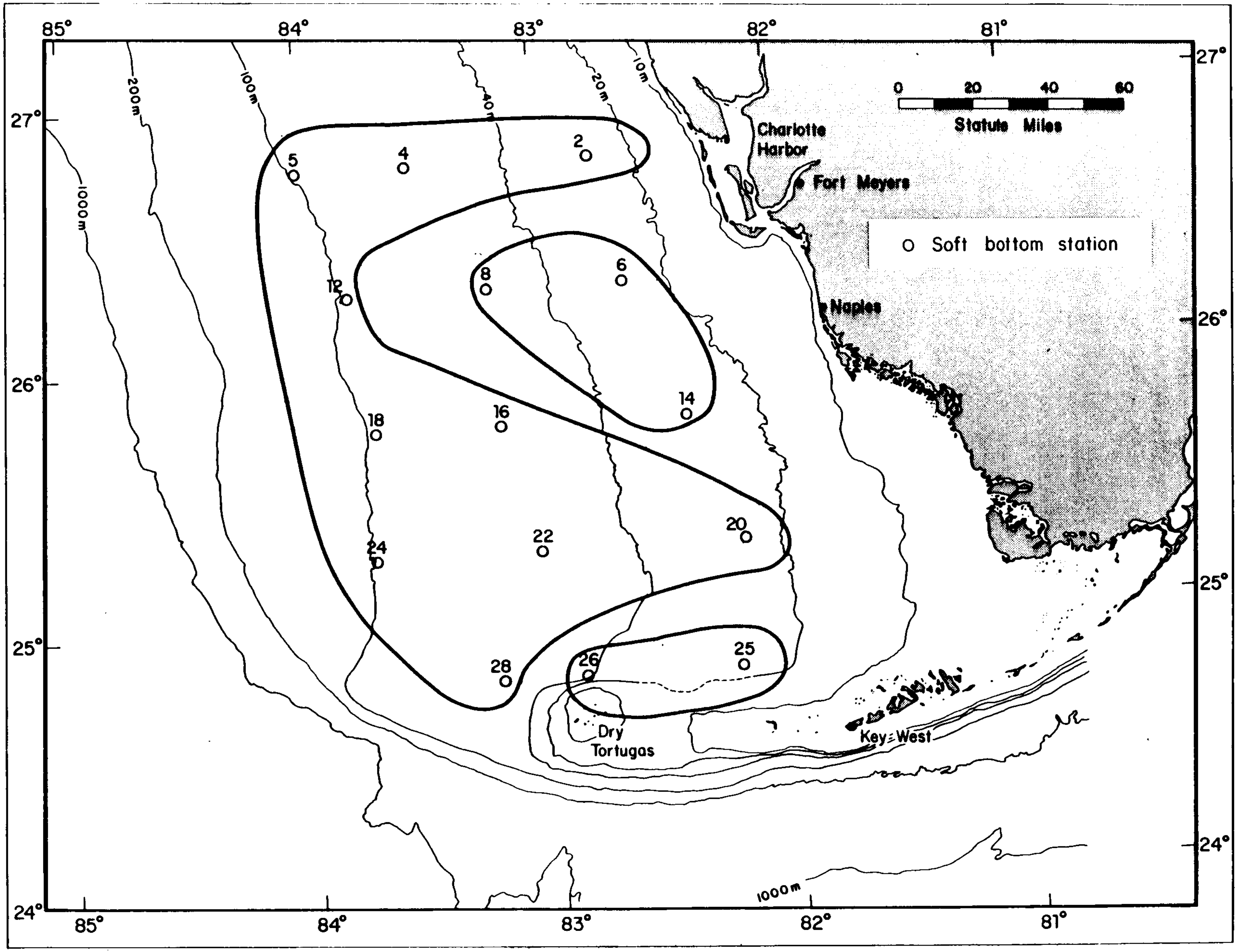

Figure 7-8. Station groups defined by principal component analysis of Fall Cruise grain size data.

The results of principal component analysis for the Spring Cruise grain size data (see Figure 7-9) were similar to those for the Fall Cruise. The first three principal components explained 85% of the variance in the Spring Cruise data. Again, three principal components were evident in the data. The first group of stations was comprised of Stations 25 and 26, those with larger silt-clay fractions. The second group of stations was comprised of the nearshore stations on Transects A, B, and C (Stations 2, 6, and 14) and the mid-shelf station on Transect B (Station 8). This group of stations yielded predominantly very fine to fine sands. The remainder were dominated by larger grain sizes and comprised the third group of stations.

Clearly, the results of the two principal component analyses were very similar. The only station to group differently between the two cruises was Station 2, the nearshore station on Transect A. At this time, it is not known whether this difference is due to real, temporal variations, redeposition after a storm event, or is merely a sampling artifact.

7.3.3.5 Carbonate Content

The distribution of percent calcium carbonate in the sediments at each soft bottom station is shown in Figure 7-10. These data were plotted using the averages of the mean values from both cruises. Basically, they show a facies change from the insoluble (quartz clastics) sediments of Station 2 (and to some extent Station 6) to the predominant carbonate facies to the southwest. This increase in abundance of quartz clastics at Stations 2 and 6 may reflect their proximity to the coast and/or sediment transport from the Caloosahatchee River (that drains Lake Okeechobee) and Charlotte Harbor.

7.3.4 Coralline Algal Nodule Layer over Sand

This bottom type is composed of patches of coralline algal rubble and nodules covering sand areas; it was identified on the videotapes from three stations. As shown in Tables 7-1 and 7-2, solid layers of algal nodules were observed at Stations 10, 11, and 23. Subbottom profile records from the Geophysics Cruise indicated that the nodules had formed overlying an unconsolidated sediment bottom. The algal nodules varied in size from two to six centimetres. An

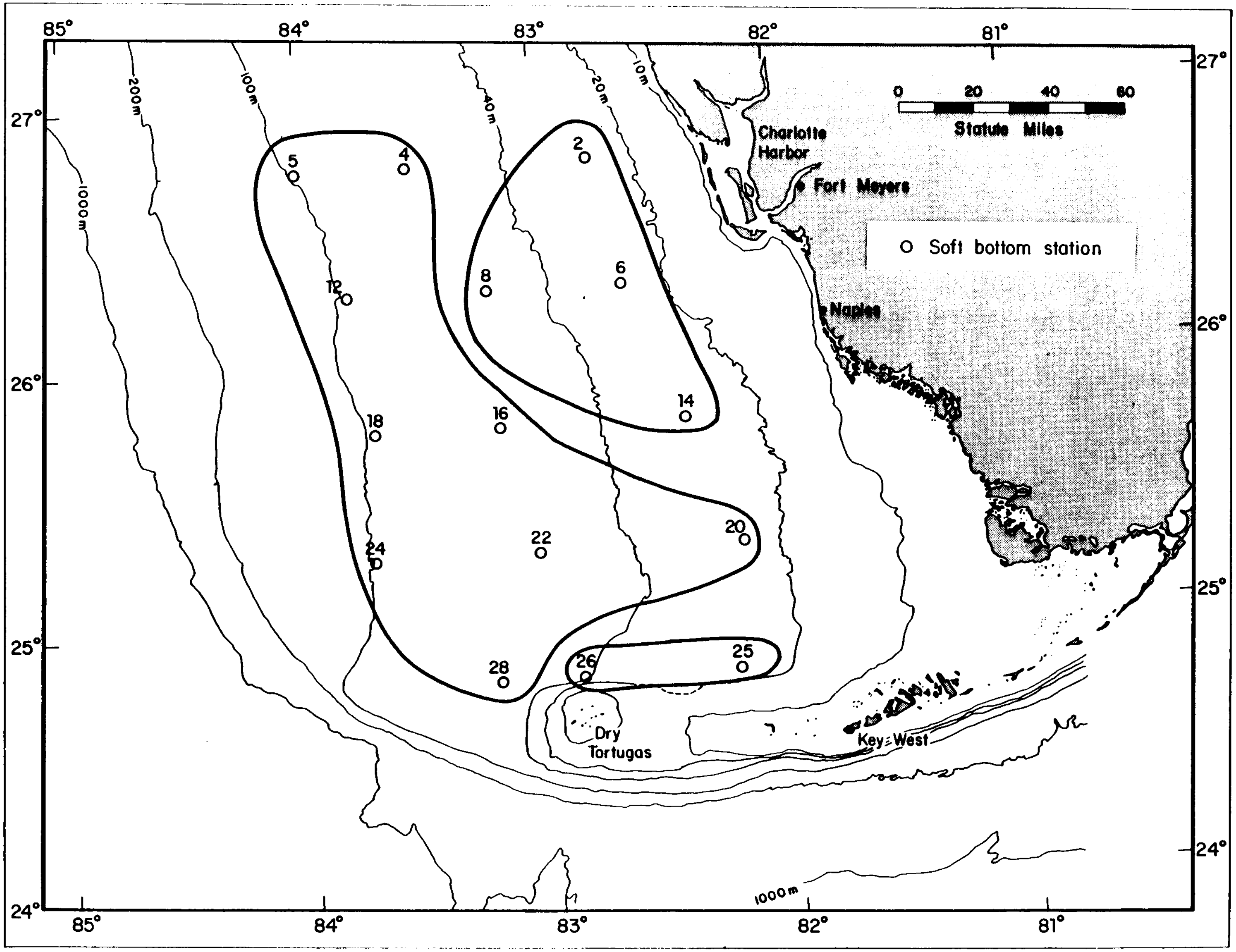

Figure 7-9. Station groups defined by principal component analysis of Spring Cruise grain size data.

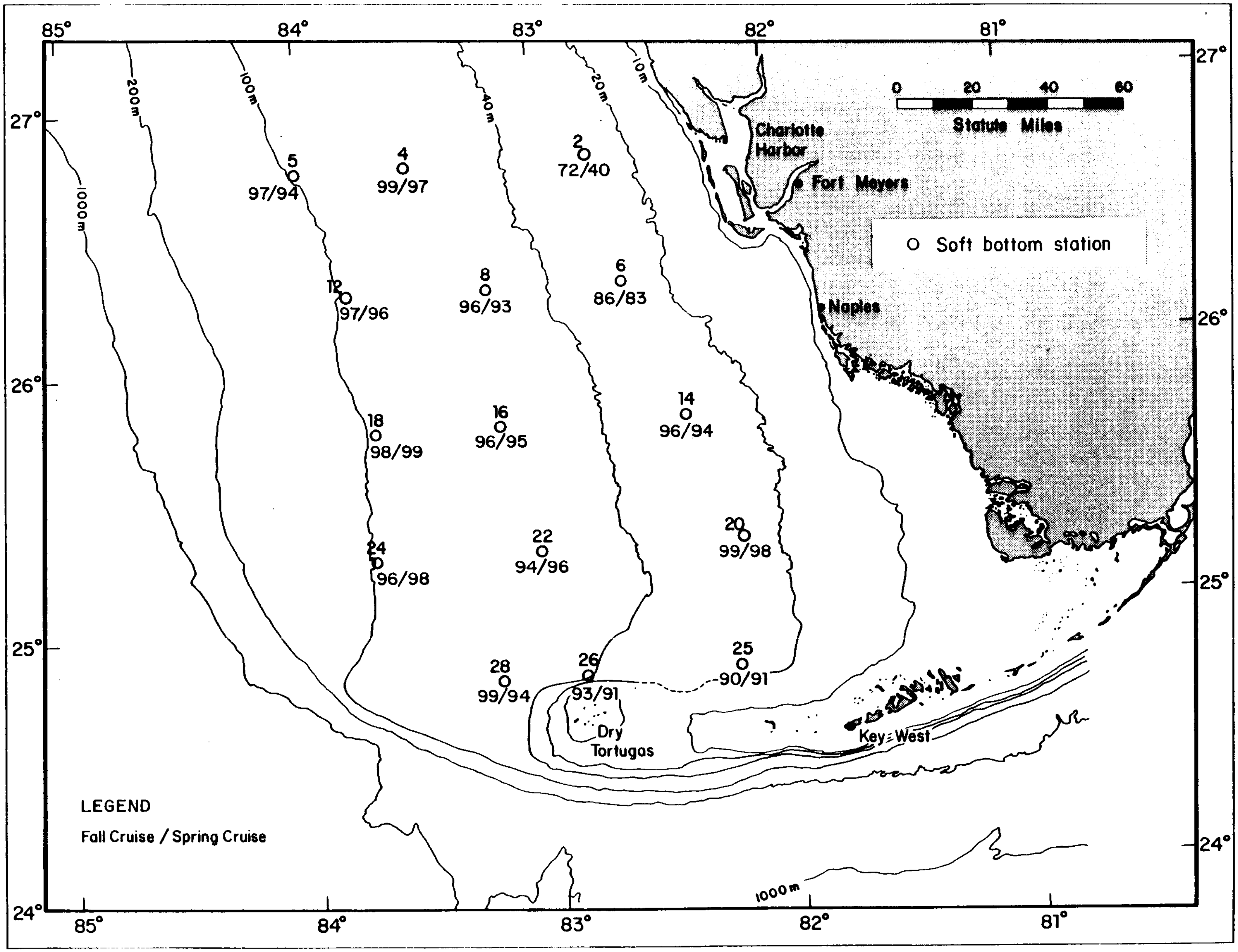

Figure 7-10. Mean percentage of $CaCO_3$ in surficial sediments at soft bottom stations.

analysis of some of the nodules dredged from Station 23 revealed that they were composed of coralline algae, worm tubes, bryozoans, and small solitary corals.

Quantitative analysis of the still photographs (Tables 7-3 and 7-4) showed that barren rubble (rock, shell, or dead algae) was observed at all stations except Station 30, although rubble was recorded at Station 29 only during the Fall Cruise and in a very low percentage (0.2%). The mean percent coverage of bare rubble within the live bottom stations was 14.3% during the Fall Cruise and 18.7% during the Spring Cruise. This relatively high average percent was due, in large part, to the fact that rubble was the predominate substrate category at Stations 9, 10, and 23 during the Fall Cruise and Stations 11 and 23, during the Spring Cruise. This high percentage of rubble appeared to be correlated with the high percentage of algal nodule cover at Stations 10, 11, and 23. Shell rubble was the dominant rubble category at Stations 1, 7, 13, 15, 19, and 27, which were in water depths of less than 32 m, i.e., with the exception of Station 27 (54 m). Rubble was frequently seen in the troughs of sand ripples during the Spring Cruise and was intermixed with the sand substrate during the Fall Cruise when no sand ripples were observed. Apparently sand is present as a thin veneer across the area. Winter storms winnow out the sand and deposit it as shallow sand ripples overlying the coarse shell rubble and algal nodule material.

7.3.5 Algal Nodule Pavement with Agaricia Accumulations

This substrate type was observed on videotapes from Stations 29 and 30 (Transect E). Subbottom profile records from the Geophysics Cruise suggested that this bottom type may actually be a "false" hard bottom since no rock outcrops or near surface rock were observed. These observations, along with dredge samples, indicate that the hard bottom is a pavement of fused dead coralline algae and hard coral (*Agaricia* spp.) that overlies a sand bottom. Quantitative slide analysis yielded average percent cover for this substrate at Stations 29 and 30 (Fall and Spring Cruises combined) of 27.5 and 40.0%, respectively.

7.4 Discussion and Summary

An important refinement introduced by the television and still camera sampling methods discussed above is the further delineation of "hard substrate" areas that are covered by a thin veneer of sand. That is, in Section 3.0, the television tows showed that only four stations had rock outcrops, with an average percent cover of 2.1%. The still photographs showed six stations with rock outcrops, with an average percent cover of 1.9%. Using the methods discussed in Section 7.2 and averaging the "Thin Sand over Hard Substrate" figures in Tables 7-1 and 7-2 (third column), an average percent "hard bottom" coverage of 39.6% is obtained. It is believed that larvae of attached epibiota require a hard substrate, free of shifting sand, for successful settlement and growth. The 39.6% substrate figure noted above suggests that much of this hard substrate is not available for larvae at these stations, because of the thin sand cover. There may be few opportunities for the establishment of new patches of live bottom or the repopulation of existing patches within the boundaries of these stations. The remaining stations, which are all in water depths exceeding 70 m, appear to have adequate hard substrate available for epibiota growth although it is not in the form of rock outcrops. The hard substrates at these deeper water stations are comprised of algal nodules and dead hard coral-coralline algal pavement. These substrates are of low relief and have the potential for burial by sands. The algal nodules may also provide an uncertain hard substrate since the nodules may be moved by bottom currents.

The results of grain size and carbonate analyses of samples collected from the soft bottom stations indicated that there are three distinct sediment types present in the sampled area. They are the insoluble (quartz clastics) facies at Station 2, the fine-grained carbonate mud at Stations 25 and 26, and the carbonate sand covering the remaining portion of the sampled area. This trend, along with the observed variability between replicates, and high carbonate values is similar to that described for the west Florida shelf north of the study area (Doyle and Sparks, 1980). The sediments at Stations 25 and 26 are probably derived from the modern carbonate sediments accumulating in Florida Bay although they appear to be similar to the west Florida lime mud facies that are present on the continental slope (Ludwick, 1964).

There is little relationship between sediment grain size and percent calcium carbonate since the shelf appears to contain both allochthonous (i.e., transported to the site of deposition from elsewhere) and autochthonous (i.e., dominant constituents formed in situ) sediments.

7.5 Literature Cited

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8.0 HYDROCARBON ANALYSIS OF SURFICIAL SEDIMENTS

8.1 Introduction

This portion of the study was undertaken to determine the types and amounts of hydrocarbons present in the surficial sediments of the southwest Florida continental shelf. This was done to provide a hydrocarbon characterization of the area prior to possible oil and gas exploration and development activities. Biogenic hydrocarbons were expected to be present. What needed to be established, however, was whether petroleum hydrocarbons were present, and if so, the type, quantity, and possible sources defined.

Biogenic hydrocarbons originating in the marine environment reflect the hydrocarbon composition of phytoplankton and zooplankton. Some key indicators of marine biogenic hydrocarbons are the isoprenoids, pristane (2, 6, 10, 14-tetramethyl pentadecane), discrete groups of normal alkanes (n-C_{15} and n-C_{17}), and a cycloalkene exhibiting a retention index of 2085 (Boehm and Quinn, 1978; Farrington and Tripp, 1975; Gearing et al., 1976). Hydrocarbons of terrigenous origin are usually representative of those found in vascular plants. Indicators of terrigenous hydrocarbons include a composite of n-alkanes in the n-C_{23} to n-C_{31} region with a preponderance of odd-numbered carbon compounds (Carbon Preference Index, CPI >1). The alkane n-C_{29} often is the most abundant (Boehm, 1978; Ehrhardt and Blumer, 1972; Thompson and Eglinton, 1978).

The presence of olefinic compounds in sediments results from biological input. Since gas chromatography - flame ionization detection (GC-FID) does not distinguish between aromatic and olefinic compounds, this fraction must be subjected to gas chromatographic mass spectrometric analysis (GC-MS) or high pressure liquid chromatography-fluorescence analysis.

Recent petroleum input (petrogenic hydrocarbons) is indicated by a smooth alkane homologous series, with an odd/even carbon ratio (CPI) equal to one (1), overriding an unresolved complex mixture (Farrington, 1980; McAuliffe, 1977; Pierce et al., 1975). In the study area, sources of petroleum could result from discharges from tankers, spills at off-loading facilities along the

Florida west coast, fluvial and aeolian transport, or could be associated with detrital clay transported via the Loop Current from Mississippi River input to the Gulf of Mexico.

Aromatic hydrocarbons are generally indicative of anthropogenic (man-induced) sources. In petroleum, the alkyl-substituted compounds predominate over the parent compound, whereas pyrolytic sources (input resulting from burning fossil fuels) exhibit primarily the parent polynuclear aromatic compound (Laflemme and Hites, 1978; Lee et al., 1977).

8.2 Materials and Methods

8.2.1 Field

Samples were collected only from soft bottom stations during the Fall Cruise (Cruise III-25 October to 23 November 1980) (Figure 8-1). A detailed procedure for the collection of surficial sediments in the field is presented in Appendix A-3.

8.2.2 Laboratory

The samples were analyzed in sets of four to six, and each set was accompanied by a reagent blank or clay-control. A standard recovery sample, consisting of clay or sediment spiked with a standard reference mixture, was also analyzed with each set. The laboratory methodology is outlined in Figure 8-2 and a more detailed account is presented in Appendix A-4.

8.3 Results

8.3.1 Extraction Efficiency and Chromatographic Resolution

All components of the standard reference mixture were satisfactorily resolved on the 30-m SE-30 glass capillary column. Extraction of the standard mix from a spiked sediment sample was completed with subsequent separation of aliphatic from aromatic-olefinic compounds.

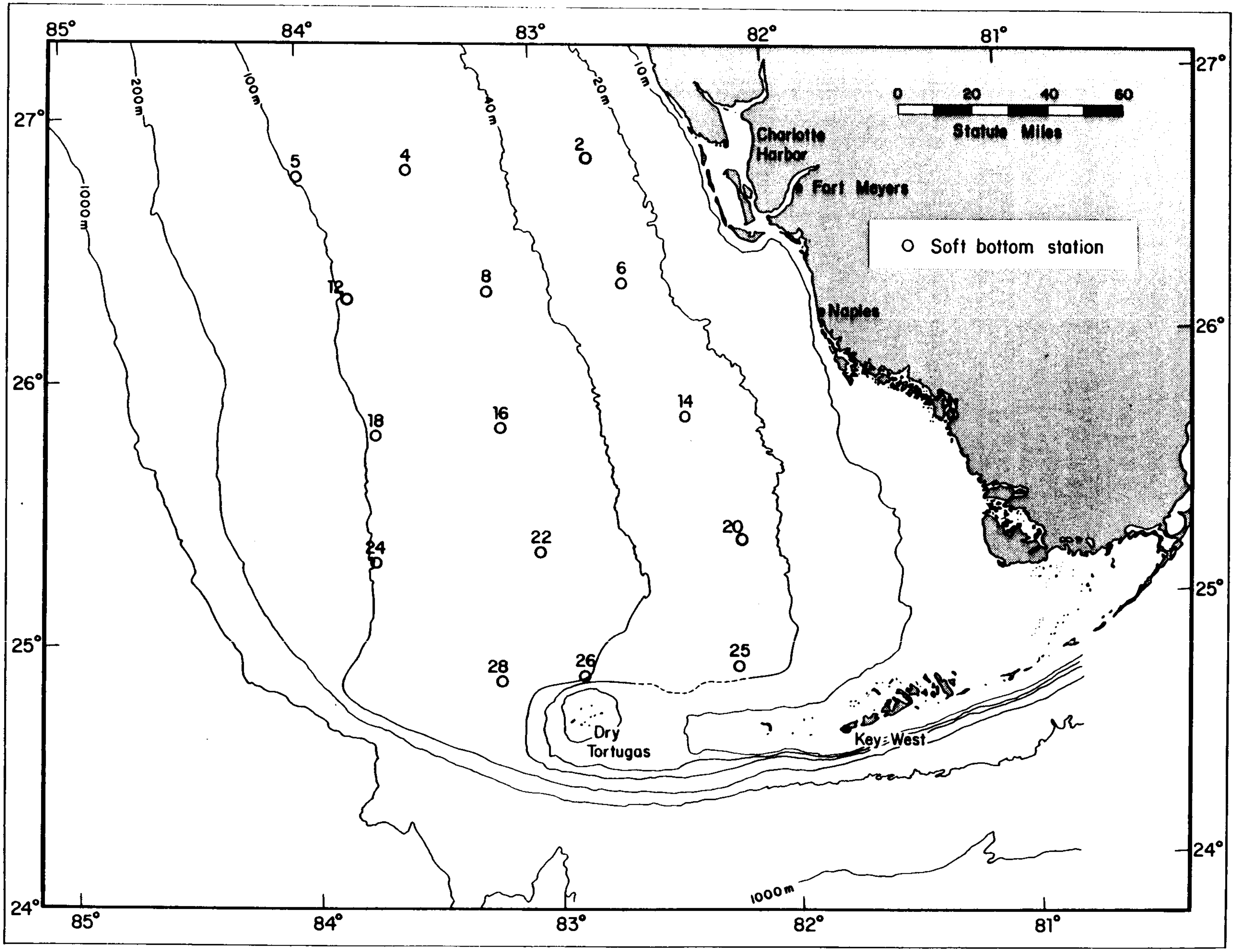

Figure 8-1. Geographic locations of hydrocarbon samples.

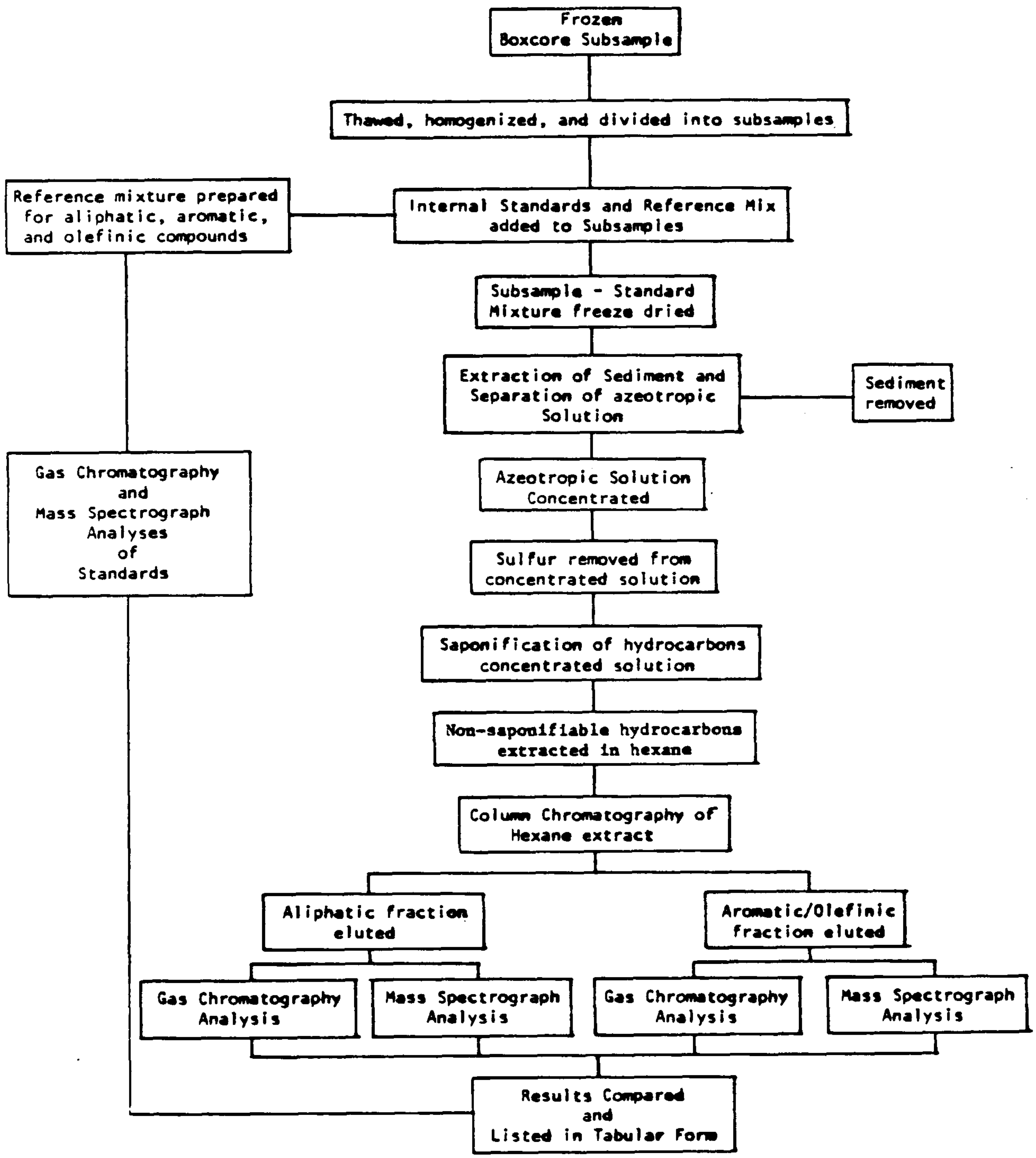

Figure 8-2. Summary of laboratory methodology for hydrocarbon analyses.

The percent recovery for each standard, based on eight standard recovery experiments, is shown in Table 8-1. Recoveries are reported relative to the known amount of internal standard added for both aliphatic and aromatic-olefinic fractions. Excellent recoveries, with good precision, were obtained for hydrocarbons exhibiting retention indices of 1600 ($n\text{-}C_{16}$) and above. Recoveries for the low boiling compounds showed some loss due to required low pressure freeze-drying and evaporation-concentration procedures. The recoveries were reproducible and corrections were made relative to the internal standard recovery. The efficiencies of recovery were well within acceptable limits of uncertainty for samples from the marine environment.

8.3.2 Blanks and Control

Neither sample blanks nor samples contained petroleum hydrocarbons indicative of fuel oil or other ship-board contaminants. Reagent blanks and control samples were freeze-dried with each batch of samples analyzed. Thus, any contaminated samples were readily detected and the data were discarded or corrected when reporting the results.

8.3.3 Hydrocarbon Distribution

Total mean aliphatic and aromatic-olefinic hydrocarbon concentrations observed in the surficial sediment at each station are shown in Figure 8-3. These data reflect a very low background hydrocarbon concentration (mean) throughout the area (0.07 to 0.78 $\mu g\ g^{-1}$ aliphatic and 0.03 to 0.50 $\mu g\ g^{-1}$ aromatic-olefinic compounds). Most sediments exhibited a greater amount of aliphatic than aromatic-olefinic compounds (ratio ranged from 1.0 to 3.2). No particular trend for this ratio is apparent with respect to station. Due to the small amount of hydrocarbons present, a small variation in either fraction could produce a large change in the ratio. In this respect, the ratio differences may be more apparent than real.

A more useful aspect of the investigation is the gas chromatographic (GC) fingerprinting of aliphatic and aromatic-olefinic hydrocarbon fractions from each station. Three major types of hydrocarbons were observed from the GC traces. These included: (1) biogenic hydrocarbons of marine origin (BM),

Table 8-1. Efficiency (percent recovery) and reproducibility (standard deviation) of eight standard hydrocarbon recoveries from spiked sediments.

Standard Compound Name	Percent Recovery Mean	Standard Deviation
Naphthalene	11	16
Biphenyl	23	18
Acenophthalene	26	20
$n-C_{15}$	35	30
Fluorene	63	11
$n-C_{16}$	60	23
9, 10-dihydroanthracene	73	6
$n-C_{17}$	85	16
Pristane	63	22
Phenanthrene	100	Internal Standard
Octadecene	81	33
$n-C_{18}$	105	14
Phytane	86	18
1-methylphenanthrene	93	11
$n-C_{19}$	96	19
3, 6-dimethylphenanthrene	99	10
Eicosene	100	Internal Standard
$n-C_{20}$	118	19
Pyrene	95	15
$n-C_{21}$	108	13
$n-C_{22}$	104	12
$n-C_{26}$	104	15
$n-C_{28}$	96	21
$n-C_{30}$	76	31
$n-C_{32}$	70	28

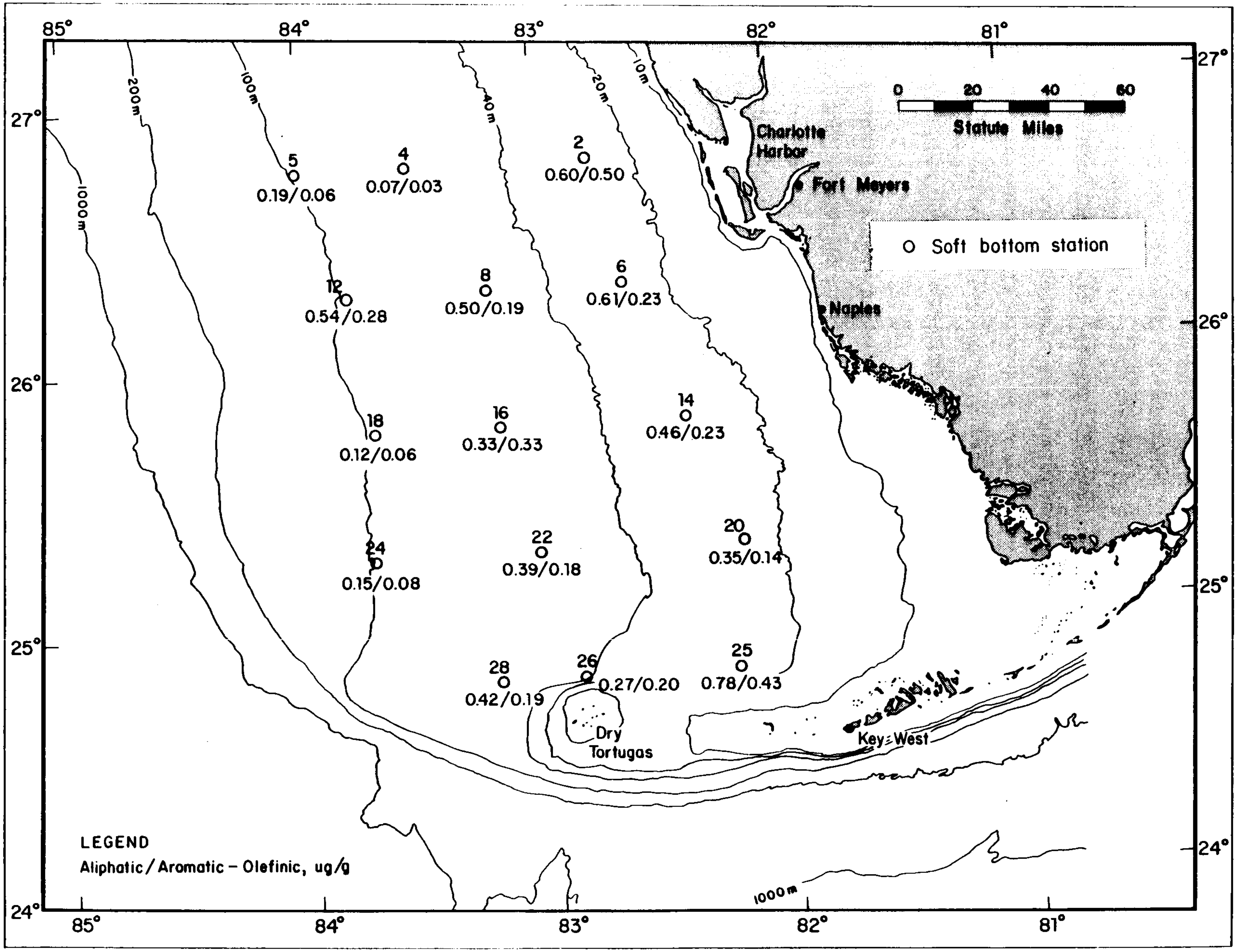

Figure 8-3. Surficial sediment aliphatic and aromatic-olefinic hydrocarbon concentrations (mean).

containing n-C_{17}, pristane, and a preponderance of the aliphatic hydrocarbon with a retention index (R.I.) of 2085 that exhibited no n-alkane homologous series or unresolved complex; (2) biogenic marine and terrigenous (BMT), including the above aspects plus the aliphatic hydrocarbon with R.I. 2900, an n-alkane homologous series showing the CPI greater than one, and containing olefinic rather than aromatic compounds; and (3) biogenic marine, terrigenous, and petrogenic (BMTP), containing the above specific compounds with an alkane CPI = 1, and containing a proportionately large concentration of aromatic relative to olefinic compounds.

Summaries of the hydrocarbon data have been compiled in Tables 8-2 through 8-5. Based on the above GC criteria and supported by GC/MS analysis of 6 of the 15 sediment samples, all of the samples exhibited BM-type hydrocarbons (Figure 8-4). Stations 4 and 16 (mid-depth stations) showed only BM, with no evidence of terrigenous or petroleum hydrocarbons. The other mid-depth stations (8 and 22), as well as the nearshore stations (2, 6, 14, and 20), showed similar hydrocarbon patterns with the presence of some 2900 aliphatic hydrocarbon. Although the 2900 compound indicates terrigenous hydrocarbons, these samples did not exhibit any n-alkane homologous series in the n-C_{23} to n-C_{30} range, so they also were classified as BM-type hydrocarbons.

Clear evidence for terrigenous hydrocarbons associated with the marine substances was evident at the offshore Stations 5 and 24. Another offshore station (18) contained very low hydrocarbon concentrations, thus evaluation of this station was difficult. The only station showing the presence of petroleum hydrocarbons (petrogenic) was Station 12, one of the offshore stations. The GC pattern is that of a weathered crude or residual oil, associated with biogenic hydrocarbons.

The transect farthest south (Stations 25, 26, and 28) exhibited a definite marine biogenic hydrocarbon origin, with quite high concentrations of hydrocarbon 2900. A series of high boiling aliphatic hydrocarbons was present in each sample. Although these compounds did not coincide with a n-alkane series, their presence, along with the 2900 hydrocarbon, was interpreted as being indicative of terrestrial origin.

Table 8-2. Total hydrocarbon content and classification for surficial sediments of the southwest Florida shelf.

		SEDIMENT	HYDROCARBON CONCENTRATION (μg/g)		
Station (Replicate)[a]	Depth (m)	% $CaCO_3$	Total Aliphatic Fraction	Total Aromatic-Olefinic Fraction	Hydrocarbon Classification[b]
2 (a-a)	25.2	72	0.60	0.40	BM
(a-b)			0.60	0.60	
4 (f-a)	55.2	99	0.05	0.02	BM
(f-b)			0.05	0.03	
(f-c)			0.10	--	
5 (f-a)	89.8	97	0.17	0.05	BMT
(f-b)			0.19	0.07	
(f-c)			0.20	0.06	
6 (f-a)	26.2	86	0.68	0.30	BM
(f-b)			0.54	0.16	
8 (a-a)	48.4	96	0.57	0.23	BM
(a-b)			0.44	0.15	
12 (f-a)	89.8	97	0.41	0.38	BMTP
(f-b)			0.68	0.18	
14 (a-a)	26.1	96	0.46	0.11	BM
(a-b)			0.45	0.35	
16 (a-a)	53.7	96	0.48	0.44	BM
(a-b)			0.30	0.22	
(a-c)			0.20	--	
18 (a-a)	86.1	98	0.16	0.07	BM
(a-b)			0.08	0.05	
20 (a-a)	22.7	99	0.41	0.15	BM
(a-b)			0.29	0.12	
22 (a-a)	52.2	94	0.37	0.16	BM
(a-b)			0.40	0.20	
24 (a-a)	88.2	96	0.17	0.10	BMT
(a-b)			0.12	0.06	

Table 8-2. Continued

Station (Replicate)[a]	Depth (m)	SEDIMENT % $CaCO_3$	HYDROCARBON CONCENTRATION (μg/g) Total Aliphatic Fraction	Total Aromatic-Olefinic Fraction	Hydrocarbon Classification[b]
25 (a-a)	24.0	90	0.81	0.46	BMT
(a-b)			0.80	0.40	
(a-c)			0.72	--	
26 (a-a)	38.0	93	0.23	0.20	BMT
(a-b)			0.30	0.20	
28 (a-a)	58.6	98	0.34	0.18	BMT
(a-b)			0.50	0.20	

[a] Replicate is denoted as (x-y) where:
x = box core replicate, and
y = subsample replicate.

[b] Hydrocarbon types are defined as:
BM = Biogenic Marine
BMT = Biogenic Marine and Terrigenous
BMTP = Biogenic Marine, Terrigenous, and Petrogenic.

Table 8-3. Concentrations of selected aliphatic hydrocarbon groups contained in surficial sediments of the southwest Florida shelf.

Station (Replicate)[a]	HYDROCARBON GROUP[b] CONCENTRATION (µg/g)					
	R.I. 1700	Pristane	R.I. 1800	Phytane	R.I. 2085	R.I. 2900
2 (a-a)	0.04	0.03	0.02	0.01	0.11	0.02
(a-b)	0.02	0.03	<0.01	<0.01	0.08	0.02
4 (f-a)	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
(f-b)	<0.01	<0.01	<0.01	<0.01	0.04	<0.01
(f-c)	<0.01	<0.01	<0.01	<0.01	0.04	<0.01
5 (f-a)	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
(f-b)	0.01	0.02	0.02	0.01	<0.01	<0.01
(f-c)	0.01	<0.01	0.01	<0.01	0.01	<0.01
6 (f-a)	0.01	0.04	<0.01	<0.01	0.16	0.05
(f-b)	0.02	0.07	<0.01	<0.01	0.09	0.09
8 (a-a)	<0.01	0.01	<0.01	<0.01	0.08	0.06
(a-b)	<0.01	0.01	<0.01	<0.01	0.15	0.05
12 (f-a)	<0.01	0.01	<0.01	0.01	0.01	0.03
(f-b)	<0.01	<0.01	<0.01	<0.01	0.03	0.02
14 (a-a)	0.01	0.04	0.02	0.01	0.18	0.10
(a-b)	0.02	0.06	0.02	0.02	0.03	0.10
16 (a-a)	<0.01	<0.01	<0.01	<0.01	0.13	0.01
(a-b)	<0.01	0.02	<0.01	<0.01	0.12	0.01
(a-c)	<0.01	0.01	<0.01	<0.01	0.05	0.01
18 (a-a)	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
(a-b)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20 (a-a)	0.03	0.02	<0.01	<0.01	0.05	0.01
(a-b)	0.02	0.03	<0.01	<0.01	0.07	0.02
22 (a-a)	<0.01	0.01	<0.01	<0.01	0.16	0.04
(a-b)	0.01	0.01	<0.01	<0.01	0.15	0.06
24 (a-a)	<0.01	<0.01	<0.01	<0.01	0.01	0.01
(a-b)	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
25 (a-a)	<0.01	0.01	<0.01	<0.01	0.40	0.10
(a-b)	<0.01	<0.01	<0.01	<0.01	0.44	0.12
(a-c)	<0.01	<0.01	<0.01	<0.01	0.44	0.11

Table 8-3. Continued

Station (Replicate)[a]	R.I. 1700	Pristane	R.I. 1800	Phytane	R.I. 2085	R.I. 2900
	HYDROCARBON GROUP[b] CONCENTRATION (μg/g)					
26 (a-a)	0.01	0.02	<0.01	0.01	0.10	0.06
(a-b)	0.01	0.01	<0.01	<0.01	0.09	0.04
28 (a-a)	0.01	0.01	<0.01	<0.01	0.12	0.04
(a-b)	0.02	0.02	0.01	0.01	0.16	0.08

[a] Replicate is denoted as (x-y) where:
x = box core replicate, and
y = subsample replicate.

[b] R.I. denotes retention index.

Table 8-4. Concentrations of selected aromatic-olefinic hydrocarbon groups contained in southwest Florida shelf surficial sediments.

Station (Replicate)[a]	Hydrocarbon Group[b] (R.I.)	Concentration (μg/g)	GC/MS Group Identification[c]
2 (a-a)	3010	<0.01	Olefinic
(a-b)	2160	0.03	--
4 (f-a)	2560	<0.01	--
(f-b)	2560	<0.01	--
(f-c)	--	--	--
5 (f-a)	3120	<0.01	Olefinic
(f-b)	3120	<0.01	--
(f-c)	CONTAMINATED		
6 (f-a)	2160	0.02	Olefinic
(f-b)	3010	0.02	--
8 (a-a)	3010	0.01	--
(a-b)	3010	0.01	--
12 (f-a)	2610	0.03	Aromatic
(f-b)	2610	0.01	--
14 (a-a)	2160	0.02	--
(a-b)	2160	0.04	--
16 (a-a)	3010	0.03	--
(a-b)	2610	0.01	--
(a-c)	--	--	--
18 (a-a)	3010	<0.01	--
(a-b)	3010	<0.01	--
20 (a-a)	3010	<0.01	Olefinic
(a-b)	2920	<0.01	--
22 (a-a)	3010	<0.01	--
(a-b)	2160	0.01	--
24 (a-a)	3010	<0.01	--
(a-b)	3010	<0.01	--
25 (a-a)	3010	0.01	--
(a-b)	3010	<0.01	--
(a-c)	--	--	--

Table 8-4. Continued

Station (Replicate)[a]	Hydrocarbon Group[b] (R.I.)	Concentration (μg/g)	GC/MS Group Identification[c]
26 (a-a)	3010	<0.01	Olefinic
(a-b)	3010	0.01	--
28 (a-a)	3010	0.01	--
(a-b)	3010	<0.01	--

[a] Replicate is denoted as (x-y) where:
x = box core replicate, and
y = subsample replicate.

[b] R.I. denotes retention index.

[c] GC/MS denotes gas chromatographic mass spectrometric analysis.

Table 8-5. Occurrence of n-alkane homologous series hydrocarbons in surficial sediment samples from the southwest Florida shelf.

Station (Replicate)[a]	Homologous Series R.I. Range[b]	C.P.I.[c]
5 (f-a)	1700-3300	2.5
(f-b)	1700-3300	1.6
(f-c)	1700-3300	2.7
12 (f-a)	2300-3200	0.99
(f-b)	2100-3000	1.15
24 (a-a)	2100-3200	3.5
25 (a-a)	2800-3200	--
(a-b)	2800-3200	--
(a-c)	2800-3200	--
26 (a-a)	2800-3200	--
(a-b)	2800-3200	--

[a] Replicate is denoted as (x-y) where:
x = box core replicate and
y = subsample replicate.

[b] R.I. denotes retention index.

[c] C.P.I. denotes carbon preference index.

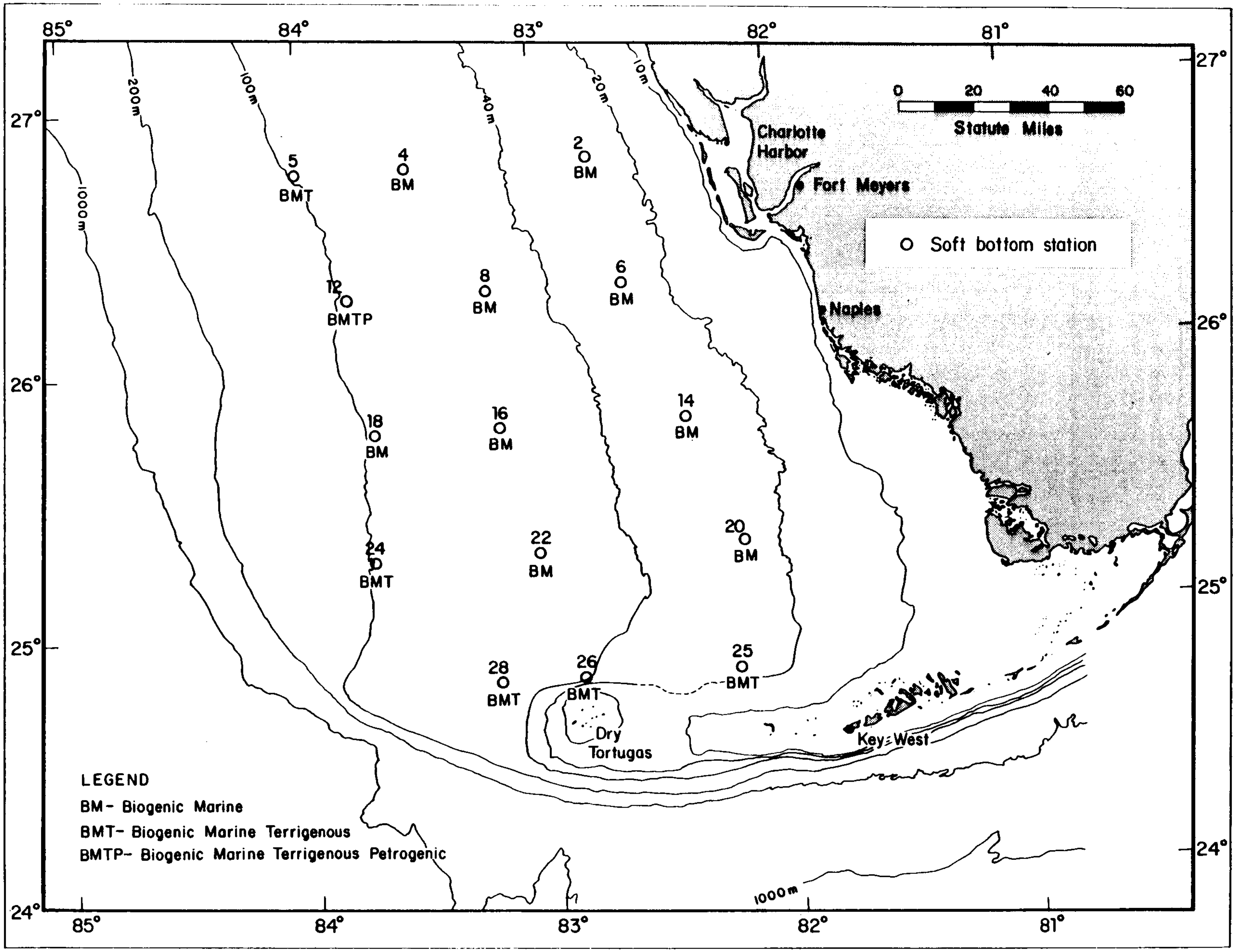

Figure 8-4. Distribution of hydrocarbon types.

8.4 Principal Component Analysis of Hydrocarbon Data

Principal component analysis (PCA) was performed on the hydrocarbon data using stations as entities and several hydrocarbon fractions as attributes. These attributes were the concentrations of the fraction extracted with hexane (aliphatic fraction), the fraction extracted with toluene (aromatic-olefinic fraction), pristane, phytane, and compounds with retention indices of 1700, 1800, 2085, 2900, 2160, 2560, 2610, 2920, 3010, and 3120. The purpose of the PCA was to investigate the relationships among the stations based on the concentrations of these organic components.

The first three principal components explained only 67% of the total variance in the data. The most obvious group of stations, based on PCA, was comprised of Stations 8, 16, 22, 26, and 28, all located along the inshore middle shelf (Figure 8-5). A second group was composed of Stations 4, 12, 18, 20, and 24. Three of these stations (12, 18, and 24) were located on the offshore middle continental shelf. One inshore middle shelf station (4) and one inner shelf station (20) were also included in this group. A third group was composed of two inner shelf stations (6 and 25). The remaining three sampling locations (Stations 2, 5, and 14) were independent of each other and the other groups.

The grouping of stations from the principal component analysis did not agree with the distribution of hydrocarbon types at the various stations (Figure 8-4). Principal component axes were primarily related to the total concentrations of aliphatic and aromatic-olefinic hydrocarbons. This lack in correlation was attributed to the generally low concentrations of many of the hydrocarbon fractions. Comparison of these station groupings with station groups derived from PCA of sediment grain sizes (Section 7.0), revealed no similarities.

8.5 Discussion

These results showed a characteristic, low-level background concentration of biogenic hydrocarbons in most of the sediments. Except for Station 12, there was little evidence of anthropogenic hydrocarbon input. The petroleum in

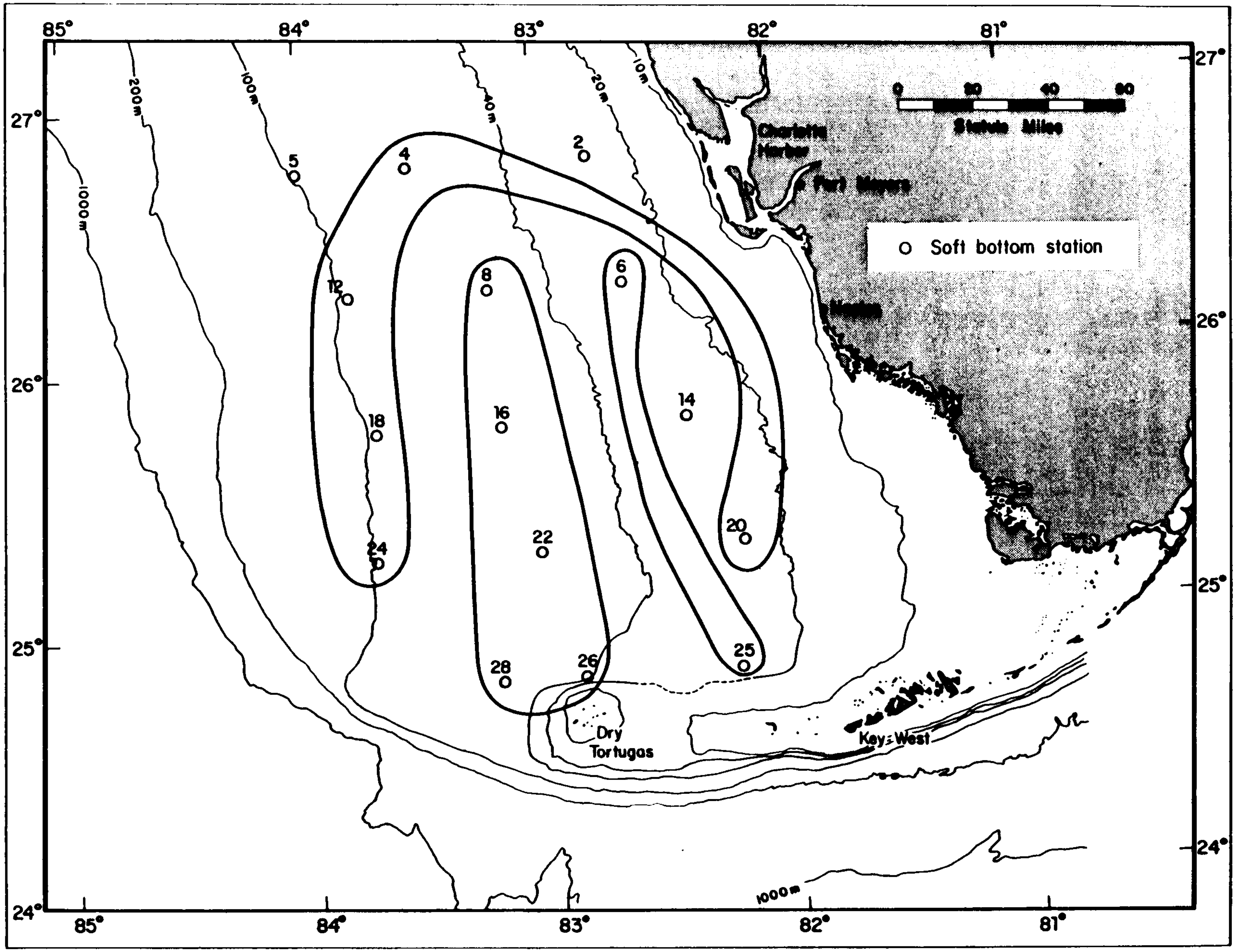

Figure 8-5. Station groups defined by principal component analysis of hydrocarbon data.

Station 12 sediment most likely originated in the northern Gulf and Mississippi River area, being carried to the offshore Florida shelf sediment in association with clay particles. Evidence of terrigenous hydrocarbons in other offshore stations (5 and 24), with none apparent in the mid-depth samples, provides support for a Mississippi River origin for these terrigenous and petrogenic compounds.

A high-boiling aliphatic hydrocarbon pattern, distinctive from that observed above, was observed in all three of the samples from the southern-most transect. These could reflect recent hydrocarbon input from the southern Florida coastal mangrove area and the Everglades.

In previous studies of surficial sediment from the northwestern Gulf of Mexico continental shelf, Weichert and Pierce (1981) have observed petroleum hydrocarbons resembling weathered crude oil, similar to the pattern observed for Station 12, yet in much higher concentrations (5-10 $\mu g\ g^{-1}$ sediment). Other investigators have reported similar concentrations of petrogenic and pyrogenic hydrocarbons in northern Gulf of Mexico sediments (Boehm, 1978; Gearing et al., 1976).

A comparison of the data reported here with previous eastern Gulf of Mexico sediment hydrocarbon data is given in Table 8-6. These data are fairly consistent, considering variations encountered when comparing results obtained from different sampling times and analytical procedures. Seasonal variations at individual stations also have been reported by Boehm (1978), who observed a change from anthropogenic input in Summer 1976 to purely biogenic in Summer 1977 at a shallow-water station near Sanibel Island, which was located approximately 50 mi east-northeast of Station 6.

Previous studies have observed petrogenic hydrocarbons at stations influenced by clay input from the Mississippi River and northern Gulf of Mexico. These were primarily stations deeper than 100 m or ones sampled north of 28°N. These stations were not sampled during the present study.

From this investigation, it may be concluded that the carbonate sediments from the southwest Florida outer continental shelf contain low levels of primarily

Table 8-6. Comparison of hydrocarbon concentrations with previous eastern Gulf of Mexico data from stations of similar sediment type.

Station	Depth (m)	Latitude (approximate)	Total Hydrocarbons ($\mu g\ g^{-1}$) Aliphatic	Aromatic-Olefinic	2900
2207[a]	20	27°57'N	1.39	1.13	0.005
2207[b]	20	27°95'N	0.50	0.39	0.01
2211[a]	50	27°57'N	0.79	1.04	0.001
2211[b]	50	27°94'N	0.58	0.51	0.01
2851[b]	30	27°06'N	0.82	--	--
2[c]	25	26°46'N	0.60	0.50	0.02
2102[a]	20	26°25'N	0.91	1.06	<.001
2102[b]	20	26°42'N	0.89	0.39	0.02
6[c]	26	26°17'N	0.60	0.23	0.07
2105[a]	100	26°25'N	0.29	0.39	<.001
2105[b]	100	26°42'N	0.40	0.53	0.01
12[c]	90	26°17'N	0.54	0.28	0.03
2960[b]	26	26°67'N	0.60	--	--
14[c]	26	25°46'N	0.46	0.23	0.10

[a] Alexander et al. (1977).
[b] Boehm (1978).
[c] Present Study.

marine biogenic hydrocarbons. Any significant hydrocarbon input to the area should be readily apparent and easily detectable.

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9.0 TRACE METALS

9.1 Introduction

Identification of localized metal pollution is most often a rather straightforward process. The scientific community, however, has demonstrated only a limited proficiency in predicting the occurrence or extent of future instances of metal pollution. For this reason, it is advantageous to survey and understand metal distribution in areas that have not yet been subjected to the activities of man, but may be at some future time. Such has been the case in this investigation of sediment trace metal content at selected stations in the potential oil and gas lease area on the southwest Florida shelf.

The purpose of this study and the data presented herein is to provide a characterization of the patterns and geochemical significance of trace metals in southwest Florida shelf sediments prior to possible oil and gas drilling and development activities. With this data base and future monitoring, we will be able to predict more logically sites which could be most affected by anthropogenic metal inputs and be able to identify and trace these inputs before they become an environmental threat.

Previous work on central and southwest Florida shelf sediments (Alexander et al., 1977; Presley et al., 1975; Trefry et al., 1978) shows the area to have very low trace metal levels. These low metal values are found because low metal-bearing calcium carbonate ($CaCO_3$) and quartz sands dominate the area. No instances of metal pollution have been identified at any of the previous Bureau of Land Management Florida shelf stations.

Nine metals were chosen for this study. These included barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), vanadium (V), and zinc (Zn). Some of these are associated with potential petroleum-related pollution while others represent some of the more toxic heavy metals often associated with the increased activities of man. Barium and chromium, for example, are common in drilling muds, while nickel and vanadium have been shown to be present in large concentrations in some oils and tars (Yen, 1975). Lead, cadmium, and zinc, three potentially toxic metals, have also been observed to be above natural levels near Gulf of Mexico industrial and population centers (Hann and Slowey, 1972; Holmes et al., 1974; Trefry and Presley, 1976a, 1976b).

Trace metal levels of sediments from the 15 soft bottom stations whose locations are shown in Figure 9-1 were investigated. Samples for trace metal analysis were collected only during the Fall Cruise (Cruise III-25 October to 23 November, 1980). The overall objectives of this section of the study were (1) to continue to expand geographically the trace metal characterization of eastern Gulf of Mexico outer continental shelf sediments, (2) to identify possible regional sediment heterogeneities and their relationship to naturally occurring trace metal distributions, (3) to assess the "availability" of the various sediment metals when subjected to a nitric acid (1 N HNO_3) assay technique, and (4) to continue the development of a standardized model for trace metal distribution in marine sediments. This last objective, based on sediment mineralogy, particle size, and provenance, will allow a more rapid assessment of subtle perturbations in heavy metal ion concentration within shelf sediments. Some of the previous year's work will also be considered in completing the above objectives.

9.2 Materials and Methods

9.2.1 Field

Sediment used for trace metal analyses was obtained by subsampling the box core with polystyrene vials. Every effort was made to take the samples near the center of the box, away from any metal parts.

All equipment and vials used in sampling were carefully pre-cleaned in HNO_3. The specific methodology for box core subsampling is outlined in Appendix A-5. A general description of the box core sampling technique is given in Section 5.0.

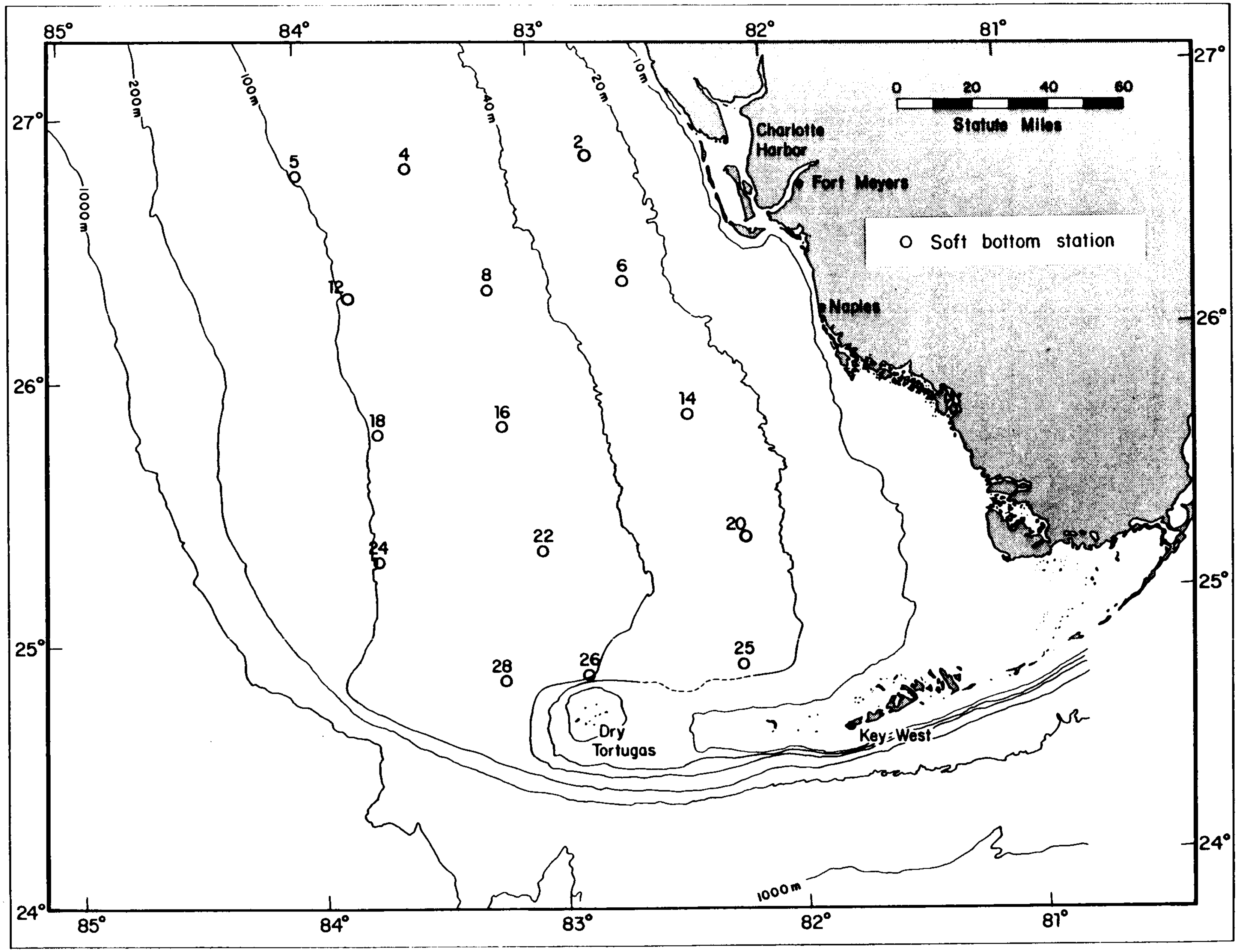

Figure 9-1. Trace metals sampling station locations.

9.2.2 Laboratory

Figure 9-2 shows a procedural flow diagram that summarizes laboratory methodology. Detailed methods are presented in Appendix A-6.

Sample preparation involved freeze-drying, mixing, and subsampling (2-g portions). All 30 sediment samples (two replicates per station) were analyzed for trace metals after "partial digestion" with 1 N HNO_3. Eight of the samples were also analyzed after total dissolution with hydrofluoric, nitric, and perchloric acids (HF-HNO_3-$HClO_4$).

Flame atomic absorption spectrophotometric (AAS) analysis of the sediment digests for Cr, Fe, and Zn was carried out using a Perkin-Elmer 460 instrument equipped with a deuterium-arc background corrector. Flameless AAS was used for detecting low levels of Cd, Cu, Ni, and Pb present. A Heated Graphite Analyzer 400 with an Auto Sampler -40 was coupled with the Perkin-Elmer 460 for flameless analyses.

All standards used were in a comparable acid matrix of 0.1 or 1.0 N HNO_3. Background correction was applied for all analyses. Method-of-additions (standard additions) analyses were also carried out for each element using a variety of sample types. These checks help evaluate matrix problems due to chemical interference (Ca from $CaCO_3$ in this case) with resultant signal suppression. Matrix problems did occur with the Cr, Cd, Pb, and some Ni determinations requiring the use of the methods-of-additions analyses.

Reproducibility of the sediment metal data was determined by replicate analysis of various samples and influenced by the very low metal levels encountered. For these very low levels, precisions (coefficient of variation) for Cd, Cu, Ni, and Pb were about 20%; Cr, 10%; Zn, 8%; and Fe, 5%.

The barium and vanadium determinations were made by instrumental neutron activation analysis (INAA) following the methods of Reed (1977) for Ba-139 and V-52.

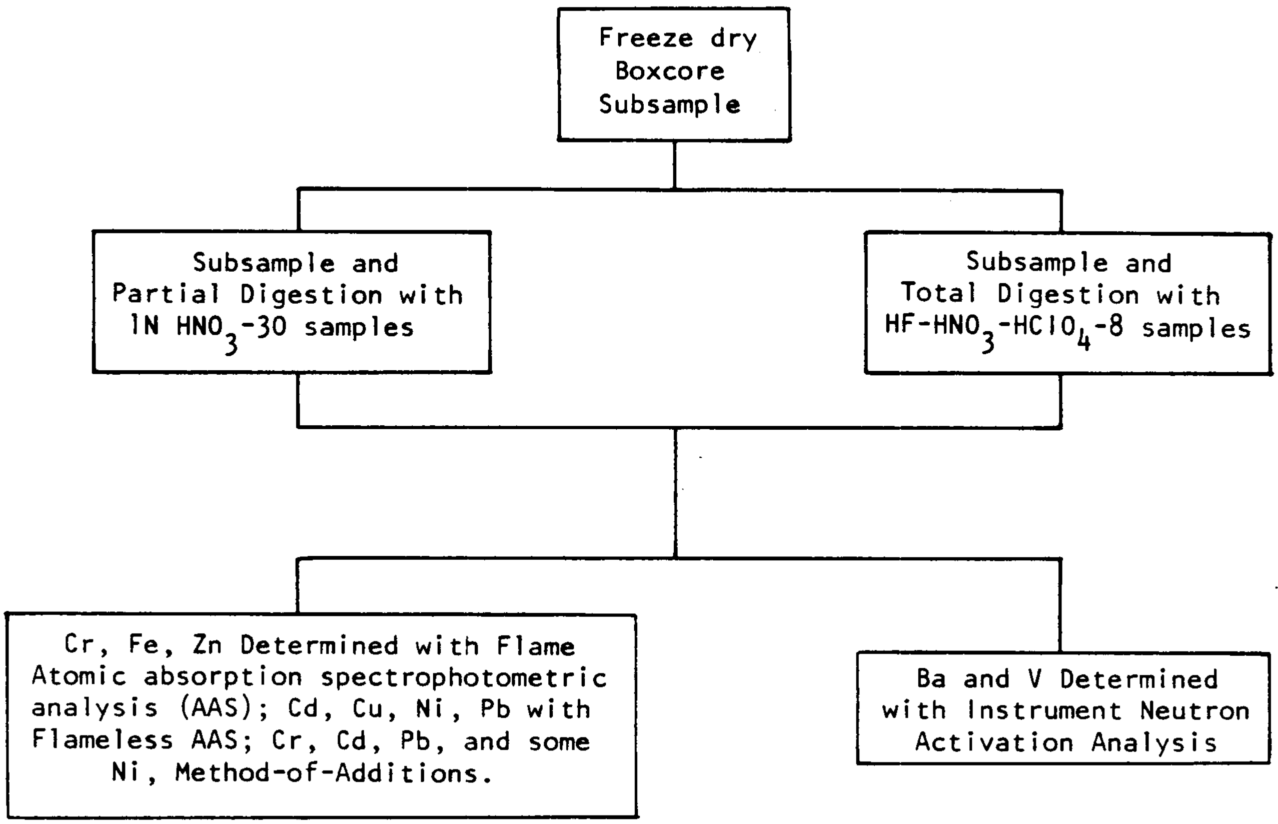

Figure 9-2. Summary of trace metals laboratory analyses.

9.3 Results and Discussion

9.3.1 Total Dissolution Trace Metal Levels

The trace metal concentrations in the surficial sediments are both low and uniform as shown in Table 9-1. This observation is directly related to the sediment mineralogy which shows >90% carbonate at 13 of the 15 stations (Figure 9-3). Even the additional two stations (2 and 6) are predominantly carbonate at 72 and 86% $CaCO_3$. The overall average carbonate content for 15 stations is 94 ± 7% with 10 stations at $\geq$96% $CaCO_3$. Grain size distribution is not quite as consistent (Figure 9-3) with a range of mean phi from 0.9 (~500 mm, medium/coarse sand) to 4.2 (~55 µm, silt/very fine sand).

When summarized, the total dissolution metal data set in Table 9-1 shows a mean relative standard deviation for the nine metals [Σ (Std. Dev./Mean) ÷ 9] of 29%, emphasizing the conformity of the data. The compilation in Table 9-2 shows that the present data set is compatible with that from previous data from the Florida shelf (Trefry et al., 1978) and that these values are somewhat lower than average carbonate rock values. Yet, more striking is a comparison of the present southwest Florida data set with that from present-day Mississippi River suspended matter. Table 9-2 shows that the Florida metal values are ~5% of those found in representative continental weathering products. One coincidence of this comparison is that the 5% value (or a 20-fold decrease) corresponds to a 20-fold dilution of typical continental aluminosilicate material by low-metal containing marine carbonate. Certainly, the sediments of the southwest Florida shelf presently have very low metal levels, and are typical of carbonate-rich deposits. These low values present an interesting, but resolvable dilemma. The low metal concentrations will be easily perturbed by pollutant or clay input from increased activity in the area; yet the low levels and good available data base will now allow quick detection of these perturbations before they become a problem.

9.3.2 Partial Digestion Trace Metal Levels

Trace metal data for the eight total dissolution samples showed a general uniformity. This data set, however, is somewhat biased since it includes only

Table 9-1. Surficial sediment trace metals (summary - total dissolution), selected grain size parameters, and total carbonate.[a]

Station (Replicate)	Water Depth (m)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	V (ppm)	Mean ϕ	$CaCO_3$ (%)	Grain Size Ratio[b]	% Clay (<4 μm)
4(f-b)	55.2	<0.1	6.1	0.9	930	3.5	3.4	4.6	14.6	5.0	0.9	99	12	2.3
5(f-a)	89.8	0.10	4.8	0.9	740	3.4	2.8	4.8	1.1	4.6	0.9	97	17	1.5
8(f-b)	48.4	<0.1	9.0	0.9	1500	3.6	2.8	9.5	19.2	7.3	2.5	96	6	2.4
14(a-a)	26.1	0.08	7.3	1.0	1190	2.9	3.4	6.6	6.0	6.6	2.9	96	5	2.0
16(a-a)	53.7	<0.1	7.1	0.8	1500	3.1	2.9	6.4	17.6	3.2	1.9	96	6	3.1
20(a-a)	22.7	<0.1	11.2	1.2	2200	4.4	3.5	3.4	12.6	11.9	1.0	99	69	0.6
22(a-a)	52.2	0.07	8.5	0.9	2120	4.1	3.6	6.9	18.9	7.9	1.8	94	5	3.3
28(a-a)	58.6	<0.1	5.9	0.9	1440	2.9	3.3	-	>3	6.6	2.1	99	7	3.9
Mean (± 1 S.D.)		0.08	7.5	0.9	1450	3.5	3.2	6.0	11.6	6.6	1.8	97	-	2.4
		(±0.02)	(±2.0)	(±0.1)	(±510)	(±0.5)	(±0.3)	(±2.0)	(±7.3)	(±2.6)	(±0.8)	(±2)		(±1.05)

[a] Grain size parameters and total carbonate values are station means resulting from the analysis of samples from the box cores collected for the macroinfauna during Cruise III.

[b] Ratio of [% Sand] to [% Silt + % Clay]

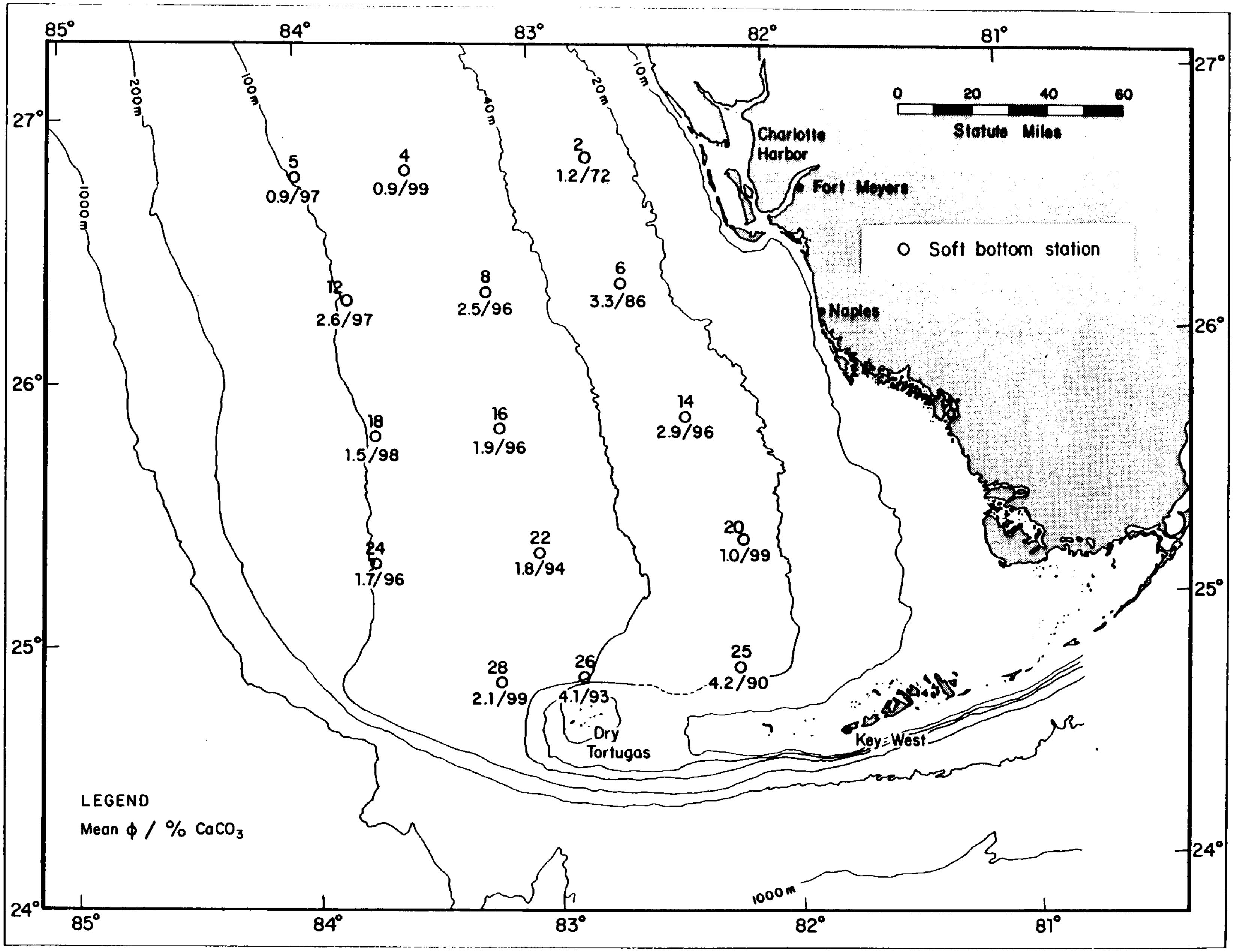

Figure 9-3. Surficial sediment mean grain size (in ϕ units) and percent carbonate distribution.

Table 9-2. Trace metal concentrations of southwest Florida shelf surficial sediments (total dissolution), carbonate rocks, and Mississippi Delta sediments.

	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	V (ppm)
SW FLA Shelf (This Study)	0.08	7.5	0.9	1450	3.5	3.2	6	11.6	6.6
MAFLA Carbonates (Trefry et al., 1978)	0.15	13	1.3	1900	3.4	2	6	~20	~5
Carbonate Rocks (Graf, 1960; Turekian & Wedepohl, 1961)	0.2 to 0.1	9	10	3800	12	8	26	10	20
Miss. River Particulates (Trefry & Presley, 1976b)	1.4	80	42	47,000	56	45	180	740	150

about one-half of the sediment trace metal stations. To augment this picture, the 1 N HNO_3 leachable trace metal values from the 30 samples are listed in Table 9-3 and summarized in Table 9-4. To provide a frame of reference between the total dissolution in 1 N HNO_3 leachable data, the average percent metal leached for each element is given in Table 9-4 (based on the eight stations listed in Table 9-1). Cadmium and chromium showed near complete removal; Fe, Ni, and Pb also had a high percent leached with 1 N HNO_3; and Cu and Ba were about one-half leachable whereas the observed Zn and V removal was low for the samples examined.

Even with the broader spectrum provided by the 30-sample data set, sediment trace metal concentrations for the southwest Florida shelf stations retained their low and relatively uniform values. Using the means and standard deviations given in Table 9-4 and again calculating a percent relative standard deviation [Σ (Std. Dev./Mean) $\div$ 9] a value of 38% is obtained. The somewhat greater variability for the leachable data set relative to the total dissolution series (29%), although small, is attributable to values from the seven additional stations (particularly Stations 2, 18, and 24). Nevertheless, considering the low metal levels observed, the variability is quite small. For all trace metals combined, the mean maximum/minimum ratio was 4.9±3.1 (Station-replicate 6-f was used as the minimum value for the Ba maximum/minimum ratio). Partly because of the low values in these ranges, no simple relationship can be used to explain metal distribution in the study area.

Data from the two samples analyzed from each of the 15 stations (Table 9-3) showed that each variation was on the same order as, or better than, the analytical precision. For example, the average deviation between the 15 pairs of numbers was 3% for Fe and 21% for Pb. These reasonably homogenous values in low metal-bearing sediment do make detection of future inputs somewhat easier.

Trace metal "availability" considerations using 1 N HNO_3 attempt to assess the potential "biological availability" of sediment metals. The ideal chemical treatment would use some analog of the digestive fluid of given benthic organisms. One can envision sophisticated treatments using enzymes or other organic chelators of metals or a simple system based on pH. Barnard (1973) reported that pH's of 6 to 8 are characteristic of invertebrate guts, with

Table 9-3. Surficial sediment trace metals (summary - 1 N HNO_3 leach).

Station (Replicate)	Water Depth (m)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	V (ppm)
2(a-a)	25.2	0.05	11.7	0.2	650	4.0	2.4	0.8	3.7	1.5
2(a-b)	25.2	0.04	9.4	0.4	680	4.0	2.6	0.7	5.8	1.5
4(f-a)	55.2	0.08	7.4	0.4	620	1.6	2.5	1.1	2.0	1.0
4(f-b)	55.2	0.06	7.0	0.4	640	1.8	2.9	1.2	10.4	0.9
5(f-a)	89.8	0.09	6.5	0.4	450	2.4	3.3	1.6	1.9	0.8
5(f-b)	89.8	0.10	5.6	0.3	430	1.7	4.2	1.5	5.3	0.8
6(f-a)	26.2	0.06	6.8	0.3	820	2.2	2.4	0.6	>1.4	1.5
6(f-b)	26.2	0.07	6.8	0.4	850	1.6	2.6	0.6	5.8	0.8
8(f-a)	48.4	0.04	8.6	2.0	1380	2.4	2.8	1.1	8.6	1.3
8(f-b)	48.4	0.02	8.6	0.5	1240	2.4	3.4	1.1	5.0	0.9
12(f-a)	89.8	0.07	7.1	0.5	700	2.8	2.8	2.0	>0.0	1.0
12(f-b)	89.8	0.05	7.2	0.5	710	2.3	1.9	2.1	7.0	1.0
14(a-a)	26.1	0.07	7.8	0.4	830	2.0	2.4	0.6	9.3	1.1
14(a-b)	26.1	0.05	7.6	0.3	840	2.3	1.6	0.6	4.4	1.1
16(a-a)	53.7	0.03	8.1	0.4	1240	2.9	1.4	1.3	6.7	1.4
16(a-b)	53.7	0.03	7.9	0.5	1270	2.8	1.4	1.4	5.3	1.1
18(f-a)	86.1	0.12	5.3	0.4	260	2.4	1.9	1.2	7.0	0.5
18(f-b)	86.1	0.11	5.6	0.4	260	3.0	1.8	1.2	6.1	0.7
20(a-a)	22.7	0.16	11.7	0.3	1870	2.6	1.8	0.7	8.3	2.6
20(a-b)	22.7	0.16	13.7	0.4	1950	2.6	1.8	0.7	5.3	1.7

Table 9-3. (Continued)

Station (Replicate)	Water Depth (m)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	V (ppm)
22(a-a)	52.2	0.07	7.9	0.5	1650	2.0	1.7	1.1	7.0	1.3
22(a-b)	52.2	0.09	8.2	0.7	1730	2.3	1.2	1.3	6.2	1.1
24(a-a)	88.2	0.12	4.7	0.4	230	1.3	2.6	0.6	6.0	1.0
24(a-b)	88.2	0.11	4.1	0.6	230	2.0	2.3	0.7	8.1	0.5
25(a-a)	24.0	0.07	5.6	0.5	710	1.6	4.1	0.9	8.6	2.1
25(a-b)	24.0	0.11	5.7	0.5	720	2.0	3.1	1.0	7.3	1.4
26(a-a)	38.0	0.09	8.1	0.7	660	1.7	1.3	1.2	~9[a]	2.1
26(a-b)	38.0	0.10	8.2	0.6	660	2.0	1.7	1.4	13.6	1.4
28(a-a)	58.6	0.10	7.1	0.5	1060	1.8	1.4	0.8	11.3	1.4
28(a-b)	58.6	0.08	6.8	0.5	1060	1.8	1.1	0.9	5.9	0.9

[a] This sample was partially (½) lost due to filter breakthrough in analysis with value estimated.

Table 9-4. Means and ranges of trace metal concentrations (1 N HNO_3 leach), percent of total metal leached, and selected parameters.

	Concentration (ppm)			
	Mean ± 1 S.D.	Minimum (Station-Replicate)	Maximum (Station - Replicate)	Percent Leached
Cd	0.08± 0.04	0.02 (8-f)	0.16 (20-a)	93 ± 6
Cr	7.6 ± 2.1	4.1 (24-a)	13.7 (20-a)	94 ± 10
Cu	0.4 ± 0.1	0.2 (2-a)	0.7 (22-a, 26-a)	45 ± 11
Fe	880 ± 480	230 (2-a)	1950 (20-a)	75 ± 9
Ni	2.3 ± 0.6	1.3 (24-a)	4.0 (2-a)	65 ± 14
Pb	2.3 ± 0.8	1.1 (28-a)	4.2 (5-a)	70 ± 25
Zn	1.1 ± 0.4	0.6 (14-a,24-a)	2.1 (12-f)	20 ± 8
Ba	6.4 ± 2.9	>0.0 (12-a)	13.6 (26-a)	48 ± 20[a]
V	1.2 ± 0.5	0.5 (24-a)	2.6 (20-a)	21 ± 10
Mean ϕ	2.2 ± 1.0	0.9 (4-f)	4.2 (25-a)	
$CaCO_3$ (%)	94 ± 7	72 (2-a)	99 (4-f, 20-a)	
(% Sand)/ (% Silt and Clay)	13.0 ± 17.4	0.3 (26-a)	69 (20-a)	
% Clay (<4 μm)	4.0 ± 4.5	0.6 (20-a)	16 (26-a)	

[a] Only five samples directly comparable as the acid leachable values exceeded the total dissolution values at three stations.

special cases probably no lower than 4. Vertebrate digestive systems, on the other hand, are commonly at pH's of 3 or even less. Malo (1977) found 0.2 N HCl to be an appropriate leaching solution. The 1 N HNO_3 was opted for because of the high $CaCO_3$ content of the sediments which makes usage of very dilute or weak acids impractical (one would have to add a great deal of acid just to neutralize the $CaCO_3$). The results show that most of the sediment trace metals are leachable in 1 N HNO_3; however, this is certainly not the case from a practical biological standpoint.

9.3.3 Relationship of Iron to Water Depth and Other Metals

Figure 9-4 gives the leachable (1 N HNO_3) Fe concentrations for each station, with the lowest values being found at outer shelf Stations 18 and 24 (water depths 86 and 88 m). Iron concentrations were correlated with water depth using the nonparametric Spearman's Correlation Coefficient (r_s) (Conover, 1971). Iron was found to be negatively correlated with water depth [r_s = -0.51, $p \leq 0.05$], indicating a significant decrease of leachable Fe concentrations with increasing water depth of the stations.

Pursuing a depth-leachable Fe relationship (Figure 9-5), four general groups have been isolated. Group A is for four of the five nearshore stations where water depths were 24 to 26 m and Fe concentrations ranged from 650 to 840 ppm. Sediment from Station 20, an expected member of Group A, had obvious oxide coatings and consequently higher Fe content. Group B included deeper water Stations 5, 12, 18, and 24 at about 90-m water depth and the lowest Fe concentrations. Group C is transitional in Fe concentrations and water depths. Trends such as these are complicated and best explained by differences in the origin and form of the sediment carbonate, sources of Fe, and remobilization/sedimentation rate phenomena.

The trend observed for Fe is less discernible for the other trace metals because of their lower variations and because the picture is one of rather subtle differences. Significantly negative Spearman's r_s correlation coefficients ($p \leq 0.05$; Steel and Torrie, 1960) were found between water depth of the stations and the concentration of the trace metals Cr (r_s = -0.56) and V

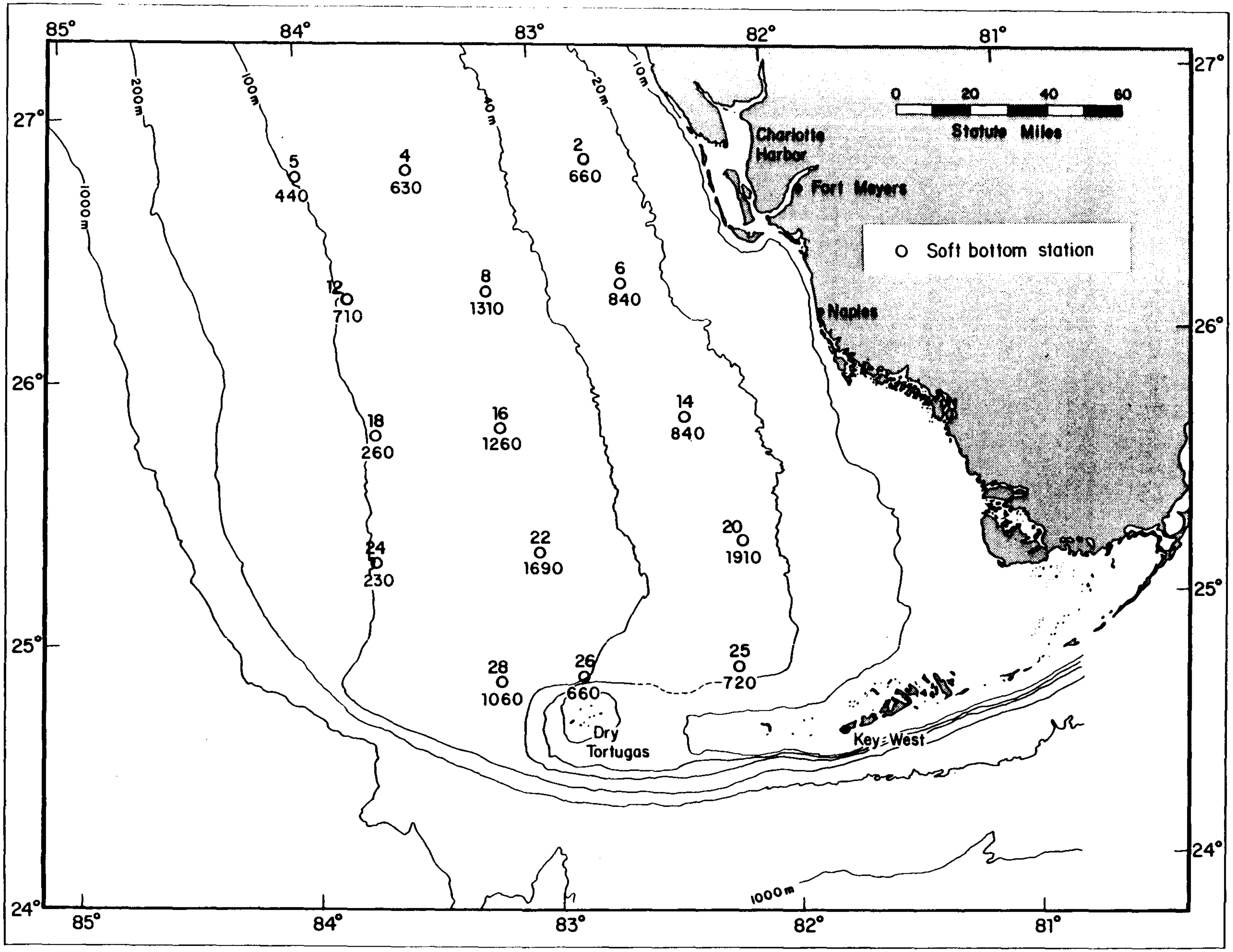

Figure 9-4. Leachable sediment iron concentrations in ppm.

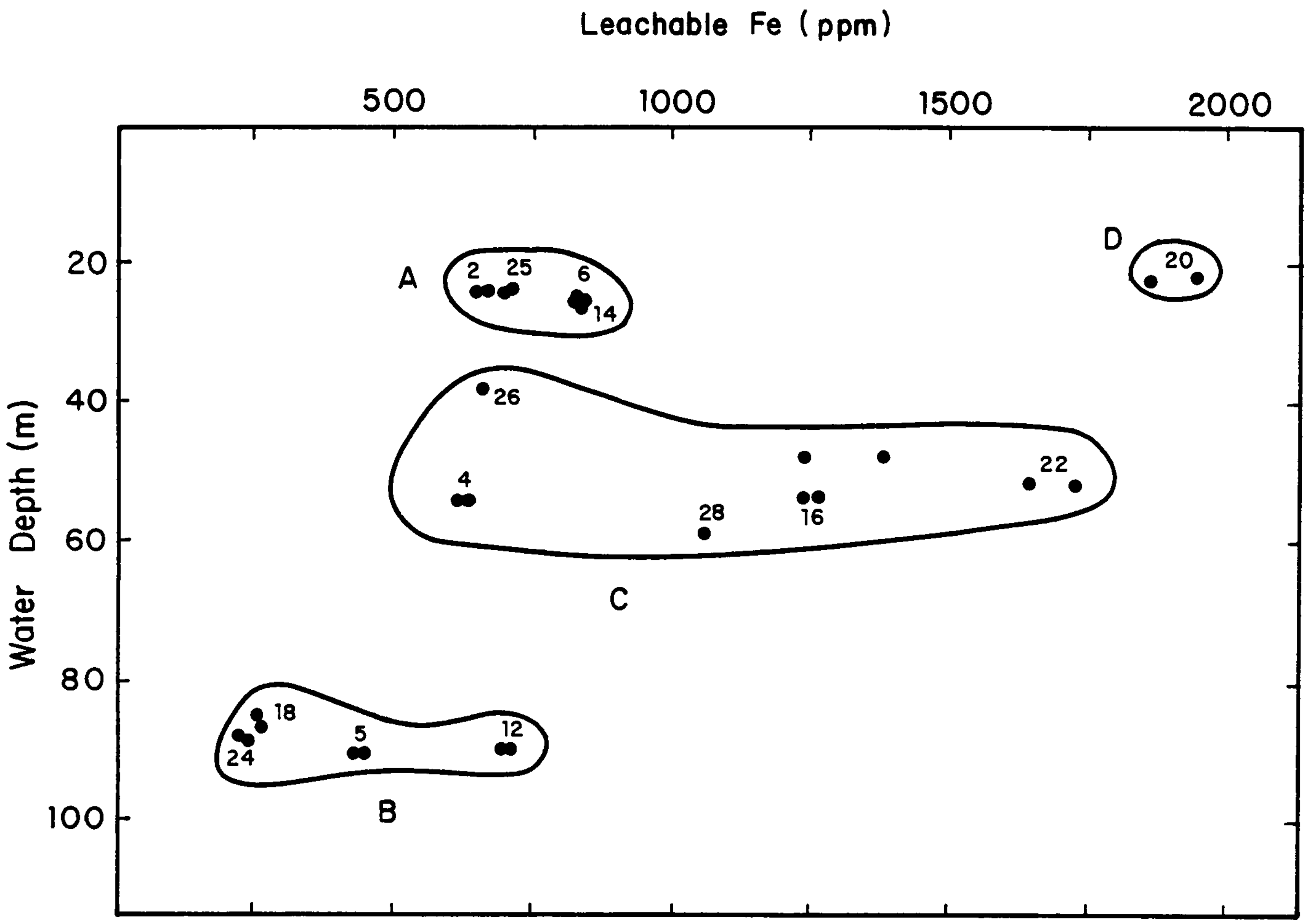

Figure 9-5. Leachable (1$\underline{N}$ HNO_3) sediment iron concentrations versus water depth at each sampling station.

(r_s = -0.84). A significant positive correlation was found between water depth and Zn (r_s = 0.52), indicating increasing Zn concentrations at deeper stations.

Previous studies on Mississippi, Alabama, and Florida (MAFLA) shelf sediments (Trefry et al., 1978) used metal/ Fe ratios to help describe observed metal trends. As Figure 9-6 suggests, this is difficult with the southwest Florida shelf data set. The insert on Figure 9-6 shows the present 30 data points and the lack of any obvious pattern. However, when the coordinates of the inserted graph are shaded on the Zn/Fe graph from the 1977/78 data, it incorporates a rather small, but complicated section of the overall picture.

Previous MAFLA work (Trefry et al., 1978) clearly demonstrated that trace metal concentrations in the area follow the trend, clay >> carbonate > quartz sand, with the important distinction being that between carbonate and quartz sand. This effort helped build the data base on trace metals in carbonates and re-emphasized the low metal values indigenous to the southwest Florida shelf.

9.3.4 Relationships of Trace Metals and Grain Size

Spearman's r_s correlations between trace metals and the phi (grain size) categories are presented in Table 9-5. No significant correlations were found between trace metal concentrations and grain size except for Cu and Zn.

Concentrations of Cu were found to be positively correlated with phi sizes 9 through 14. These phi categories correspond to medium clay sediments and finer sediments (Shepard, 1973). Cu tended to be associated (found in higher concentrations) with sediments of finer grain size.

Concentrations of Zn were found to be associated with the 12-ϕ grain size category which corresponds to very fine clay sediments.

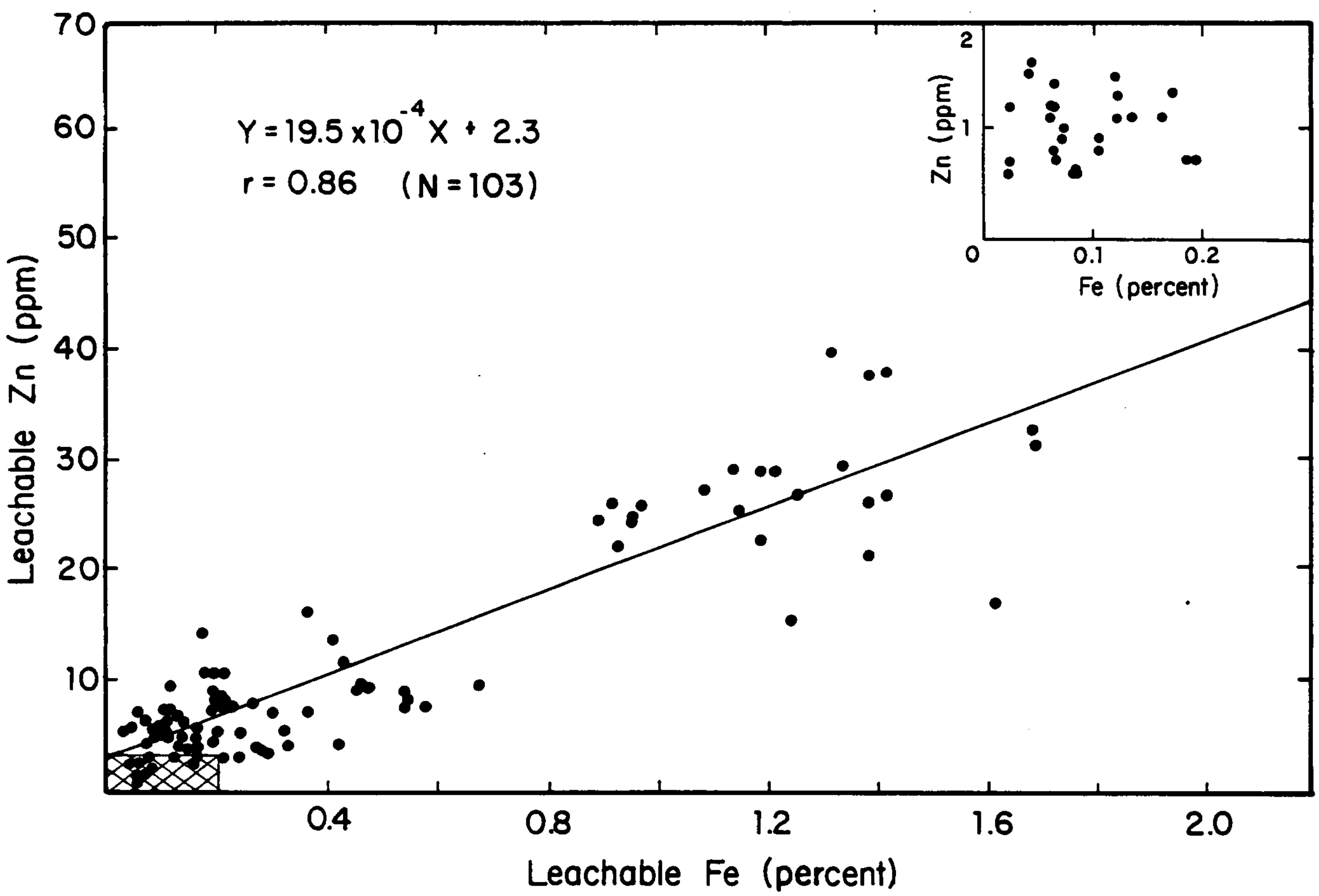

Figure 9-6. Sediment leachable Fe versus leachable Zn concentrations for the entire MAFLA area from Trefry et al. (1978). Insert shows comparable data for the southwest Florida shelf. Cross-hatched area denotes location of insert on graph.

Table 9-5. Spearman's r_s correlation coefficients between trace metal concentrations and grain size categories.

Phi	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Ba[a]	V[a]
	Trace Metals								
1	-0.05	0.50	0.05	0.03	0.39	-0.47	0.38	-0.25	0.14
2	-0.14	0.27	-0.12	-0.15	0.21	-0.26	0.41	-0.26	-0.12
3	-0.07	0.15	-0.31	-0.22	0.24	-0.06	0.33	-0.29	-0.34
4	0.26	0.04	-0.28	-0.11	0.10	-0.06	0.08	-0.16	-0.39
5	0.29	-0.16	-0.12	-0.13	0.07	-0.08	-0.01	0.08	-0.46
6	-0.40	-0.06	-0.25	0.13	0.23	-0.02	-0.45	0.21	-0.27
7	-0.29	-0.17	0.20	0.24	-0.39	0.06	-0.20	0.06	0.06
8	-0.10	-0.14	0.43	0.19	-0.34	0.05	-0.03	0.12	0.27
9	-0.16	-0.02	0.66*	0.21	-0.25	-0.14	0.36	0.01	0.23
10	-0.13	-0.06	0.73*	0.17	-0.34	-0.20	0.43	0.00	0.23
11	-0.04	-0.05	0.78*	0.19	-0.42	-0.24	0.41	0.09	0.21
12	-0.11	-0.08	0.74*	0.07	-0.40	-0.14	0.53*	0.03	0.14
13	-0.06	-0.20	0.71*	0.02	-0.46	-0.21	0.35	0.09	0.14
14	0.03	-0.19	0.60*	0.11	-0.41	-0.30	0.22	0.07	0.25

[a] Values based on one replicate per station.

* $p \leq 0.05$ (Steel and Torrie, 1960)

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10.0 SOFT BOTTOM BIOTA

10.1 Introduction

Fifteen soft bottom stations (Figure 10-1) were chosen after a preliminary television and still camera survey of the study area (see Section 3.0). Sampling included the collection of both visual data (television and still camera) and organisms (box corer and otter trawl). The objective of this sampling was to qualitatively and quantitatively characterize the epibiota and macroinfauna of soft bottom areas of the southwest Florida shelf. This characterization was necessary to provide the Minerals Management Service with preliminary information for decisions on leasing activities and environmental stipulations.

10.2 Materials and Methods

10.2.1 Field Methods

Sampling methodology for soft bottom stations was described in Section 5.0. Specifically, the following types of samples were collected during fall, 1980 and spring, 1981:

1) Box core samples to quantitatively characterize the infaunal communities of the study area;

2) Subsamples from box-cores to quantitatively characterize the sediment type, grain size distribution, and carbonate content in the study area (see Section 7.0 for description);

3) Video records and bottom photographs (slides) to generally characterize substrates, epifauna, and algae of the study area;

4) Otter trawl samples to qualitatively characterize the algae, epifauna, and fishes of the study area.

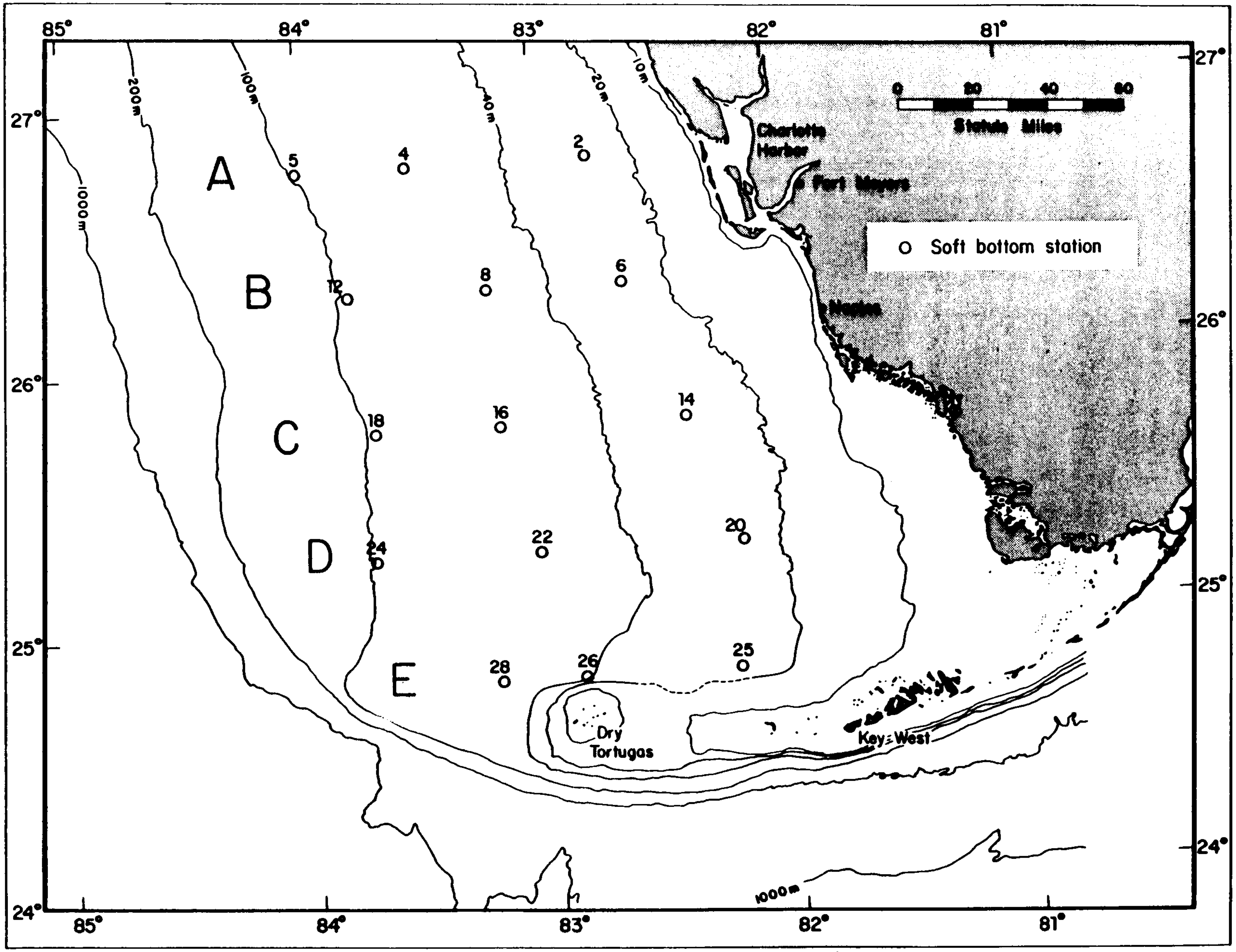


Figure 10-1. Location of soft bottom stations.

Box core samples were processed on board the ship by elutriating the sediment in a sieving device through a 0.5-mm mesh sieve (Figure 10-2). Briefly, the water was pumped through the sieving device, separating the floatable organisms into a 0.5-mm net. The heavier organisms with remaining sediment were removed, narcotized in 15% $MgSO_4$ solution for 30 min, and preserved in 10% buffered formalin. The light fractions (floatable organisms) were similarly preserved.

10.2.2 Laboratory Methods

Still camera photographs were analyzed using a photoreader. Data on type of bottom, algal species observed, percentage algal cover, and conspicuous animals observed were tabulated on standardized bench sheets.

Procedures for processing otter trawl samples are presented in Figure 10-3. Initially, macroalgae were separated from the samples. This fraction was rinsed with water, preserved in 6% buffered formalin, and analyzed using the procedures presented in Figure 10-4. Algae were sorted to the lowest practical taxon, blotted with paper towels to remove excess water, and weighed using a Cenco triple-beam balance. Otter trawl fauna were sorted and organisms identified to the lowest taxon possible. In many instances specimens were damaged or missing various body parts that made identification to the species level or, occasionally, higher taxonomic levels dubious. Attempts to do so would have substantially increased the probability of misidentification. In these instances, doubtful identifications were not made since they were not practical and often not possible.

The procedures used to process box core samples are presented in Figure 10-5. Macroalgae were removed from the box core samples and processed as outlined in Figure 10-4. Both fractions (light and heavy) from the box core samples were then washed through a 0.5-mm sieve and preserved in 70% isopropyl alcohol. The light fraction was rough sorted using a binocular dissecting microscope. The heavy fraction was pan sorted. Identifications were made using a high-power stereo microscope or a compound microscope.

To evaluate vertical distribution of infauna in the sediment, cores from Stations 4 and 12 (Spring Cruise, 1981) were divided into upper (0 to 15 cm

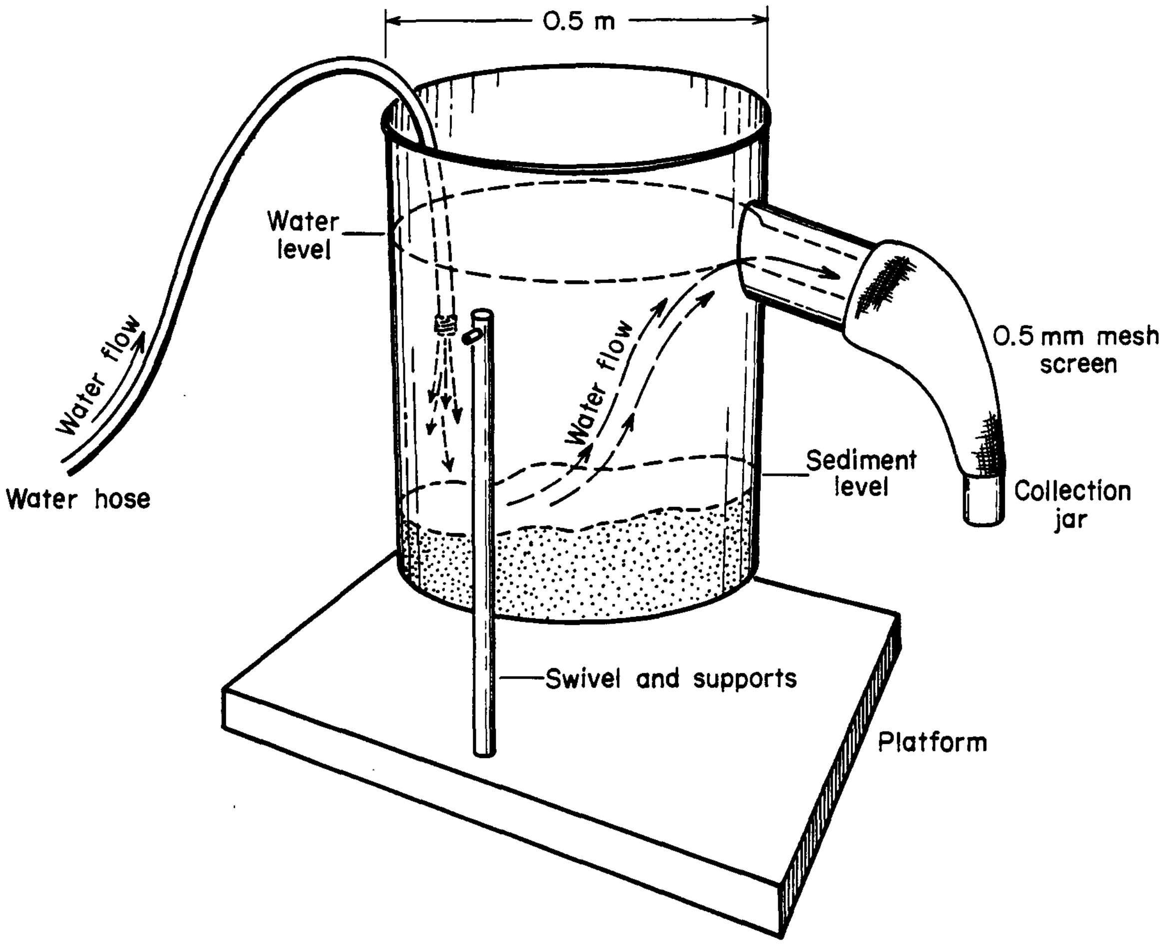


Figure 10-2. Box core sieving device.

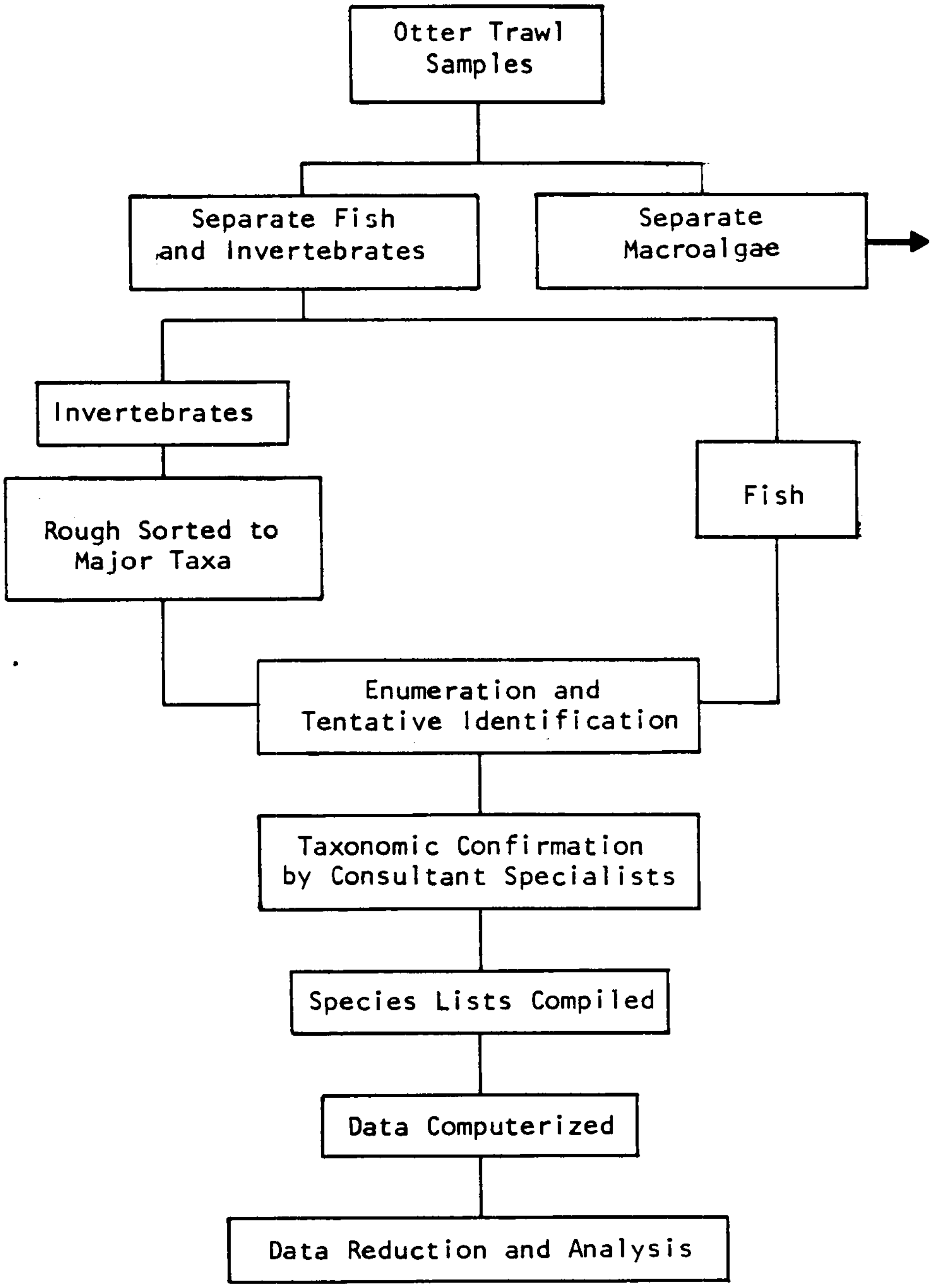


Figure 10-3. Schematic diagram for laboratory analysis of trawl samples.

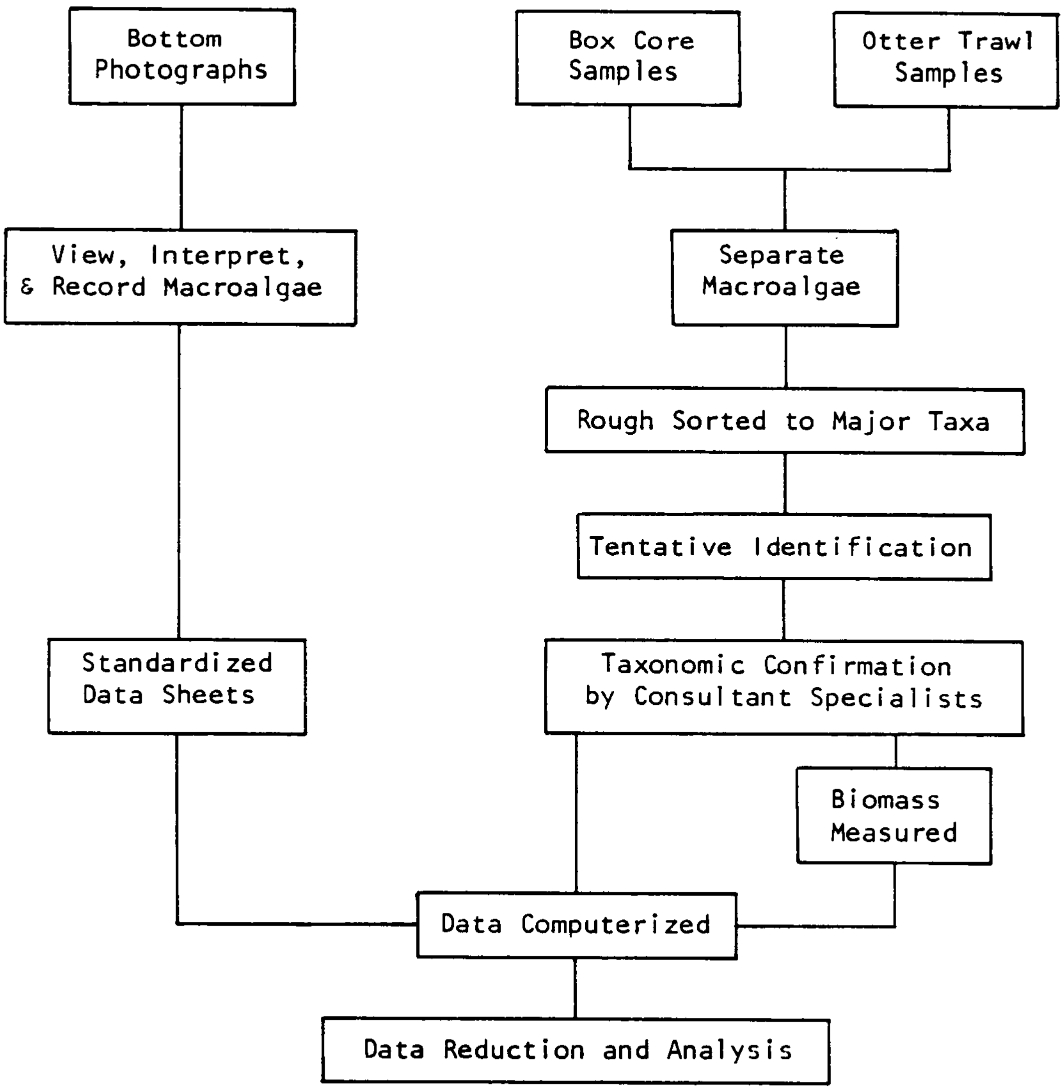


Figure 10-4. Schematic diagram for the laboratory analysis of macroalgae.

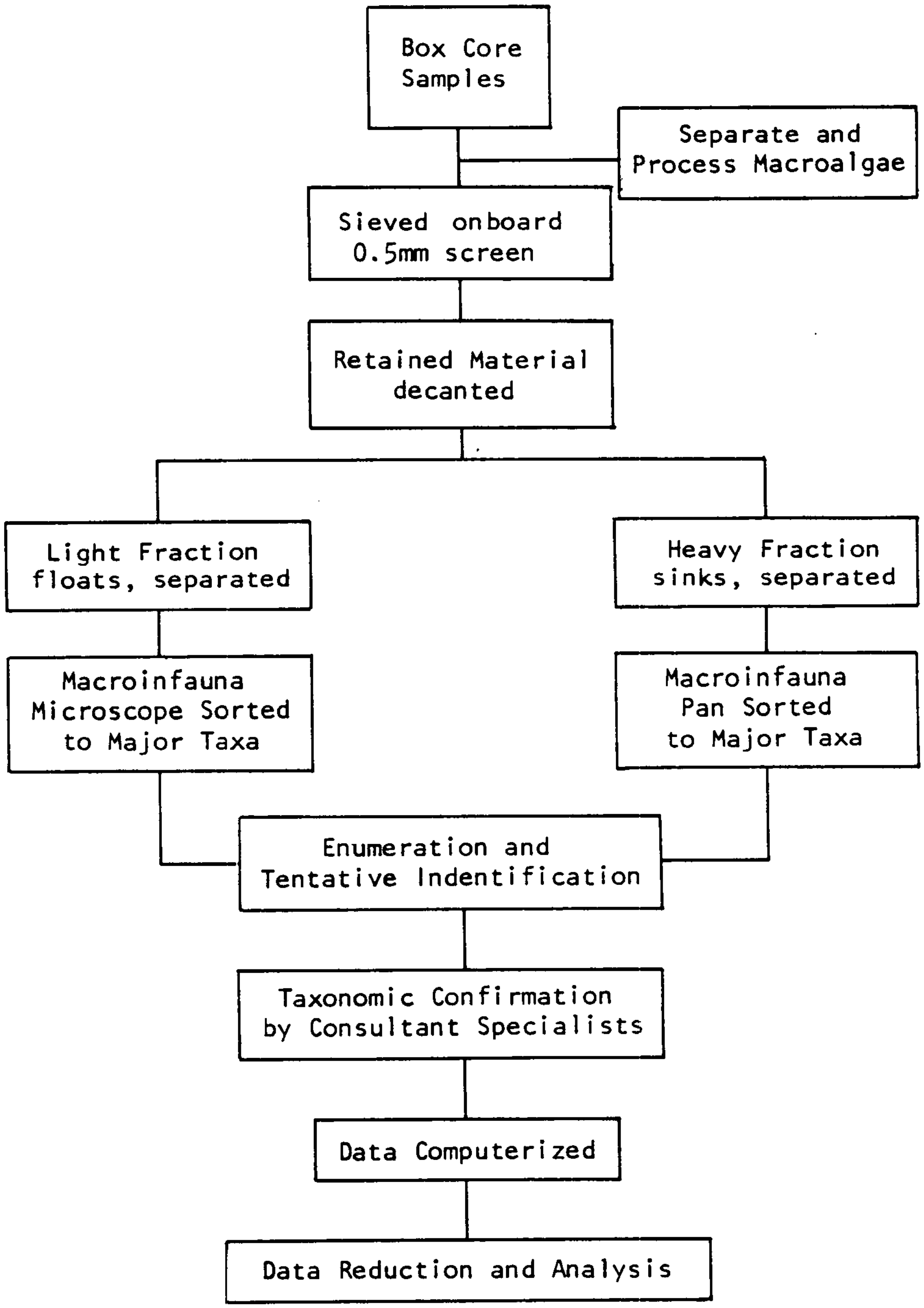


Figure 10-5. Schematic diagram for the laboratory analysis of macroinfauna.

deep) and lower (15 to 30 cm deep) fractions. Each fraction was processed as a separate sample. Sieve size selection was evaluated at Stations 6 and 8 (Spring Cruise, 1981) by initially sieving the sample through a 1.0-mm sieve and then through a 0.5-mm sieve. Organisms retained by each sieve were processed as separate samples. Comparisons of the upper and lower fractions, the sieve size fractions, and species saturation curves were made to assess the adequacy of the box core samples in characterizing the macroinfaunal communities of the study area. Results of the laboratory analysis were computerized for further analysis.

Data analysis consisted of computing the following community parameters:

1) Faunal density, which was reported as numbers of individuals per square metre;

2) Taxonomic richness, which was reported as the total number of taxa collected per station;

3) Margalef's index (Margalef, 1958), which was computed using

$$D = (S-1)/\log_e N,$$

where S is the number of taxa and N is the total number of individuals;

4) Shannon-Weaver index of diversity (Shannon and Weaver, 1963), which was computed using

$$H' = -\Sigma\, p_i \log_e p_i$$

where p_i is the portion of the individuals of taxon i relative to the total number of individuals;

5) Shannon-Weaver index of diversity with Basharin's correction (Basharin, 1959) which was computed using

$$H'' = H' - (S-1)/2N$$

where H' is the Shannon-Weaver index of diversity, S is the total number of taxa, and N is the total number of individuals;

6) Gini's index of diversity, which was computed using the dominance measure

$$DM = \Sigma\, n_i\, (n_i-1)/N\,(N-1) \qquad \text{(Simpson, 1949)}$$

where n_i is the number of individuals of taxon i and N is the total number of individuals, and using

$$d = 1 - DM \qquad \text{(Gini, 1912)}$$

to compute actual diversity; and

7) Equitability (Pielou, 1966), which was computed using

$$J' = H'/ \log_e S$$

where H' is the Shannon-Weaver index of diversity and S is the total number of taxa.

Faunal similarity indices used were as follows:

1) The Morisita's index (Morisita, 1959). The computational formula for this index is

$$C\lambda = 2 \sum_{i=1}^{s} n_{1i}\, n_{2i} \,/\, (\lambda_1 + \lambda_2)\quad N_1\, N_2$$

where

$$\lambda_1 = \sum_{i=1}^{s} \frac{n_{1i}\ (n_{1i} - 1)}{N_1\ (N_1 - 1)}$$

and

$$\lambda_2 = \sum_{i=1}^{s} \frac{n_{2i} \quad (n_{2i} - 1)}{N_2 \quad (N_2 - 1)}$$

and where N_1 and N_2 are the total number of individuals in samples 1 and 2, and n_{1i} and n_{2i} are the number of individuals of the i th taxon in samples 1 and 2. The value of $C\lambda$ is approximately 1 when the samples are identical and 0 when no common taxa are present. This index is relatively free from sample size effects.

2) The Bray-Curtis index (Smith, 1976). This index is called the Czekanowski coefficient for binary (presence-absence) data. The formula for this index is

$$D_{ij} = \sum_{k=1}^{n} \left| x_{ki} - x_{kj} \right| / \sum_{k=1}^{n} (x_{ki} + x_{kj})$$

where D_{ij} is the ecological distance between samples i and j, X_{ki} is the abundance of taxon k in sample i, X_{kj} is the abundance of taxon k in sample j, and n is the number of taxa. A flexible sorting algorithm was used for the clustering analysis which used the Bray-Curtis index.

10.3 Results

10.3.1 Epiflora

10.3.1.1 Photographic Analysis

Values of the average percent incidence of macroalgae (Fall and Spring Cruises combined), defined as the percent of the still camera photographs in which macroalgae were present, are shown in Figure 10-6. These values ranged from 95.1% at Station 4 to 0% at Stations 12, 25, and 26. The low values at Station 25 were due to the high turbidity (low visibility) which hindered macroalgae observations. Higher values were found at Stations 4, 16, 20, and 28.

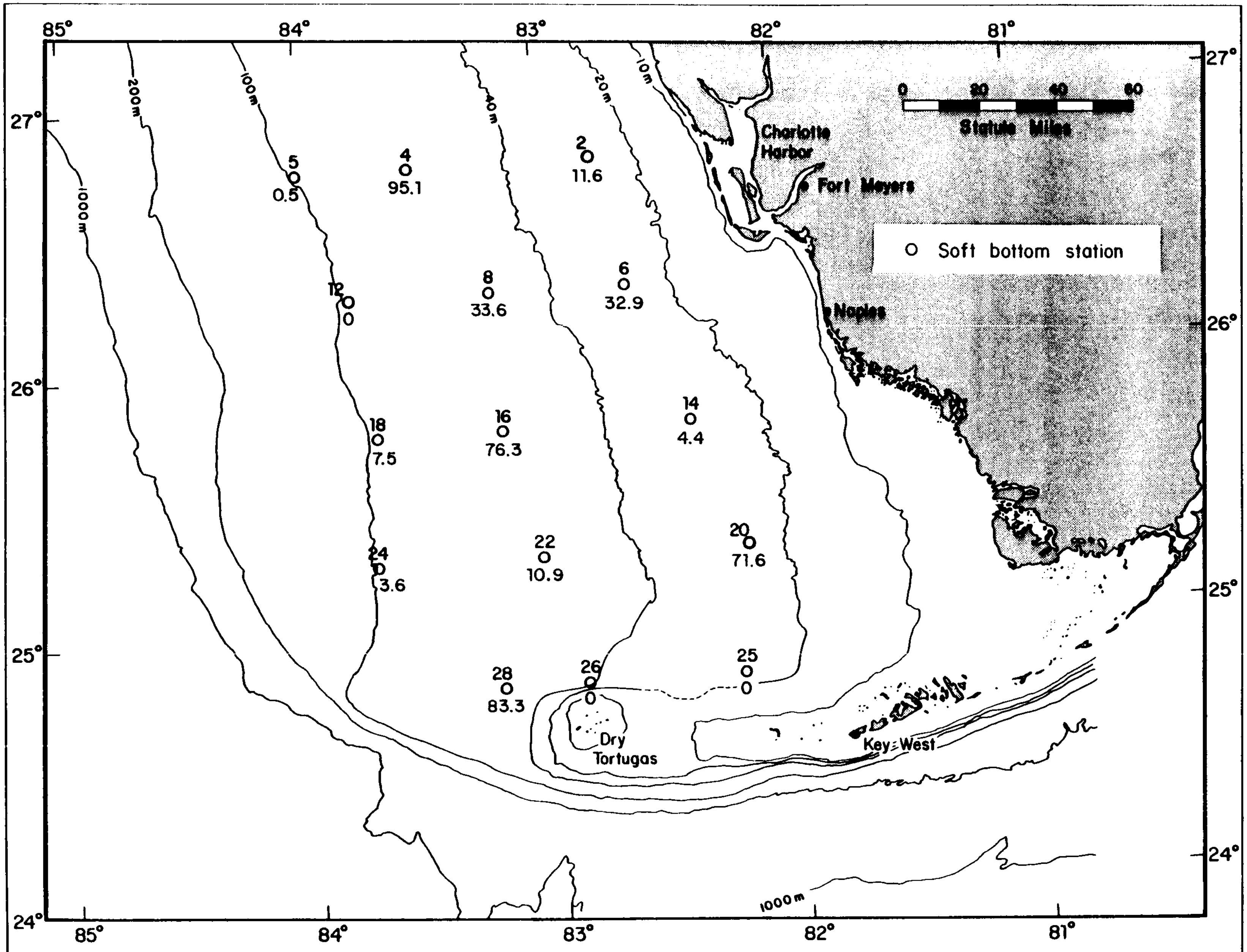


Figure 10-6. Mean percent incidence of macroalgae among still camera photos taken at soft bottom stations.

Analysis of the photographic data revealed that the frequency of stations having macroalgae was variable among transects. All of the stations on Transects A, C, and D, two stations on Transect B, and one station on Transect E had macroalgae present.

Additionally, the proportion of inner shelf stations (20 to 40 m) at which macroalgae were not found (0.2) was equal to the proportion of deeper stations at which macroalgae were not found. This observation suggested that depth was not a factor within the study area with respect to the distribution of macroalgae, i.e., all depths appeared to be in the photic zone.

Resolution of the photographs was sufficient to distinguish taxonomic groups among Chlorophycophyta, and biomass dominants (e.g., *Caulerpa* spp., *Halimeda* spp., *Udotea* spp.) were recognizable. Forms of red and brown algae and mixtures of species from more than one division were less distinct. Percent incidence of these taxonomic groups in algal slides taken at vegetated stations is presented in Table 10-1. *Caulerpa* spp. (green algae) occurred at 10 of the 12 vegetated soft bottom stations, with a mean percent incidence of 50% in the algal photographs. Unidentified Chlorophycophyta (green algae) were the most frequently encountered group (11 of 12 vegetated stations) and occurred, on the average, in 18% of the photographs from stations at which algae were present. *Halimeda* spp. (green algae) occurred with a mean percentage of 14% in the algal slides from the vegetated stations.

A similar pattern of distribution of cover (as a percent of vegetated area) was found. Average percent coverage of *Caulerpa* spp. was greatest among the recognizable groups of taxa comprising, on the average, 60% of the vegetated area, and unidentified Chlorophycophyta were second with a mean percent coverage of 13%. *Halimeda* spp. had a mean percent coverage of 9%. The percent coverages as an average percent of the vegetated area for macroalgae at the vegetated stations are presented in Table 10-2.

10.3.1.2 Box Core and Trawl Sample Analysis

Box cores produced more algae than otter trawls during both seasons. Trawl catches usually consisted of drift algae or fragments of attached forms. The

Table 10-1. Composition of macroalgae expressed as percent incidence in photographs from the vegetated soft bottom stations.

	Vegetation Group % Incidence*						
Vegetated Station	A	B	C	D	E	F	G
2	15	10	5	50	15	0	10
4	6	95	1	25	3	1	8
5	1	0	0	0	0	0	0
6	97	0	0	3	0	0	0
8	91	13	1	6	0	0	0
14	71	0	0	29	0	0	0
16	89	25	1	4	0	0	3
18	0	0	0	23	0	0	77
20	77	3	6	22	0	0	0
22	71	0	0	17	0	0	14
24	0	0	40	20	0	0	40
28	81	23	0	13	0	0	1

* All vegetation groups were mutually exclusive categories and were defined as follows:

A - *Caulerpa* spp.

B - *Halimeda* spp.

C - Other singular species, usually *Udotea* spp.

D - Unidentified Chlorophycophyta (green algae)

E - Unidentified Rhodophycophyta (red algae)

F - Unidentified Phaeophycophyta (brown algae)

G - Mixed unidentified Rhodophycophyta and Phaeophycophyta

Table 10-2. Average percent coverage by vegetation groups within vegetated areas at soft bottom stations.

Vegetated Station	Vegetation Group Cover* Average % of Vegetated Area within Station						
	A	B	C	D	E	F	G
2	5.0	7.0	1.0	50.0	22.0	0.0	15.0
4	2.0	82.0	0.2	13.0	1.0	0.2	3.0
5	100.0	0.0	0.0	0.0	0.0	0.0	0.0
6	99.0	0.0	0.0	1.0	0.0	0.0	0.0
8	92.0	5.0	0.4	2.0	0.0	0.0	0.0
14	75.0	0.0	0.0	25.0	0.0	0.0	0.0
16	94.0	4.0	<0.2	0.7	0.0	0.0	1.0
18	0.0	0.0	0.0	41.0	0.0	0.0	59.0
20	86.0	1.0	3.0	9.0	0.0	0.0	0.0
22	89.0	0.0	0.0	7.0	0.0	0.0	4.0
24	0.0	0.0	93.0	2.0	0.0	0.0	5.0
28	79.0	12.0	0.0	8.0	0.0	0.0	<0.2

* All vegetation groups were mutually exclusive categories and were defined as follows:

A - *Caulerpa* spp.

B - *Halimeda* spp.

C - Other singular species, usually *Udotea* spp.

D - Unidentified Chlorophycophyta (green algae)

E - Unidentified Rhodophycophyta (red algae)

F - Unidentified Phaeophycophyta (brown algae)

G - Mixed unidentified Rhodophycophyta and unidentified Phaeophycophyta condition of algae collected by box cores was variable. Identifications were impeded by fragmentation of delicate forms, absence of holdfasts, and uneven preservation.

At the stations where macroalgae were found, the number of species ranged from 1 to 8 (including unique fragments), and averaged 3 to 4 species. The highest number of species was found at Station 2 (Table 10-3). The most frequent species were Caulerpa sertularioides and Halimeda discoidea. The alga tentatively identified as Fauchea peltata (red alga) and several species of Sargassum also were common at numerous stations. Sargassum natans is typically considered pelagic and, therefore, was most likely collected as the box core or otter trawl passed through the water column. Overall, samples were dominated by Chlorophycophyta and Rhodophycophyta. There were 50% fewer species in April 1981 (Spring Cruise) than in November 1980 (Fall Cruise). Species present in 1980, but absent in 1981, included Pseudocodium floridanum (green alga), Udotea conglutinata (green alga), and Sargassum natans (brown alga).

Wet weight biomass data reflected the relative abundance of species noted by incidence and photographs (Table 10-4). The ranked incidences of species was correlated significantly ($r = 0.83$, $p < 0.001$) with individual wet weights of the species, indicating the prevalence of attached algae. Use of parametric correlation coefficient requires a bivariate normal distribution (Elliott, 1977). Biomass is not normally distributed since areas of low mean biomass have a lower variability of biomass while areas of high biomass have higher variability. It was, therefore, necessary to transform the biomass values in order to obtain a valid test of the correlation between biomass and the relative abundances of the species. Biomass values were transformed using logarithms and percent total values were transformed using arcsine - square root.

Marine angiosperms (flowering plants), Thalassia testudinum (turtle grass) and Halophila baillonis (seagrass), were recovered in box core samples. The turtle grass was present in small quantities at Station 24 (depth 88 m) with Caulerpa spp., and at Station 25 (depth 24 m), where it was the only macrophyte recovered in the study. Halophila spp. were collected at Station 14 (depth 26 m) with Caulerpa spp. and Halimeda spp.

Table 10-3. Algal species composition of vegetated stations based on box core and trawl samples (+ denotes presence, 0 denotes absence).

Station	Species	Fall Cruise	Spring Cruise
2	*Halimeda discoidea*	+	+
	Pseudocodium floridanum	+	0
	Udotea conglutinata	+	0
	Udotea cyathiformis	+	0
	Sargassum hystrix	+	0
	Chondria floridana	+	+
	Fauchea peltata (?)	+	+
	Unknown fragment 1	+	0
4	*Caulerpa sertularioides*	+	0
	Halimeda discoidea	+	+
	Pseudocodium floridanum	+	0
	Dictyota sp.	+	0
	Fauchea peltata (?)	+	+
5	*Halimeda discoidea*	0	+
6	*Caulerpa sertularioides*	+	0
	Fauchea peltata (?)	+	0
8	*Caulerpa sertularioides*	+	+
	Halimeda discoidea	+	+
	Fauchea peltata (?)	0	+
14	*Caulerpa sertularioides*	+	+
	Halimeda discoidea	+	0
	Unknown fragment 2	+	0
16	*Caulerpa sertularioides*	+	+
	Halimeda discoidea	+	+
	Sargassum filipendula	+	+
	Sargassum polycertatium	+	+
	Fauchea peltata (?)	0	+
18	*Caulerpa sertularioides*	+	0
	Sargassum natans	+	0
22	*Caulerpa sertularioides*	+	+
	Unknown fragment 3	+	0
24	*Caulerpa sertularioides*	+	+
	Sargassum hystrix	0	+
28	*Caulerpa sertularioides*	+	+
	Halimeda discoidea	+	+
	Sargassum hystrix	0	+
	Unknown fragment 4	+	0
	Unknown fragment 5	+	0

Table 10-4. Distribution of wet weights for all macroalgae (at all stations).

Species	Total Weight (g)	% Total
Caulerpa sertularioides	1,738.7	81.3
Halimeda discoidea	146.4	6.8
Sargassum hystrix	78.0	3.6
Chrondria floridana	52.5	2.4
Sargassum natans	40.2	1.8
Fauchea peltata	18.1	0.8
Pseudocodium floridanum	7.6	0.8
Sargassum filipendula	10.3	0.4
Sargassum polyceratium	10.0	0.4
Dictyota sp.	9.0	0.4
Unknown fragment 3	4.0	0.1
Unknown fragment 4	3.8	0.1
Unknown fragment 2	2.7	0.1
Udotea conglutinata	2.4	0.1
Unknown fragment 1	2.4	0.1
Udotea cyathiformis	1.2	<0.1

10.3.2 Epifauna and Fishes

10.3.2.1 Fishes

Fishes were collected at soft bottom stations using an otter trawl (Section 5.0). The number of taxa collected at each station can be used for comparative purposes, but the relative abundance of animals collected must be interpreted with caution due to the qualitative nature of the trawls.

A total of 99 taxa of fishes was collected during the Fall Cruise. The number of taxa collected at each station, along with the number of animals sampled, is presented in Table 10-5. The number of taxa present ranged from one at Station 20 to 34 at Station 16. Of the 2,398 individuals that were returned to the lab, 1,063 (44%) were represented by five species: the dusky flounder Syacium papillosum (16%), the inshore lizardfish Synodus foetens (12%), the bank sea bass Centropristis ocyurus (6%), the dwarf sand perch Diplectrum bivittatum (5%), and the fringed filefish Monacanthus ciliatus (5%). Of the 99 taxa present, 52 were represented by 5 or fewer individuals.

Bothidae was the most widely represented family collected. Bothids constituted 24% of the total catch (576 animals) and 12% of the total number of taxa (12 species) collected. This family was present at all stations except Station 20. Syacium papillosum was the most common bothid and was taken at all stations except 2, 6, 20, and 25.

Triglidae was the second most widely represented family collected. A total of 8 species of triglids was collected, constituting 5% of the total catch (123 individuals) and 8% of the total taxa. Searobins were collected at all stations except 6, 20, and 25.

Spring Cruise fish collections are summarized in Table 10-5. In all, 77 taxa were taken, 39 of which were represented by 5 individuals or less. Stations 2 and 14 accounted for the lowest numbers of taxa captured (7 at each station). Maximum taxonomic richness was observed at Station 8, where 33 fish taxa were collected.

Table 10-5. Number of taxa and relative abundance of fishes collected during the Fall and Spring Cruises.

	Fall Cruise		Spring Cruise	
Station	No. of Taxa	No. of Fish	No. of Taxa	No. of Fish
2	8	20	7	47
4	18	38	20	262
5	21	377	11	26
6	21	126	11	101
8	28	327	33	273
12	20	86	16	100
14	17	75	7	58
16	34	340	29	94
18	17	78	15	86
20	1	1	11	35
22	22	89	24	123
24	19	264	20	120
25	16	172	11	49
26	21	169	13	431
28	32	236	25	221

A total of 4 species constituted 48% of the total catch of 2,026 individuals. The four most abundant species were: the ragged goby Bollmannia communis (17%), Synodus foetens (12%), Syacium papillosum (11%), and Centropristis ocyurus (7%). Bollmannia communis was captured predominantly (350 of 352 specimens) at Station 26.

The Bothidae and Triglidae were again the most prevalent families collected. A total of 12 bothids and 8 triglids was collected. Together they constituted 15% of the species and 22% of the total number of fish collected. Syacium papillosum was the most abundant bothid (228 specimens) and was collected at every station except Station 26.

Very few fish were observed in the visual records. It was believed this was primarily due to the television's limited field of view and avoidance of the towed sled by the fish (Continental Shelf Associates, Inc., 1982; Thompson et al., 1982).

10.3.2.2 Epifauna

Thirty-three taxa of sponges and one ascidian were collected in the otter trawl samples from the soft bottom stations, which indicated that the trawl passed over live bottom patches in addition to soft bottom areas. Other epifauna included crustaceans, molluscs, and echinoderms. A total of 209 taxa of macroinvertebrates was identified from the Fall Cruise otter trawl samples, and a total of 164 taxa was identified from the Spring Cruise otter trawl samples. A list of these taxa is presented in Appendix B-6.

Visual observations at the stations generally indicated low abundances of epifauna, which was substantiated by the trawl samples. The visual records indicated that a number of stations (2, 5, 8, 14, 16, 20, 22, and 28) had isolated sponges and corals present, but in abundances much less than one individual per m^2.

10.3.2.3 Faunal Similarity

Data from the otter trawl samples were analyzed using normal and inverse clustering analysis. The Czekanowski coefficient, which is the qualitative equivalent of the Bray-Curtis similarity coefficient (Smith, 1976), was used as the distance measure. This ecological distance measure utilizes binary (presence-absence) data, and was chosen due to the qualitative nature of the otter trawl data.

The results of the normal analysis of the Fall Cruise otter trawl data are presented in Figure 10-7. The associated dendrogram for this analysis is presented in Figure 10-8. Three groups of stations were indicated from the analysis. The largest group of stations (identified as I on Figure 10-7) was composed of the offshore middle shelf stations (5, 12, 18, and 24) and four inshore middle shelf stations (8, 16, 22, and 28). The sponges Ircinia felix and Ircinia strobilina, the crabs Portunus spinicarpus and Stenocionops furcata, and the shrimp Solenocera atlantidis and Tozeuma serratum consistently occurred at these stations.

Three inner shelf stations (2, 6, and 14) and the inshore middle shelf station on Transect A (4) formed a second group of stations (identified as II on Figure 10-7). Three species of portunid crabs (Portunus spinimanus, Portunus ordwayi, and Portunus gibbesi) and two species of penaeid shrimp (Metapenaeopsis goodei and Sicyonia brevirostris) were found at the stations in this group.

The southerly inner shelf stations (20 and 25) and an inshore middle shelf station on Transect E (26) composed the third group of stations (identified as III on Figure 10-7). The crabs Hepatus epheliticus and Portunus spinimanus, the penaeid shrimps Penaeus duorarum and Sicyonia typica, and Alpheus spp. (caridean shrimp) were found at the stations in this group.

Results of normal clustering analysis of the Spring Cruise otter trawl data are presented in Figure 10-9. The associated dendrogram for this analysis is presented in Figure 10-10. The first group of stations was composed of four offshore middle shelf stations (5, 12, 18, and 24) and two inshore middle shelf stations (8 and 16) (identified as I on Figure 10-9). Taxa which were found at

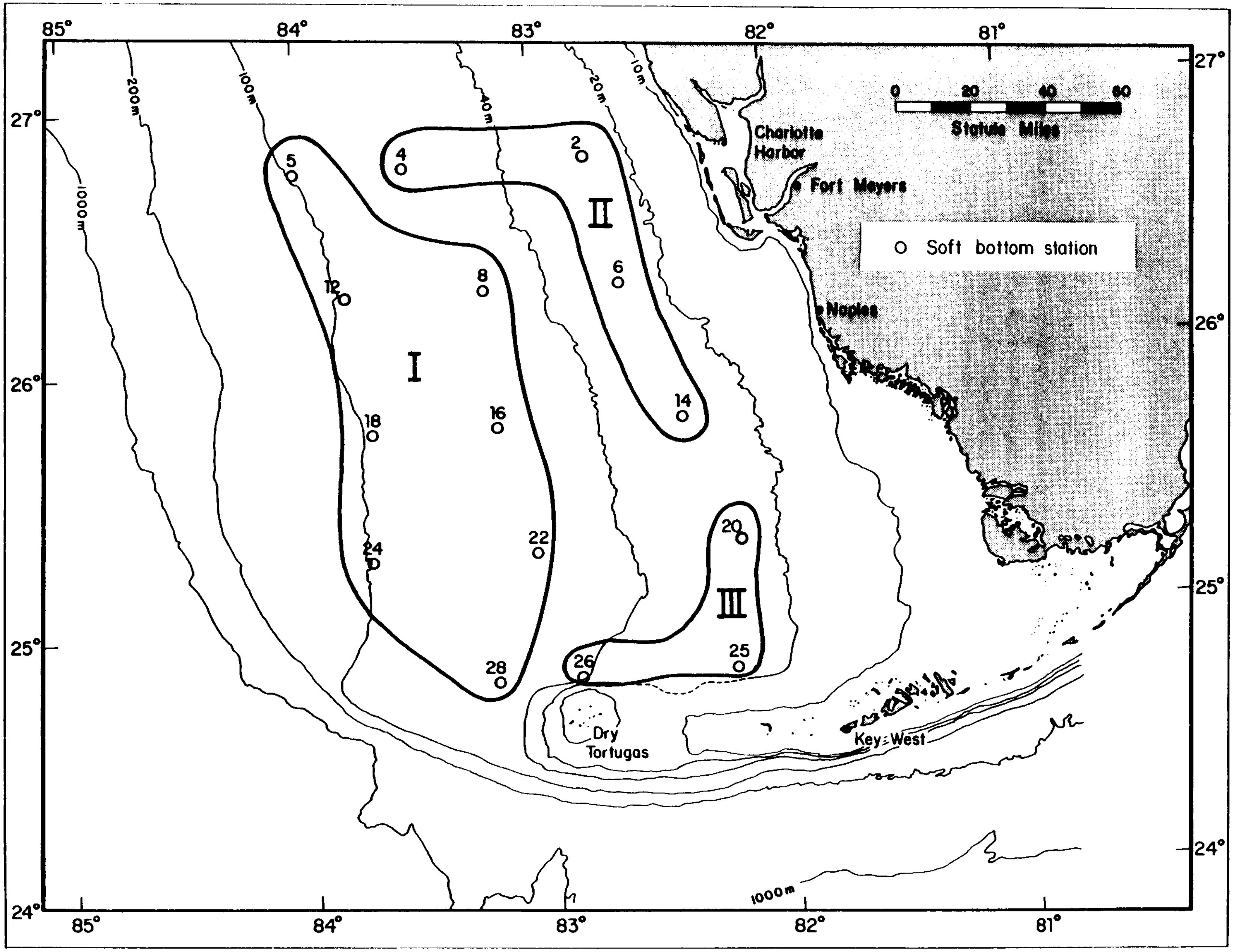
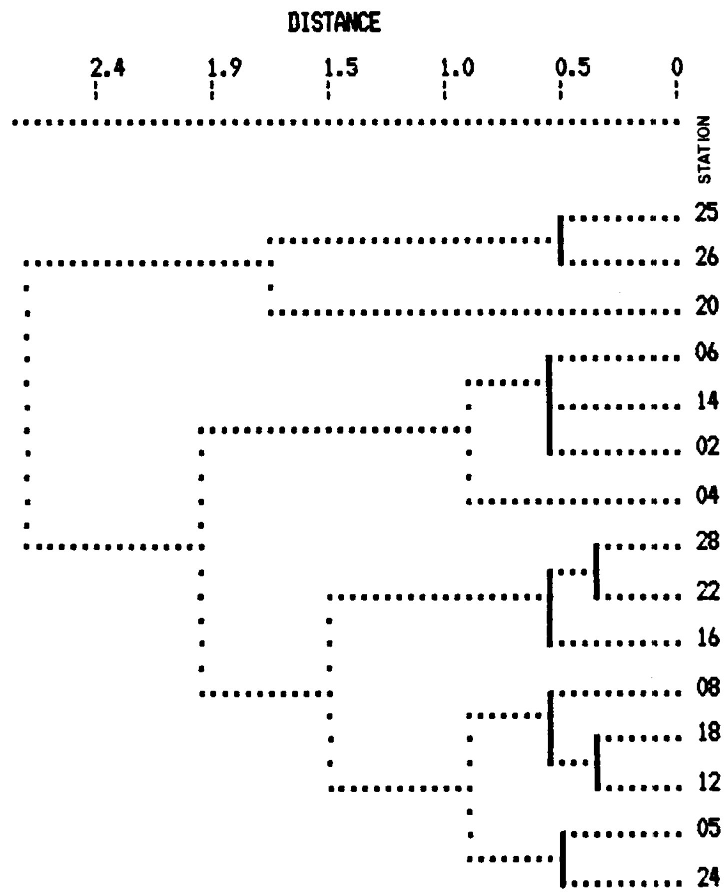


Figure 10-7. Results of normal clustering analysis of Fall Cruise trawl data.

SW FLORIDA-OTS QUAL DATA->3 OCC - REPS AVERAGED - CRUISE 3
SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.6000 - % INCREASE ABOVE THRESHOLD= 25.85.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.6000 0.7000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .
NOTE: LABEL ON INPUT SAS DATA SET IS "S

Figure 10-8. Dendrogram for normal clustering analysis of Fall Cruise trawl data.

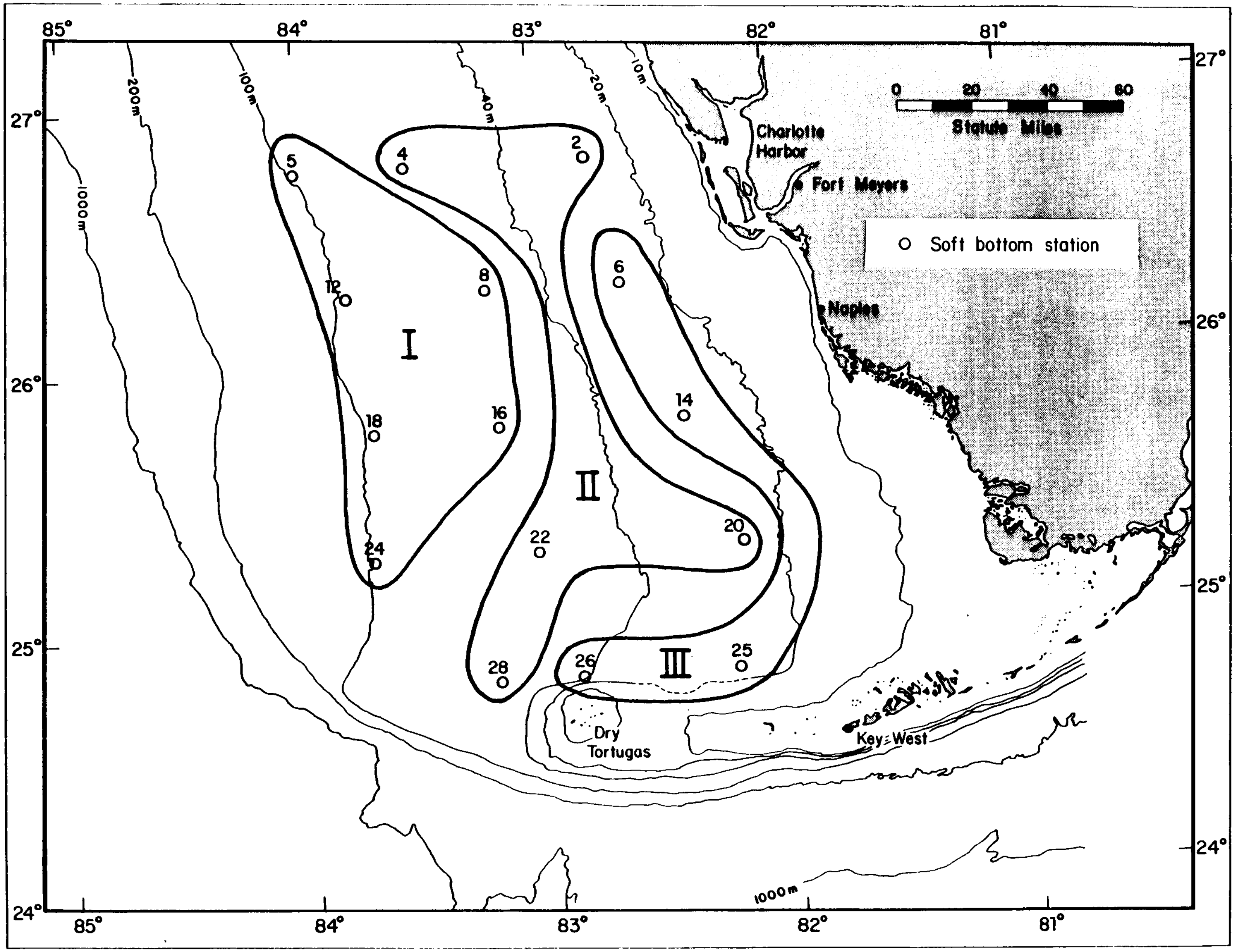
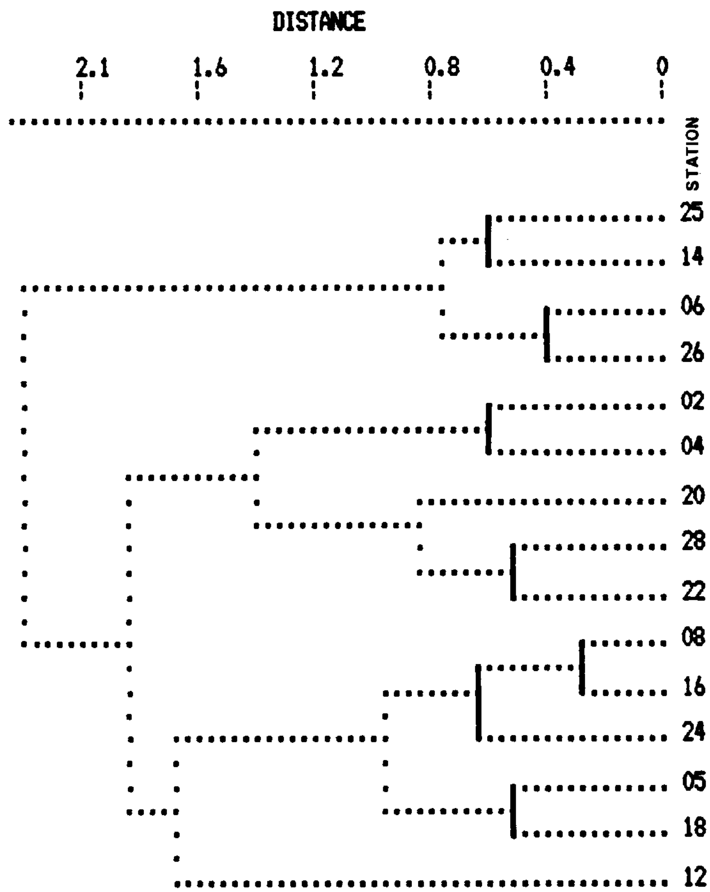


Figure 10-9. Results of normal clustering analysis of Spring Cruise trawl data.

SW FLORIDA-OTS QUAL DATA->3 OCC - REPS AVERAGED - CRUISE 4
SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.7000 - % INCREASE ABOVE THRESHOLD= 16.65.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.7000 0.8000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .
NOTE: LABEL ON INPUT SAS DATA SET IS "S

Figure 10-10. Dendrogram for normal clustering analysis of Spring Cruise trawl data.

the stations in this group included Podochela lamelligera (brachyuran crab), Stenorhynchus sp. A (brachyuran crab), unidentified Paguridae (anomuran crabs), Tosia parva (starfish), and unidentified Ophiuroidea (brittle stars).

The second group of stations was composed of three inshore middle shelf stations (4, 22, and 28) and two inner shelf stations (2 and 20) (identified as II on Figure 10-9). Two algae, Fauchea hassleri (red alga) and Halimeda discoidea (green alga), were among the epibiota at these stations. Epifauna at these stations included the sponges, in family Hymedesmiidae and Aiolochroia crassa, and unidentified Ophiuroidea.

Taxa at the third group of stations (inner shelf Stations 6, 14, and 25 and inshore middle shelf Station 26) (identified as III on Figure 10-9) included Portunus spinimanus (crab), Parthenope granulata (crab), and the penaeid shrimps Penaeus duorarum and Sicyonia brevirostris. None of the taxa used in the clustering analysis were unique to this group of stations, but were consistently found at the stations of this group.

Normal clustering analysis of the combined otter trawl data for both cruises revealed no distinctive trends in temporal variation at the stations.

10.3.3 Macroinfauna

10.3.3.1 Adequacy of Replication

Five box core samples were collected at each of the 15 soft bottom stations and processed for macroinfauna. To evaluate the adequacy of this level of replication, taxon area curves (Gleason, 1922; Holme, 1953) were constructed for each station for Fall and Spring Cruises (Appendix B-7; see Figure 10-11 for examples). The relative percentage increase between replicates 4 and 5 was used as the criterion for determination of adequate replication, with a greater than 10% increase of additional taxa considered unacceptable (i.e., not enough replication). Due to the random method of obtaining bottom grab samples (i.e., remotely deployed) randomization of replicates for determination of taxon saturation curves was deemed adequate. However, it was realized that certain combinations of replicate order will change the configuration of the saturation

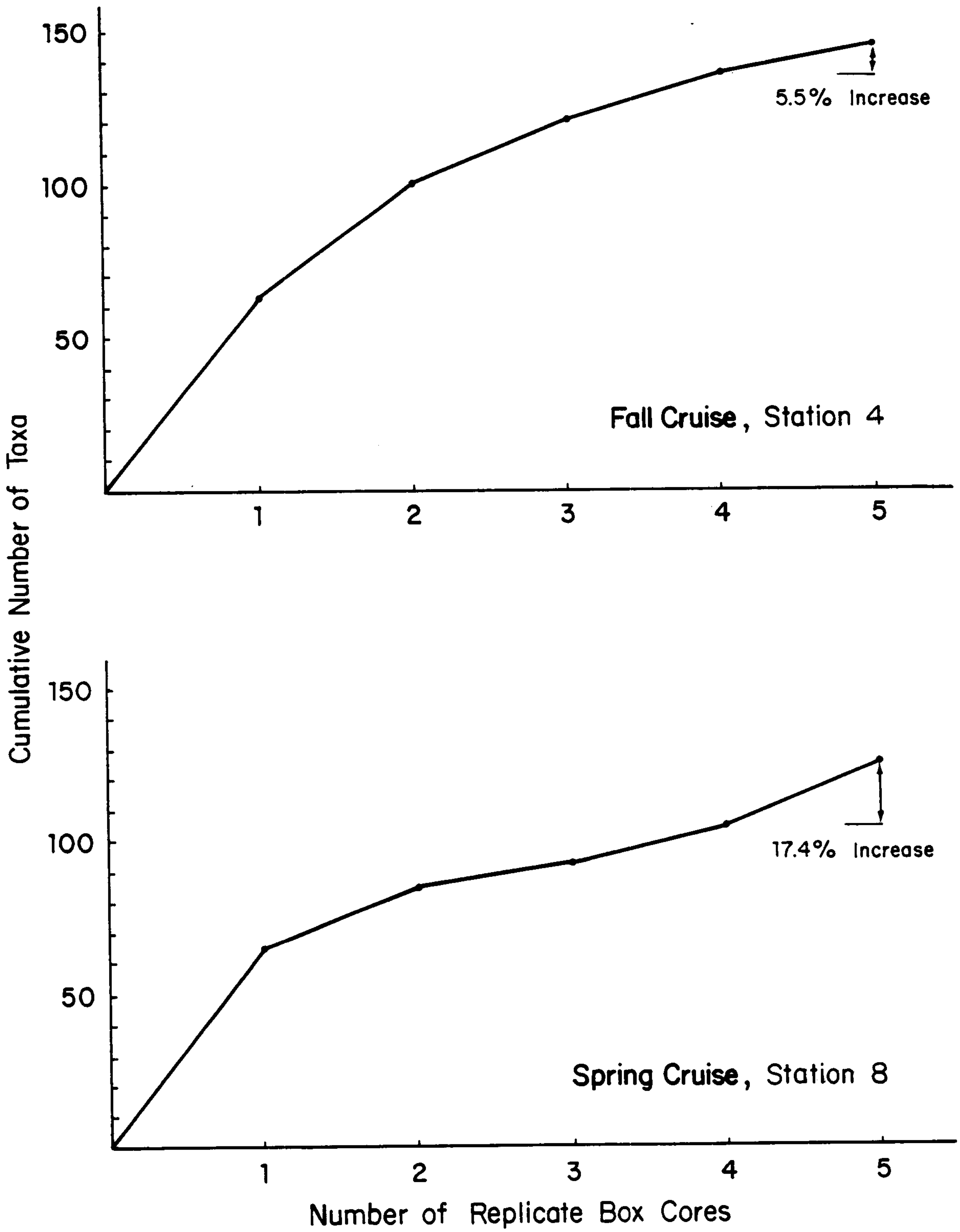


Figure 10-11. Examples of macroinfauna taxon - area curves.

curves. Therefore, each taxon saturation curve was derived as the mean of three replicate combination orders as follows: 1) replicates 1, 2, 3, 4, and 5; 2) replicates 5, 4, 3, 2, and 1; and 3) replicates 2, 3, 4, 5, and 1. The ideal saturation curve would be the average or mean curve of all possible replicate orders (120 combinations for 5 replicates). It was found that a mean curve using 3 replicate combinations significantly reduced the bias of a single curve, and the mean curve was not nearly as time consuming to construct as the "ideal" curve. There are no generally agreed upon standards of sampling adequacy for the marine benthos. The taxon area criterion has been discussed by various authors (Gleason, 1922; Holme, 1953; Ursin, 1960; Williams, 1964; and Holme and McIntyre, 1971) but a universal standard of "saturation" has not been established. This is partially due to the fact that the number of samples required to "adequately" sample an area depends upon the variability of the individual observations, which, in turn, is dependent upon the size or scale of the individual station. A large station would require a greater number of samples than a small station, presumably because the large station would encompass a greater number of habitats and therefore a greater number of species.

Results of the analysis of taxon saturation are summarized in Table 10-6. For the Fall Cruise, the mean increase between replicates 4 and 5 was 9.9%. Eight of the stations met the criterion of less than or equal to 10% increase; seven stations exhibited a greater than 10% increase. For the Spring Cruise, the mean increase between replicates 4 and 5 was 10.2%. Ten of the stations met the criterion of less than or equal to 10% increase and five stations exhibited an increase greater than 10%. Stations that did not have an acceptable saturation during the Fall Cruise were 5 (11.3%), 8 (11.5%), 12 (11.7%), 16 (12.5%), 18 (10.1%), 22 (11.9%), and 24 (13.7%); similarly, stations that did not have an acceptable saturation during the Spring Cruise were 8 (17.4%), 12 (12.3%), 18 (16.3%), 20 (11.3%), and 24 (11.7%). Of the stations that did not have acceptable saturation, four were the same stations (8, 12, 18, and 24). Except for Stations 8 and 18 during the Spring Cruise, which showed increases of 17.4% and 16.3%, respectively, taxon saturations at all other stations were only slightly higher than the 10% criterion. It is of particular importance to note that of the stations that exceeded the 10% criterion, four of these did so for both cruises. This consistent deviation could have been the result of: 1)

Table 10-6. Percentage increase in taxa numbers from fourth to fifth replicates of taxon saturation curves.

Transect	Station No.	Fall Cruise	Spring Cruise
	2	7.5	5.3
A	4	5.5	9.3
	5	11.3	9.7
	6	9.7	10.0
B	8	11.5	17.4
	12	11.7	12.3
	14	8.1	9.5
C	16	12.5	9.4
	18	10.1	16.3
	20	9.2	11.3
D	22	11.9	7.7
	24	13.7	11.7
	25	9.0	7.3
E	26	8.5	9.9
	28	8.7	6.0
AVERAGE		9.9	10.2

too few samples being taken at these stations; or 2) station sizes were too large, thereby sampling multiple habitat types. Since the cores were deployed from a ship that was not at anchor (ship's position was maintained as close as possible to a fixed buoy), the second alternative as well as the first is quite feasible. Habitat patch sizes are known to be quite variable for the west Florida continental shelf (Gould and Stewart, 1955; Doyle and Sparks, 1980; Culter and Mahadevan, 1983, in prep.). However, inspection of the grain size data (Appendix B-4) did not reveal greater variability of the mean grain sizes among replicates at stations which exceeded the 10% criterion than at stations which did not exceed the 10% criterion. It was believed that the overall sampling effort yielded good results in spite of many samples which did not quite meet the "arbitrary" 10% saturation criterion. Additional replicates would have been valuable especially for the borderline saturation cases. Overall, the adequacy of soft bottom sampling with five box cores (0.325 m^2) can be considered generally acceptable in terms of taxon saturation, except at Stations 8 and 18 during the Spring Cruise.

10.3.3.2 Adequacy of Box Core Depth Penetration in Sediment

Results of the core fractionation analyses (comparison of upper and lower 15 cm of the box core sample) at Stations 4 and 12 are presented in Table 10-7. The upper 15-cm sediment fractions contained 95% of the total taxa found at both Stations 4 and 12, with only 5% of the "new" (exclusive) taxa found below 15 cm. Most of the individuals collected were also from the upper portion: 94% at Station 4 and 96% at Station 12. The relative proportions of taxa and number of individuals for upper versus lower portions varied only slightly between polychaete and non-polychaete faunal groups.

Eighteen taxa which were exclusively found in the lower 15 cm of the box core samples are listed in Table 10-8. Considering the data obtained from the upper 15 cm of the box core samples, these eighteen taxa added very little information on the fauna at the two stations examined. Therefore, sampling of the upper 15 cm of the core sample appears to be sufficient for collecting the majority of taxa and number of organisms at each station.

Table 10-7. Summary of results of core fractionation analysis of Spring Cruise box core samples.

		Number of Taxa (% of Total)			Number of Individuals (% of Total)		
Station	Core Fraction	Polychaetes	Non-Polychaetes	Combined	Polychaetes	Non-Polychaetes	Combined
4	Upper 15 cm	102 (92)	95 (99)	197 (95)	894 (93)	516 (94)	1410 (94)
4	Lower 15 cm	9 (8)	1 (1)	10 (5)	64 (7)	33 (6)	97 (6)
12	Upper 15 cm	81 (96)	67 (93)	148 (95)	756 (96)	343 (94)	1099 (96)
12	Lower 15 cm	3 (4)	5 (7)	8 (5)	30 (4)	20 (6)	50 (4)

Table 10-8. Listing of taxa found exclusively in the lower 15 cm of the box core samples.

Station	Taxa		Number of Individuals
4	*Dacrydium* sp.	(bivalve)	1
	Clavadorum sp.	(polychaete)	1
	Typosyllis sp.	(polychaete)	2
	Notomastus sp.	(polychaete)	1
	Branchiosyllis exilis	(polychaete)	1
	Sigalionidae sp.	(polychaete)	1
	Nereidae sp.	(polychaete)	1
	Onuphis pallidula	(polychaete)	1
	Glycera sp.	(polychaete)	1
	Exogone sp.	(polychaete)	1
12	Pogonophora sp.		1
	Processa cf. *vicina*	(decapod)	1
	Jerbarnia sp. A	(amphipod)	1
	Lysianopsis sp. A	(amphipod)	1
	Ampelisca sp. B	(amphipod)	1
	Palaenotus heteroseta	(polychaete)	1
	Nereidae sp.	(polychaete)	1
	Glyceridae sp.	(polychaete)	1

10.3.3.3 Adequacy of Sieve Size Used

The sieve size analyses also exhibited consistent results (Table 10-9). Slightly more than half (62% at Station 6; 57% at Station 8) of the enumerated taxa were retained on the 1.0-mm sieve. However, the majority of individuals were retained by the 0.5-mm sieve (81% at Station 6; 82% at Station 8).

Thirty-three taxa and fifty-four taxa were exclusively retained by the 0.5-mm sieve (i.e., taxa that passed through the 1.0-mm sieve) at Stations 6 and 8, respectively (Table 10-10). Considering the data base at these stations, it is obvious that the 0.5-mm sieve added substantial information in terms of faunal composition, richness, and density. Therefore, the 0.5-mm sieve, as used in the present study, was necessary to adequately describe the macroinfaunal communities in the study area.

10.3.3.4 Taxonomic Composition/Dominant Species

A total of 1,033 taxa was identified from 55,979 organisms collected during both sampling cruises. The Fall Cruise was represented by 678 taxa (24,965 individuals) and the Spring Cruise by 730 taxa (31,014 individuals).

Composite taxon lists and faunal counts for all stations sampled during the Fall and Spring Cruises are presented in Appendix B-8. Infaunal specimens were identified by consulting taxonomists to the lowest taxon possible. However, the condition of individual specimens (often immature or damaged) and the limitations imposed by gaps in existing systematic information for various groups often restricted identifications to relatively high taxonomic levels. Thus, in many instances, listings such as "unidentified Nemertina" or "Lumbrineidae spp." resulted.

Polychaetes were the most diverse invertebrate group, representing 50.7% (Fall Cruise) and 47.2% (Spring Cruise) of the total taxa collected (Table 10-11). Crustaceans were the next most diverse group with 29.0% (Fall Cruise) and 26.7% (Spring Cruise) of the total taxa. Molluscs represented 10.3% (Fall Cruise) and 17.0% (Spring Cruise). Minor miscellaneous taxa, such as oligochaetes, nematodes and nemertines, composed 9.6% and 9.1% for the Fall and Spring

Table 10-9. Summary of results of sieve size analysis of Spring Cruise box core samples.

Station	Sieve Size (mm)	Number of Taxa (% of Total) Polychaetes		Non-Polychaetes		Combined		Number of Individuals (% of Total) Polychaetes		Non-Polychaetes		Combined	
6	1.0	21	(62)	32	(62)	53	(62)	112	(21)	236	(33)	348	(19)
6	0.5	13	(38)	20	(38)	33	(38)	434	(79)	483	(67)	917	(81)
8	1.0	37	(58)	35	(57)	72	(57)	146	(16)	166	(21)	312	(18)
8	0.5	27	(42)	27	(43)	54	(43)	741	(84)	642	(79)	1383	(82)

Table 10-10. Listing of taxa which were exclusively retained by the 0.5-mm sieve (Spring Cruise sieve size analysis of box core sampling).

Station	Taxa		Number of Individuals
6	Glottidia pyramidata	(brachiopod)	10
	Pseudotanais sp. A	(tanaid)	15
	Leptochelia sp. A	(tanaid)	2
	Leptochelia sp. B	(tanaid)	2
	Cycloleberis americana	(ostracod)	1
	Harbansus sp.	(ostracod)	6
	Sarsiella sp.	(ostracod)	4
	Lucinidae sp. (spat)	(bivalve)	1
	Tellinidae sp. (spat)	(bivalve)	4
	Strombiformis bilineatus	(gastropod)	1
	Eulima sp.	(gastropod)	1
	Utriculastra canaliculata	(gastropod)	2
	Caecum sp.	(gastropod)	4
	Volvulella sp.	(gastropod)	5
	Cumella sp. B	(cumacean)	1
	Oxyurostylis cf. smithi	(cumacean)	1
	Aoridae sp.	(amphipod)	1
	Synchelidium americanum	(amphipod)	7
	Photis sp. A	(amphipod)	1
	Ampelisca cf. agassizi	(amphipod)	1
	Tharyx annulosus	(polychaete)	3
	Sthenelais boa	(polychaete)	2
	Ceratocephale aculata	(polychaete)	6
	Nereis riisei	(polychaete)	2
	Macroclymene zonalis	(polychaete)	2
	Prionospio steenstrupi	(polychaete)	4
	Haplosyllis spongicola	(polychaete)	1
	Eusyllis sp. A	(polychaete)	1
	Armandia maculata	(polychaete)	3
	Myriochele oculata	(polychaete)	4
	Palaenotus heteroseta	(polychaete)	1
	Minuspio cirrifera	(polychaete)	5
	Phyllodocidae spp.	(polychaete)	2
8	Glottidia pyramidata	(brachiopod)	6
	Priapulida sp.		1
	Pycnogonida sp.		1
	Holothuroidea sp. (juv.)		1
	Echinoidea sp. (juv.)		1
	Leptochelia sp. B	(tanaid)	1
	Sarsiella sp.	(ostracod)	7
	Cylindroleberidinae sp.	(ostracod)	1
	Podocopoda spp.	(ostracod)	9
	Copepoda sp.		14

Table 10-10. (Continued)

Station	Taxa		Number of Individuals
8 (Continued)	*Chirodotea* sp.	(isopoda)	2
	Veneridae spp. (spat)	(bivalve)	11
	Lucina sp.	(bivalve)	2
	Argopecten sp. (juv.)	(bivalve)	2
	Crassinella sp. (juv.)	(bivalve)	9
	Cardiomya costellata	(bivalve)	1
	Musculus sp. (juv.)	(bivalve)	2
	Caecum sp.	(gastropod)	1
	Volvulella sp. (juv.)	(gastropod)	1
	Turbonilla sp.	(gastropod)	1
	Dentalium sp.	(scaphopod)	1
	Aoridae sp.	(amphipod)	1
	Synchelidium americanum	(amphipod)	3
	Heterophoxus sp. A	(amphipod)	1
	Parametopella sp. A	(amphipod)	3
	Phtisica marina	(amphipod)	2
	Oediceros sp. A	(amphipod)	1
	Palaenotus heteroseta	(polychaete)	4
	Cossura delta	(polychaete)	17
	Magelona sp. A	(polychaete)	17
	Sthenelais boa	(polychaete)	1
	Mediomastus spp.	(polychaete)	5
	Eusyllis sp. A	(polychaete)	25
	Chone sp.	(polychaete)	12
	Nephtyidae spp.	(polychaete)	5
	Polynoidae spp.	(polychaete)	3
	Maldanidae spp.	(polychaete)	5
	Goniada sp.	(polychaete)	1
	Tharyx marioni	(polychaete)	2
	Prionospio steenstrupi	(polychaete)	2
	Spio pettiboneae	(polychaete)	2
	Magelona pacifica	(polychaete)	1
	Euclymene sp.	(polychaete)	2
	Sphaerosyllis spp.	(polychaete)	3
	Synelmis albini	(polychaete)	5
	Spiophanes berkeleyorum	(polychaete)	5
	Cabira incerta	(polychaete)	1
	Pectinaria gouldii	(polychaete)	1
	Exogone atlanticum	(polychaete)	2
	Spionidae spp.	(polychaete)	75
	Lumbrineridae spp.	(polychaete)	1
	Nereidae spp.	(polychaete)	4
	Pionosyllis procera	(polychaete)	1
	Spiophanes bombyx	(polychaete)	1

Table 10-11. Total number of taxa and the percentage composition of the major faunal groupings for the Fall and Spring Cruises[a].

Stat.	Total No. of Taxa		Polychaeta				Mollusca			
			No. of Taxa		% of Total		No. of Taxa		% of Total	
	Cruise		Cruise		Cruise		Cruise		Cruise	
	III	IV	III	IV	III	IV	III	IV	III	IV
2	181	113	99	44	54.7	38.9	17	21	9.4	18.6
4	147	207	79	110	53.7	53.1	18	37	12.2	17.9
5	126	161	65	84	51.6	52.2	13	20	10.3	12.4
6	118	90	56	34	47.5	38.0	19	23	16.1	25.6
8	120	129	61	64	50.8	49.6	15	25	12.5	19.4
12	135	158	79	84	58.5	53.2	12	16	8.9	10.1
14	131	138	44	61	33.6	44.2	19	20	14.5	14.5
16	184	203	97	105	52.7	51.7	19	25	10.3	12.3
18	143	193	74	99	51.7	51.3	10	27	7.0	14.0
20	138	156	66	79	47.8	50.6	6	25	4.3	16.0
22	177	212	94	108	53.1	50.9	13	38	7.3	17.9
24	140	182	75	84	53.6	46.2	11	40	7.8	22.0
25	74	97	40	47	54.0	48.4	8	18	10.8	18.6
26	83	126	38	48	45.8	38.1	10	26	12.0	20.6
28	200	222	102	92	51.0	41.4	21	32	10.5	14.4
Mean $\bar{x}$	140	159	71	76	50.7	47.2	14	26	10.3	17.0
Std. dev. S	35.3	43.0	21.2	25.1	5.7	5.6	4.6	7.4	3.0	4.1

[a] Cruise III denotes the Fall Cruise, Cruise IV denotes the Spring Cruise.

Table 10-11. (Continued)

Stat.	Crustacea				Miscellaneous			
	No. of Taxa		% of Total		No. of Taxa		% of Total	
	Cruise		Cruise		Cruise		Cruise	
	III	IV	III	IV	III	IV	III	IV
2	43	36	23.8	31.9	22	12	12.2	10.6
4	34	44	23.1	21.3	16	16	10.9	7.7
5	40	46	31.7	28.6	8	11	6.3	6.8
6	28	25	23.7	28.0	15	8	12.7	8.9
8	28	24	23.3	18.6	16	16	13.3	12.4
12	31	45	23.0	28.5	13	13	9.6	8.2
14	58	47	44.3	34.1	10	10	7.6	7.2
16	55	53	29.9	26.1	13	20	7.1	9.9
18	46	48	32.2	24.9	13	19	9.1	9.8
20	52	39	37.7	25.0	14	13	10.1	8.3
22	54	49	30.5	23.1	16	17	9.0	8.0
24	45	45	32.1	24.7	9	13	6.4	7.1
25	17	19	23.0	19.6	9	13	12.2	13.4
26	26	40	31.3	31.7	9	12	10.8	9.5
28	63	78	31.5	35.1	14	20	7.0	9.0
Mean $\bar{x}$	41	43	29	26.7	13	14	9.6	9.1
Std. dev. S	13.6	14.0	6.2	5.0	3.7	3.7	2.4	1.9

Cruises, respectively. While the standard deviation was generally high for numbers of taxa (high between-station variation), the variation for percentage of total taxa for the major faunal groups was low, i.e., the relative proportions of the major taxa did not change substantially between cruises.

Abundances of dominant taxa (those comprising greater than 1% of total faunal counts) are presented on a station-by-station basis in Appendix B-9. Polychaetes represented most of the dominant taxa for the Fall Cruise. Unidentified Nematoda, unidentified Paraonidae (polychaetes), Synelmis albini (polychaete), unidentified Oligochaeta, Lucina radians (bivalve), and Fabricia sp. (polychaete) were the most abundant taxa. Other animals that occurred consistently in relatively high numbers throughout the study area were Minuspio cirrifera (polychaete), Prionospio cristata (polychaete), unidentified Nemertina, Selenaria sp. (bryozoan), Mediomastus sp. (polychaete), Notomastus hemipodus (polychaete) and Myriochele oculata (polychaete).

Dominance showed a similar pattern for the Spring Cruise, with polychaetes dominating the fauna. The miscellaneous taxa of unidentified Nematoda, unidentified Nemertina, and unidentified Oligochaeta were again represented in large numbers. The polychaetes Prionospio cristata, Synelmis albini, and Fabricia sp. were especially abundant. Other commonly encountered species were Lucina radians (bivalve), Ampharete acutifrons (polychaete), Sphaerosyllis spp. (polychaete), Minuspio cirrifera (polychaete), Magelona pettiboneae (polychaete), Mediomastus spp. (polychaete), and Selenaria sp. (bryozoan). Juvenile bivalves of the families Tellinidae and Veneridae were also quite common.

Excluding the meiofaunal components (nematodes, ostracods and copepods), eight taxa were considered dominants in the study area (based on the criterion that they comprised at least 5% of the faunal density in at least one third of the stations which were sampled). These eight taxa were: Oligochaeta, Nemertina, Paraonidae (polychaete), Fabricia sp. (polychaete), Prionospio cristata (polychaete), Synelmis albini (polychaete), Ampharete acutifrons (polychaete) and Lucina radians (bivalve). Spatial and seasonal abundance patterns of these dominant taxa are shown in Figures 10-12 through 10-19. In general, the results indicate that (1) Oligochaeta, Nemertina, Paraonidae (polychaete),

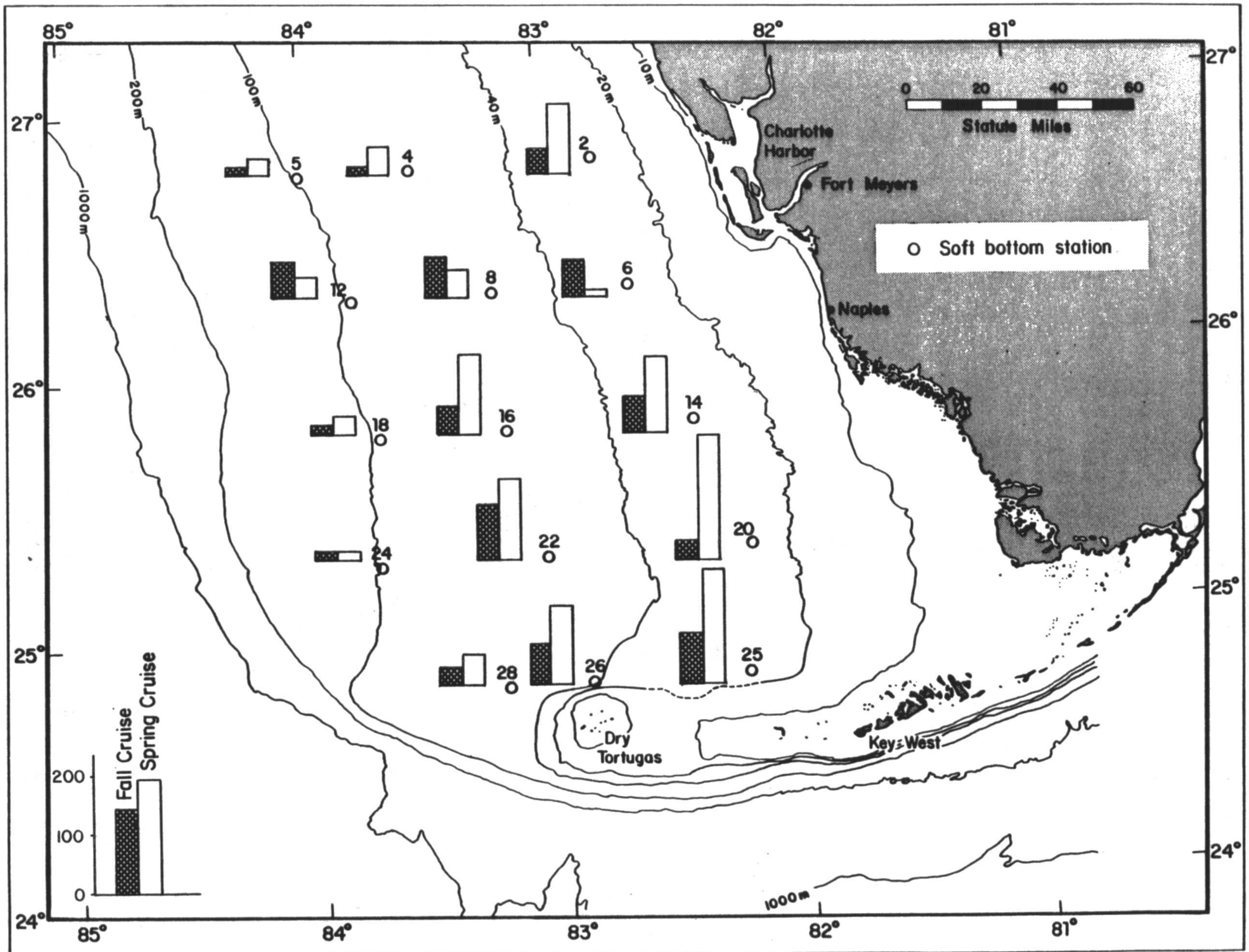


Figure 10-12. Total abundance (actual numbers per five replicates) of nemertines collected by box core.

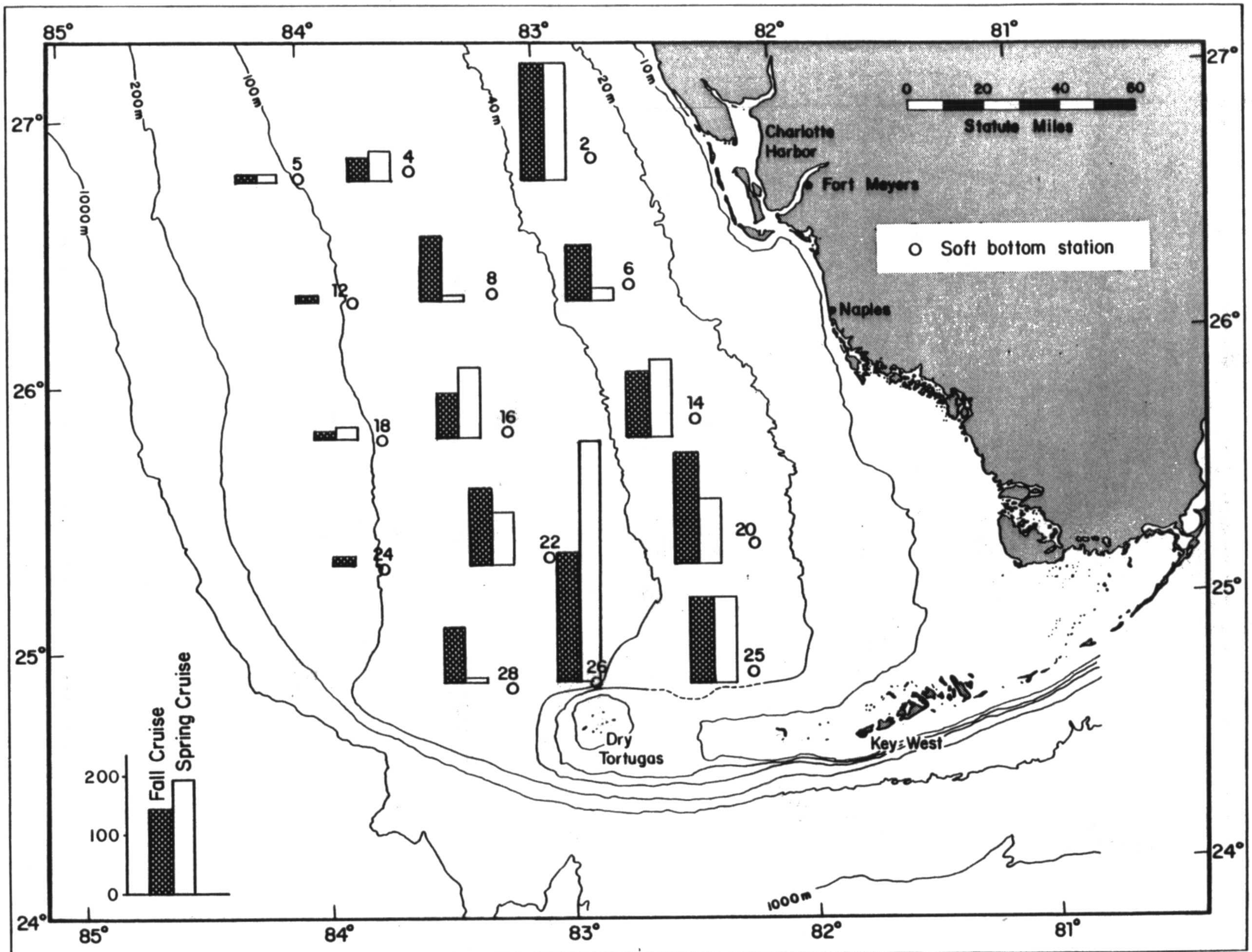


Figure 10-13. Total abundance (actual numbers per five replicates) of oligochaetes collected by box core.

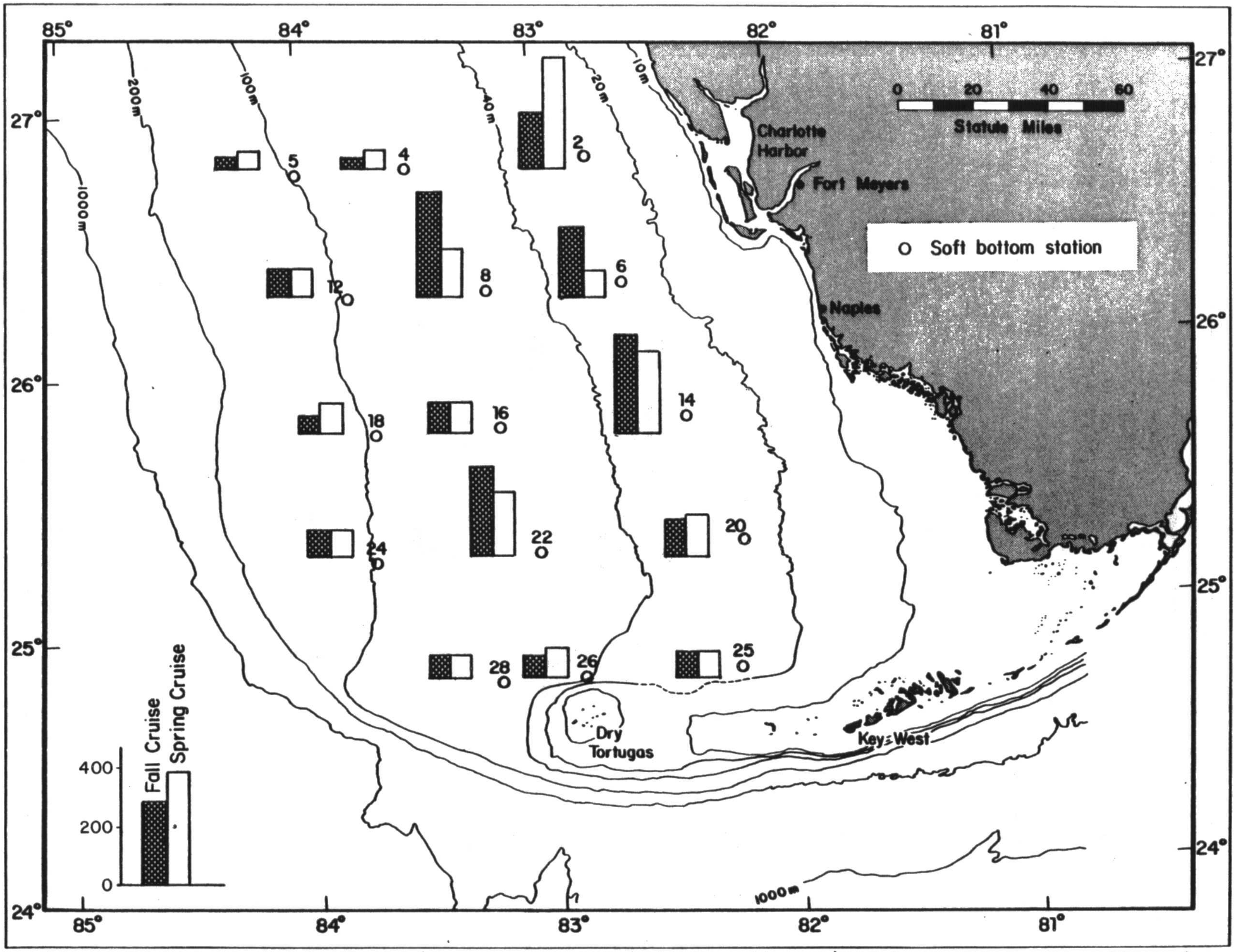


Figure 10-14. Total abundance (actual numbers per five replicates) of Paraonidae spp. collected by box core.

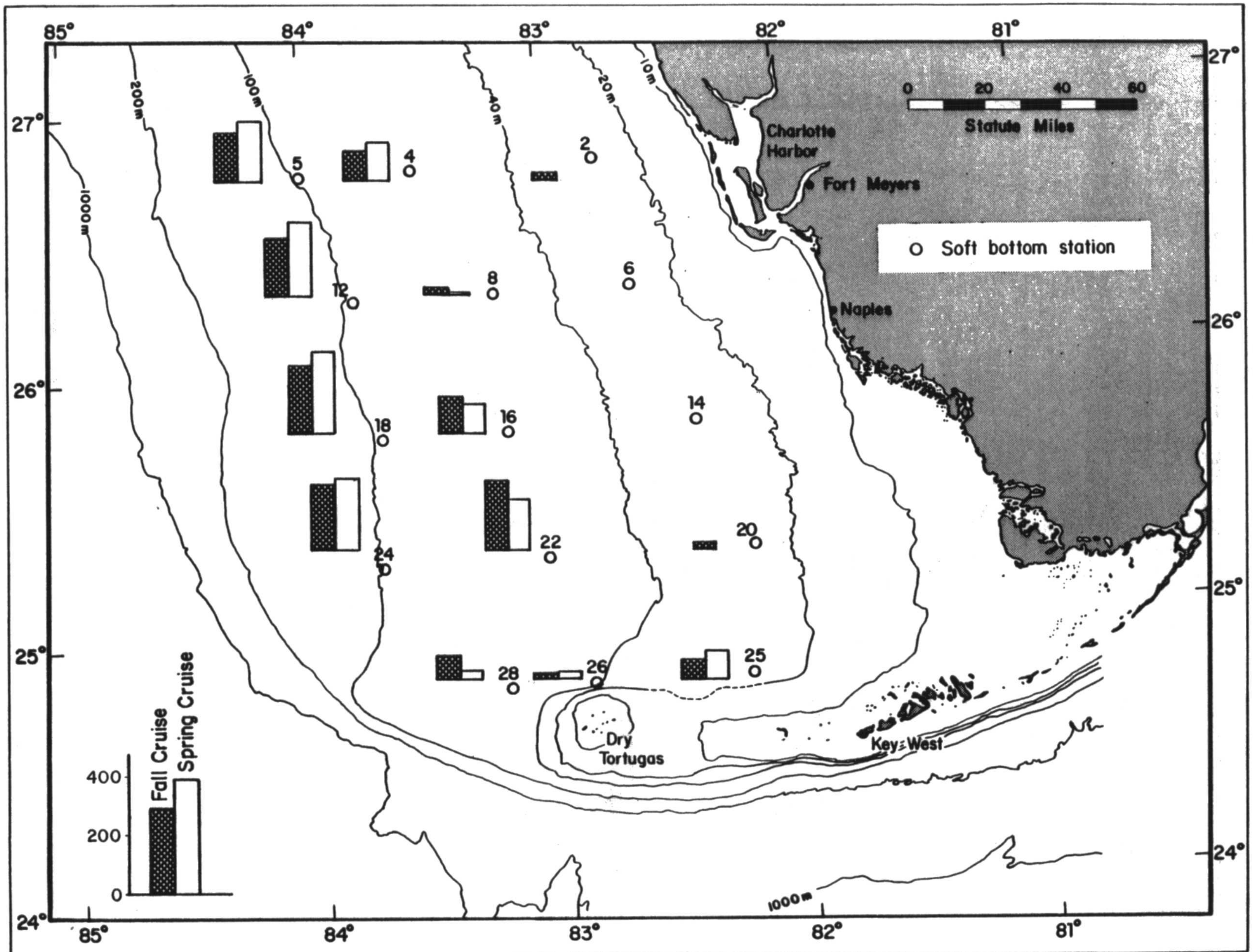


Figure 10-15. Total abundance (actual numbers per five replicates) of Synelmis albini collected by box core.

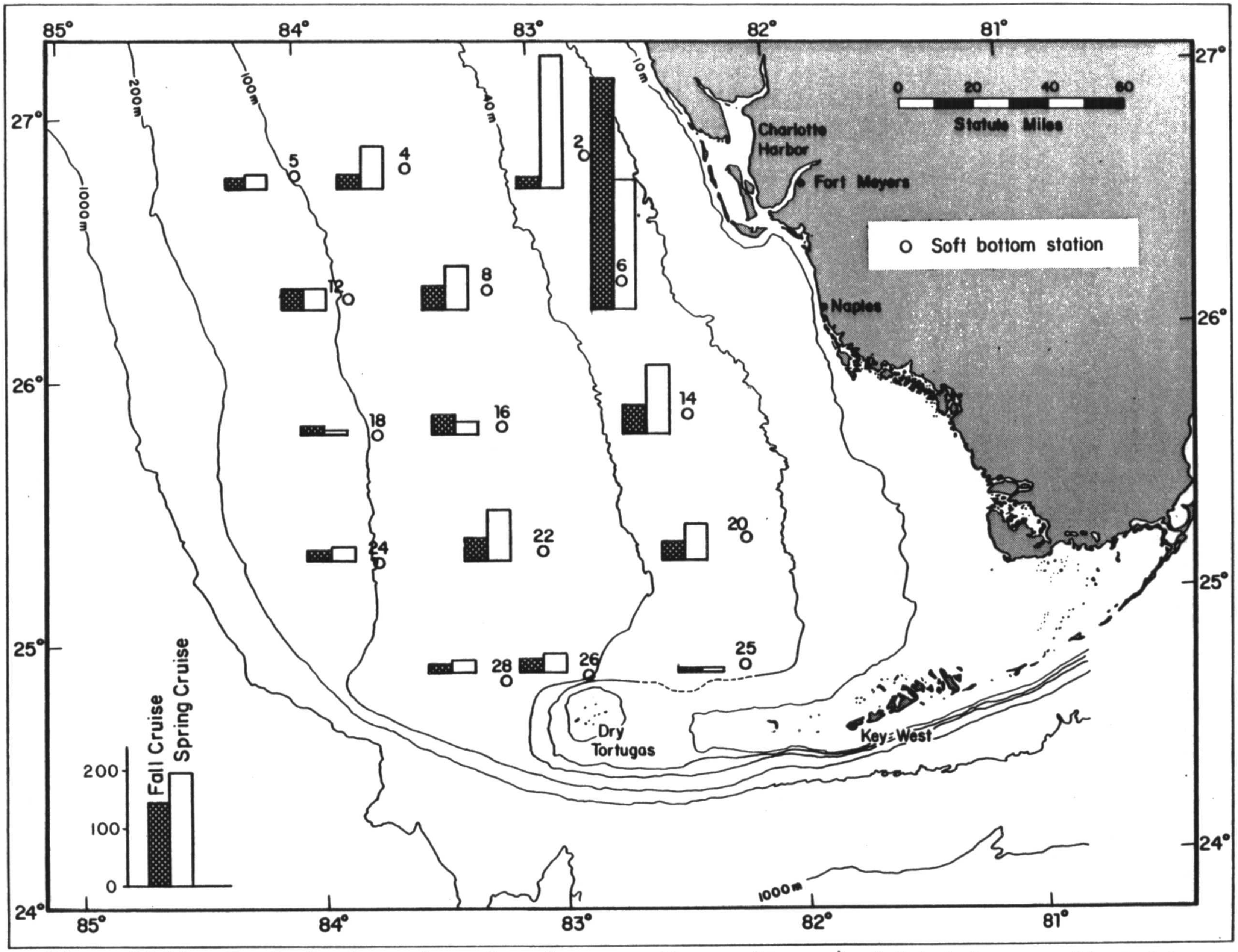


Figure 10-16. Total abundance (actual numbers per five replicates) of Fabricia sp. collected by box core.

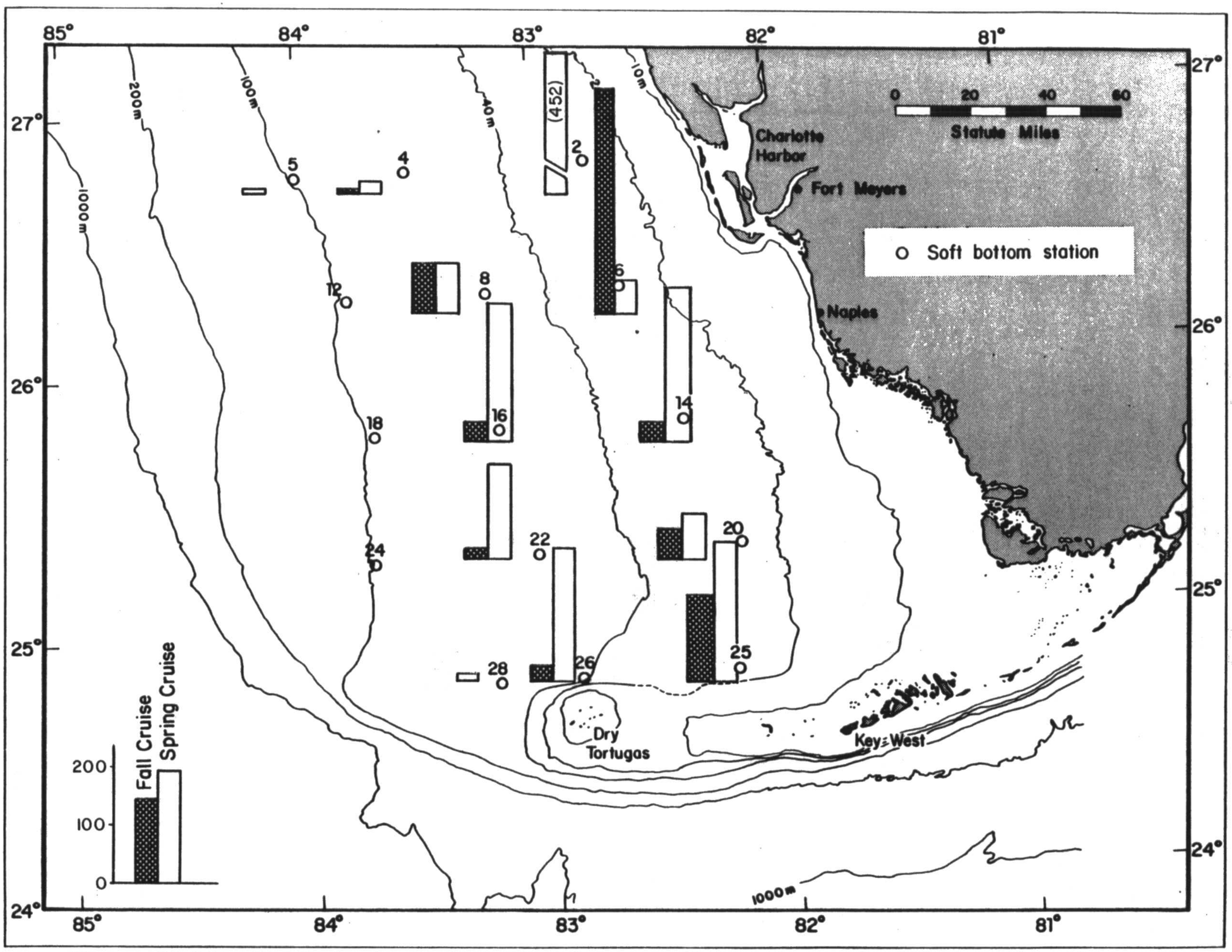


Figure 10-17. Total abundance (actual numbers per five replicates) of <u>Prionospio</u> <u>cristata</u> collected by box core.

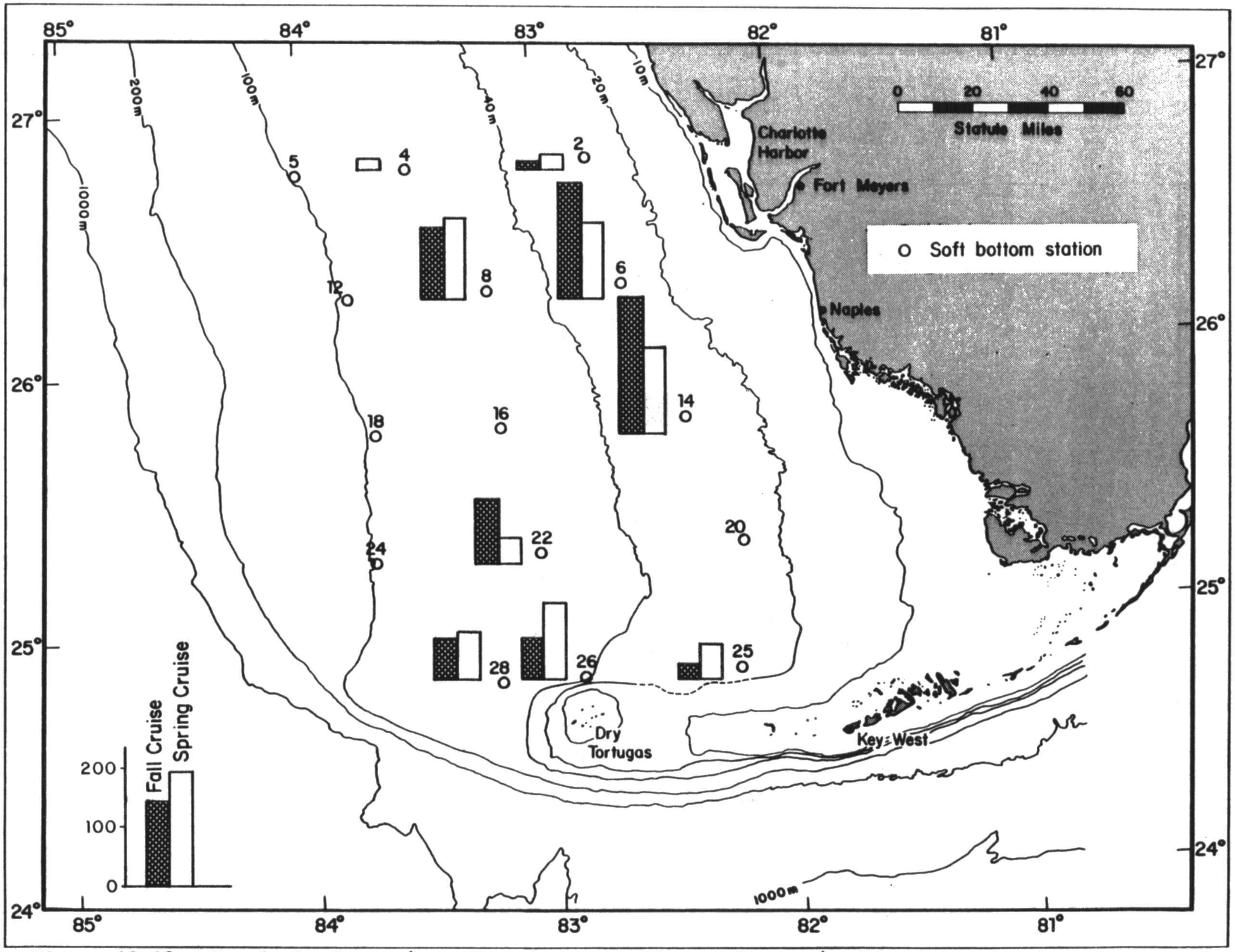


Figure 10-18. Total abundance (actual numbers per five replicates) of Lucina radians collected by box core.

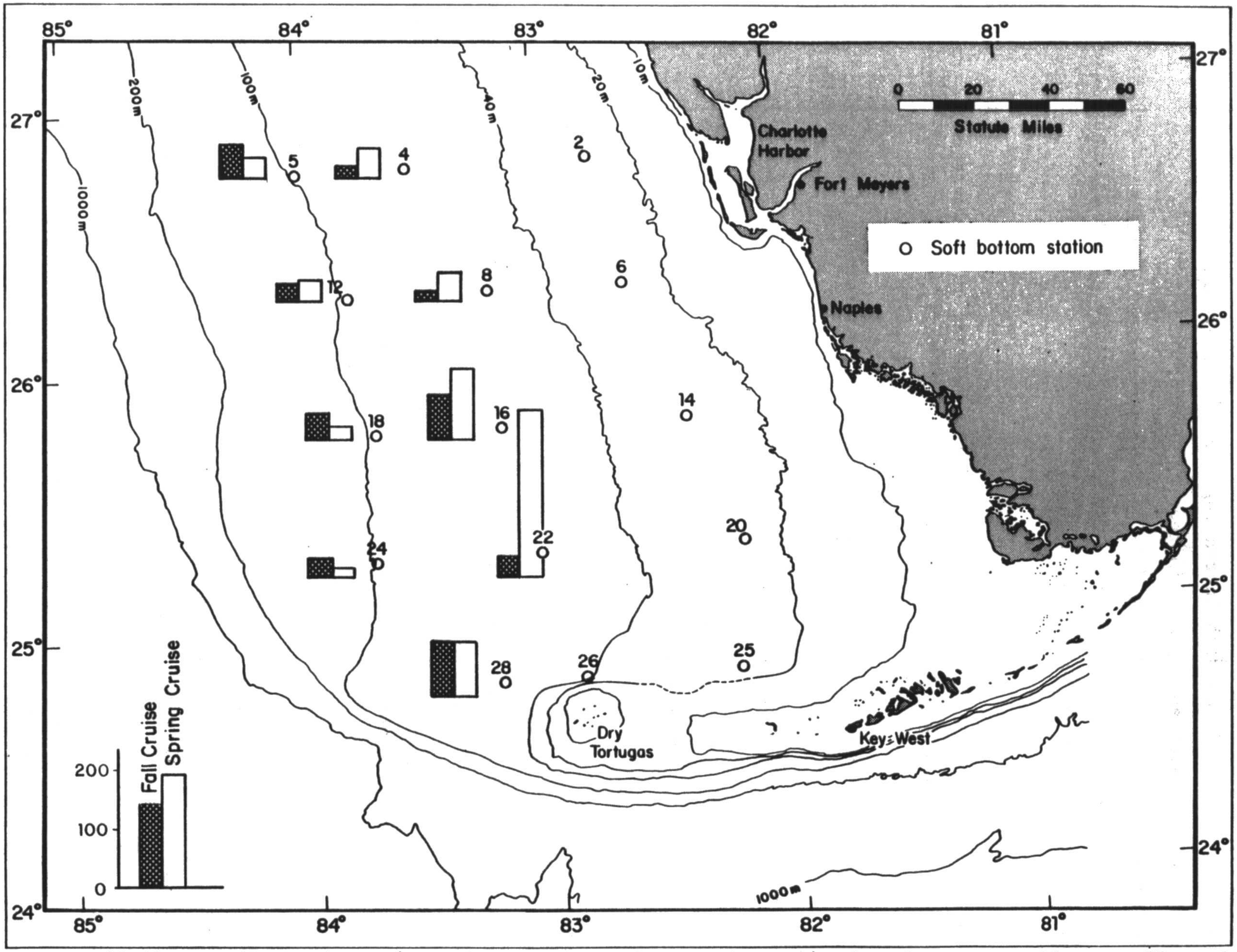


Figure 10-19. Total abundance (actual numbers per five replicates) of Ampharete acutifrons collected by box core.

Fabricia sp. (polychaete) and Prionospio cristata (polychaete) generally decreased in abundance with increasing depth; (2) Synelmis albini (polychaete) increased in abundance with increasing depth; and (3) the other dominant species, Ampharete acutifrons (polychaete) and Lucina radians (bivalve), did not exhibit any specific depth preference. Abundance of all dominant taxa and faunal density varied between fall and spring.

Other dominant taxa in the study area that comprised over 5% of the total abundance at each station at which they were present but did not occur at one third of the stations sampled are listed in Table 10-12.

Based on the above twenty-one dominant taxa and the previously described eight persistent dominant taxa, the following groups of stations can be qualitatively recognized as faunally similar:

Group 1: Stations 4, 5, 12, 18, and 24 (offshore; S. albini)
Group 2: Stations 8, 14, 16, 20, and 22 (nearshore; Paraonidae, P. cristata).

All other stations are somewhat different in the composition of dominants and therefore considered dissimilar to each other and to members of Groups 1 and 2. It should be noted that the offshore S. albini dominated stations (Group 1) were very similar to each other in the composition of dominants; Group 2, although generally similar, showed considerable differences in the proportion and type of dominants between the stations.

10.3.3.5 Faunal Density

Faunal densities (Table 10-13) ranged from 2,074 organisms/m^2 (Station 5, Fall Cruise) to 11,110 organisms/m^2 (Station 2, Spring Cruise). Excluding meiofauna, faunal density (Table 10-14) ranged from 2,012 (Station 5, Fall Cruise) to 8,161 organisms/m^2 (Station 14, Fall Cruise). Generally, faunal densities decreased from nearshore to offshore stations (Figure 10-20). This trend was less pronounced at the southernmost transect (Stations 25, 26, and 28). Variations at corresponding stations between sampling periods were occasionally pronounced but did not substantially affect the proportions of the

Table 10-12. Taxa which comprised over 5% of the total abundance in the study area and occurred at less than one-third of the stations.

Taxa	Stations At Which Taxa Were Dominant	Cruise
Eunice vittata	2	Fall
Progoniada regularis	4	Fall
Seleneria sp.	4	Fall
Mediomastus sp.	4	Fall
Myriochele oculata	6	Fall
Armandia maculata	6	Fall
Magelona sp. A	8	Fall
Photis sp. A	14	Fall
Microdeutopos myersi	14	Fall
Platidia clepsydra	18	Fall
Lembos sp. A	20	Fall
Minuspio cirrifera	25,26	Fall
	25	Spring
Magelona pettibonae	25	Fall
	25	Spring
Tellina spp.	25	Fall
Caecum pulchellum	26	Fall
Sigambra sp. A	26	Fall
Sphaerosyllis sp.	4,24,26	Spring
Minuspio cirrobranchiata	18	Spring
Veneridae sp. (juv.)	18,24	Spring
Sigambra tentaculata	26	Spring
Sipuncula spp.	26	Spring

Table 10-13. Macroinfaunal density and abundance of major taxa for the Fall and Spring Cruises[a].

	Total Organisms		No./m^2		POLYCHAETA Total Polychaetes		POLYCHAETA % of Total Organisms		POLYCHAETA No./m^2	
	Cruise		Cruise		Cruise		Cruise		Cruise	
Station	III	IV	III	IV	III	IV	III	IV	III	IV
2	2017	3611	6206	11110	1057	1395	54.5	38.6	3252	4292
4	831	1510	2551	4646	456	912	54.9	60.4	1403	2806
5	674	1105	2074	3400	456	767	67.6	69.4	1403	2360
6	2856	1265	8788	3892	1825	524	63.9	41.4	5615	1612
8	1571	1695	4834	5215	875	878	55.7	51.8	2692	2702
12	994	1149	3059	3535	678	786	68.2	68.4	2086	2418
14	2841	2576	8742	7926	886	1267	31.2	49.2	2726	3898
16	1465	2336	4508	7188	806	1315	55.0	56.3	2480	4046
18	1141	1474	3511	4535	627	916	55.0	62.1	1929	2818
20	1964	2490	6043	7661	559	835	28.5	33.5	1720	2569
22	2037	2739	6268	8428	1136	1749	55.8	63.9	3495	5382
24	1130	1252	3477	3852	631	789	55.8	63.0	1942	2428
25	1857	2956	5714	9095	1082	1659	58.3	56.0	3329	5095
26	1580	2850	4862	8769	622	1115	39.4	39.1	1914	3431
28	2008	2081	6179	6403	878	909	43.7	43.7	2702	2797
Mean $\bar{x}$	1644	2072	5121	6377	838	1054	52.4	53.1	2579	3244
Standard Deviation S	657	784	2023	2415	349	351	11.9	11.7	1074	1080

[a] Cruise III denotes Fall Cruise; Cruise IV denotes Spring Cruise.

Table 10-13. (Continued)

	MOLLUSCA						CRUSTACEA					
	Total Molluscs		% of Total Organisms		No./m^2		Total Crustaceans		% of Total Organisms		No./m^2	
	Cruise		Cruise		Cruise		Cruise		Cruise		Cruise	
Stat.	III	IV	III	IV	III	IV	III	IV	III	IV	III	IV
2	78	75	3.9	2.1	240	231	170	295	8.4	8.2	523	908
4	74	127	8.9	8.4	228	391	116	164	14.0	10.9	357	505
5	35	86	5.2	7.8	108	265	105	114	15.3	10.3	323	351
6	372	194	13.0	15.3	1145	597	223	151	7.9	11.9	686	465
8	157	200	10.0	11.8	483	615	89	89	5.7	5.3	274	275
12	111	107	11.2	9.3	342	329	84	118	8.5	10.3	258	363
14	481	408	16.9	15.8	1480	1255	1164	401	41.0	15.6	3582	1234
16	106	91	7.2	3.9	326	280	219	328	14.9	14.0	674	1007
18	209	146	18.3	9.9	643	449	145	245	12.7	16.6	446	754
20	54	123	2.7	4.9	166	378	721	320	36.7	12.9	2219	985
22	238	185	11.7	6.8	732	569	208	256	10.2	9.3	640	788
24	200	169	17.7	13.5	615	520	168	142	14.9	11.3	520	437
25	188	391	10.1	13.2	579	1203	185	164	10.0	5.5	569	505
26	391	534	24.7	18.7	1203	1643	80	331	5.1	11.6	246	1018
28	210	292	10.5	14.0	646	898	361	559	18.0	26.9	1111	1720
Mean $\bar{x}$	194	209	11.5	10.0	596	642	269	245	14.9	12.0	829	754
Standard Deviation S	132	137	6	5	406	422	295	130	10.5	5.2	907	399

Table 10-13. (Continued)

	MISCELLANEOUS					
	Total Misc. Organisms		% of Total Organisms		No./m²	
	Cruise		Cruise		Cruise	
Station	III	IV	III	IV	III	IV
2	712	1846	35.3	51.1	2191	5680
4	185	307	22.3	20.3	569	945
5	78	138	11.8	12.5	240	425
6	436	396	15.3	31.3	1342	1218
8	450	525	28.6	31.2	1385	1625
12	121	136	12.2	12.0	372	425
14	310	396	10.9	19.4	954	1538
16	334	528	22.8	25.8	1028	1852
18	160	138	14.0	11.3	492	514
20	630	500	32.1	48.7	1939	3729
22	455	602	22.3	20.0	1400	1689
24	131	167	11.6	12.1	403	468
25	402	1212	21.6	25.2	1237	2292
26	487	549	30.8	30.5	1499	2677
28	559	152	27.8	15.4	1720	988
Mean $\bar{x}$	363	506	21.3	24.5	1118	1738
Standard Deviation S	196	464	8.3	12.5	604	1434

Table 10-14. Density (# organisms/m^2) of macroinfauna (excluding meiofauna) during the Fall and Spring Cruises.

Transect	Station No.	Fall Cruise	Spring Cruise
	2	5,080	6,670
A	4	2,419	4,219
	5	2,012	3,277
	6	8,049	2,769
B	8	4,385	4,067
	12	2,948	3,397
	14	8,161	7,107
C	16	4,083	6,182
	18	3,397	4,316
	20	5,108	5,027
D	22	5,757	7,665
	24	3,406	3,637
	25	5,348	7,984
E	26	4,560	8,151
	28	5,038	6,114

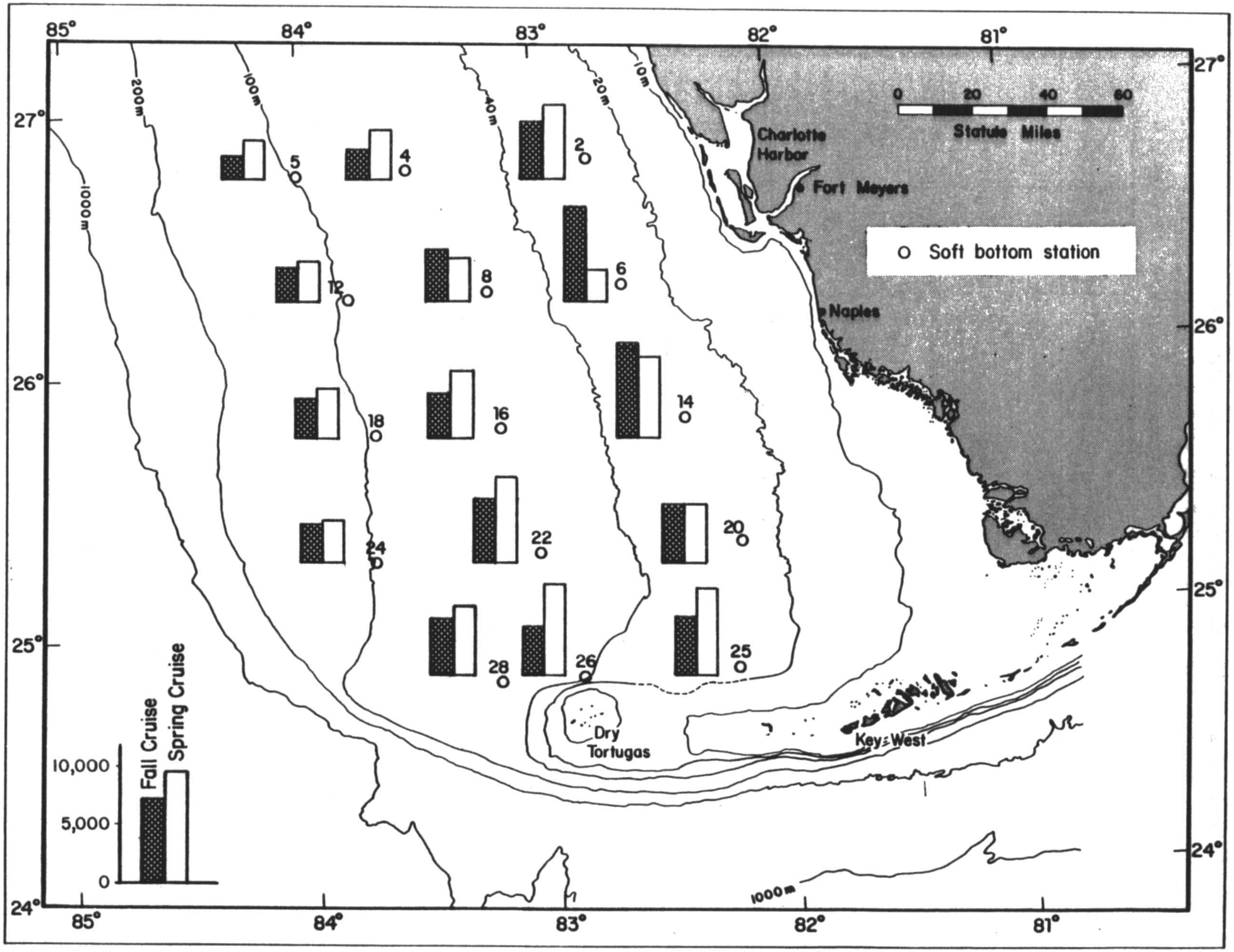


Figure 10-20. Total density of infauna (individuals per m^2) collected by box core.

composition by the major faunal groups. The polychaetes represented most of the fauna (52.4%, Fall Cruise; 53.1%, Spring Cruise) followed by the crustaceans (14.9%, Fall Cruise; 12.0%, Spring Cruise) and molluscs (12.0%, Fall Cruise; 10.0%, Spring Cruise).

When meiofaunal organisms were excluded (Table 10-15), polychaetes were proportionally greater in percentage composition (56.92%, Fall Cruise; 61.60%, Spring Cruise) followed by crustaceans (16.40%, Fall Cruise; 14.03%, Spring Cruise) and molluscs (12.39%, Fall Cruise; 11.93%, Spring Cruise). Miscellaneous taxa accounted for only 14.39% (Fall Cruise) and 12.44% (Spring Cruise). Temporal and spatial patterns of the densities of polychaetes (Figure 10-21), crustaceans and molluscs (Figures 10-22 and 10-23) show that except for the southernmost transect (E), densities generally decreased with increasing depth and seasonal changes were occasionally pronounced.

10.3.3.6 Taxonomic Richness

Taxonomic richness, as total number of taxa per station, and the Margalef's index (Margalef, 1958) are presented in Table 10-16. Meiofaunal groups were excluded since they were not adequately sampled with a 0.5-mm sieve. Figure 10-24 shows the spatial and temporal patterns of the total number of taxa per station excluding meiofauna. Station 28 (southernmost transect - offshore station) exhibited the greatest taxonomic richness (188 taxa for the Fall Cruise and 213 taxa for the Spring Cruise) while Station 25 (nearshore station on the same transect) exhibited the lowest richness (66 taxa for the Fall Cruise and 94 taxa for the Spring Cruise). In general, offshore middle and inshore middle shelf stations on each transect exhibited greater taxonomic richness than corresponding inner shelf stations. Latitudinal and seasonal variations in taxonomic richness were minimal.

10.3.3.7 Taxonomic Diversity and Equitability

Diversity as Shannon's and Gini's indices (Gini, 1912; Shannon and Weaver, 1963; Simpson, 1949) and equitability as Pielou's index (Pielou, 1966) are presented in Table 10-16 for the data. Meiofaunal groups were excluded since they were not sampled adequately with a 0.5-mm sieve. Shannon's index varied

Table 10-15. Percentage composition of major taxa (excluding meiofauna).

Transect	Station Number	Polychaeta Fall Cruise	Polychaeta Spring Cruise	Crustacea Fall Cruise	Crustacea Spring Cruise	Mollusca Fall Cruise	Mollusca Spring Cruise
A	2	64.02	64.35	10.30	13.61	4.72	3.46
	4	58.00	66.51	14.76	11.97	9.43	9.26
	5	69.73	72.02	16.05	10.71	5.36	8.09
B	6	69.76	58.22	8.52	16.80	14.23	21.56
	8	61.39	66.44	6.25	6.76	11.01	15.12
	12	70.76	71.18	8.75	10.69	11.60	9.69
C	14	33.40	54.85	43.89	17.36	18.14	17.66
	16	60.74	65.45	16.51	16.29	7.98	4.53
	18	56.78	65.29	13.13	17.47	18.93	10.40
D	20	33.67	51.10	43.44	19.59	3.25	7.52
	22	60.71	70.22	11.12	10.28	12.71	7.42
	24	57.02	66.76	15.27	12.02	18.05	14.30
E	25	62.25	63.82	10.64	6.33	10.83	15.07
	26	41.97	42.09	5.39	12.49	26.38	20.16
	28	53.63	45.75	22.05	28.13	12.82	14.69
AVERAGE FOR STUDY AREA		56.92	61.60	16.40	14.03	12.39	11.93

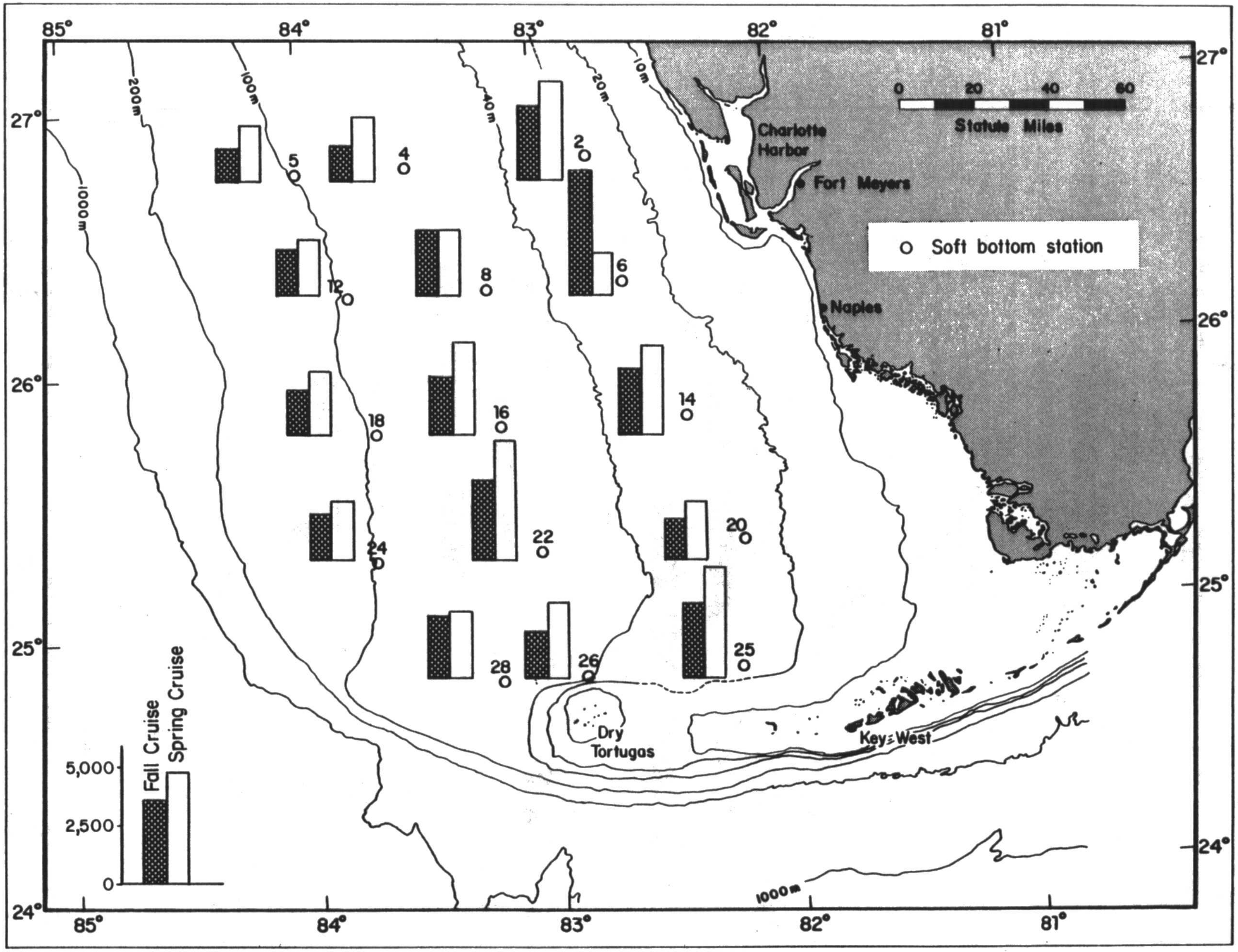


Figure 10-21. Total density of polychaetes (individuals per m^2) collected by box core.

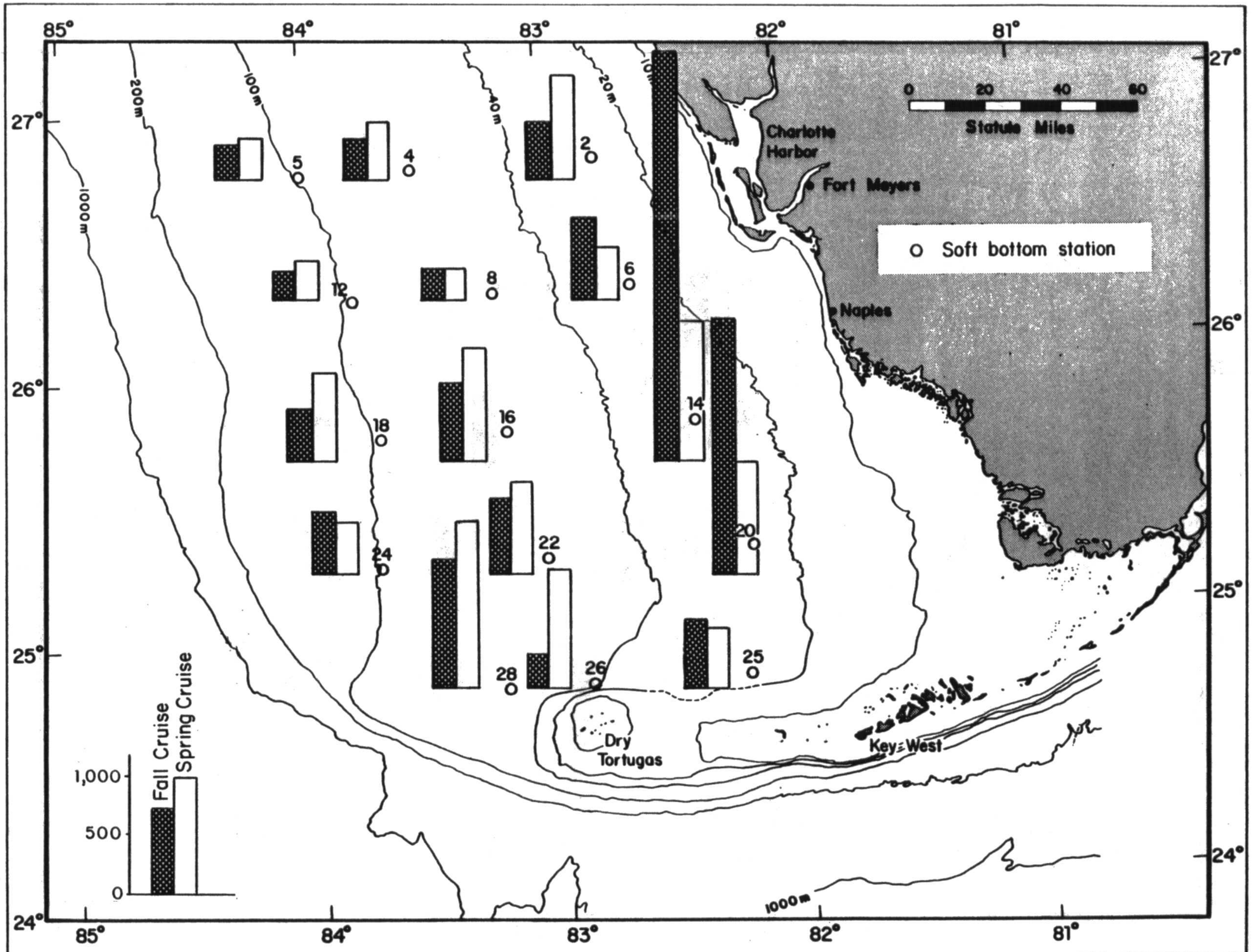


Figure 10-22. Total density of crustaceans (individuals per m^2) collected by box core.

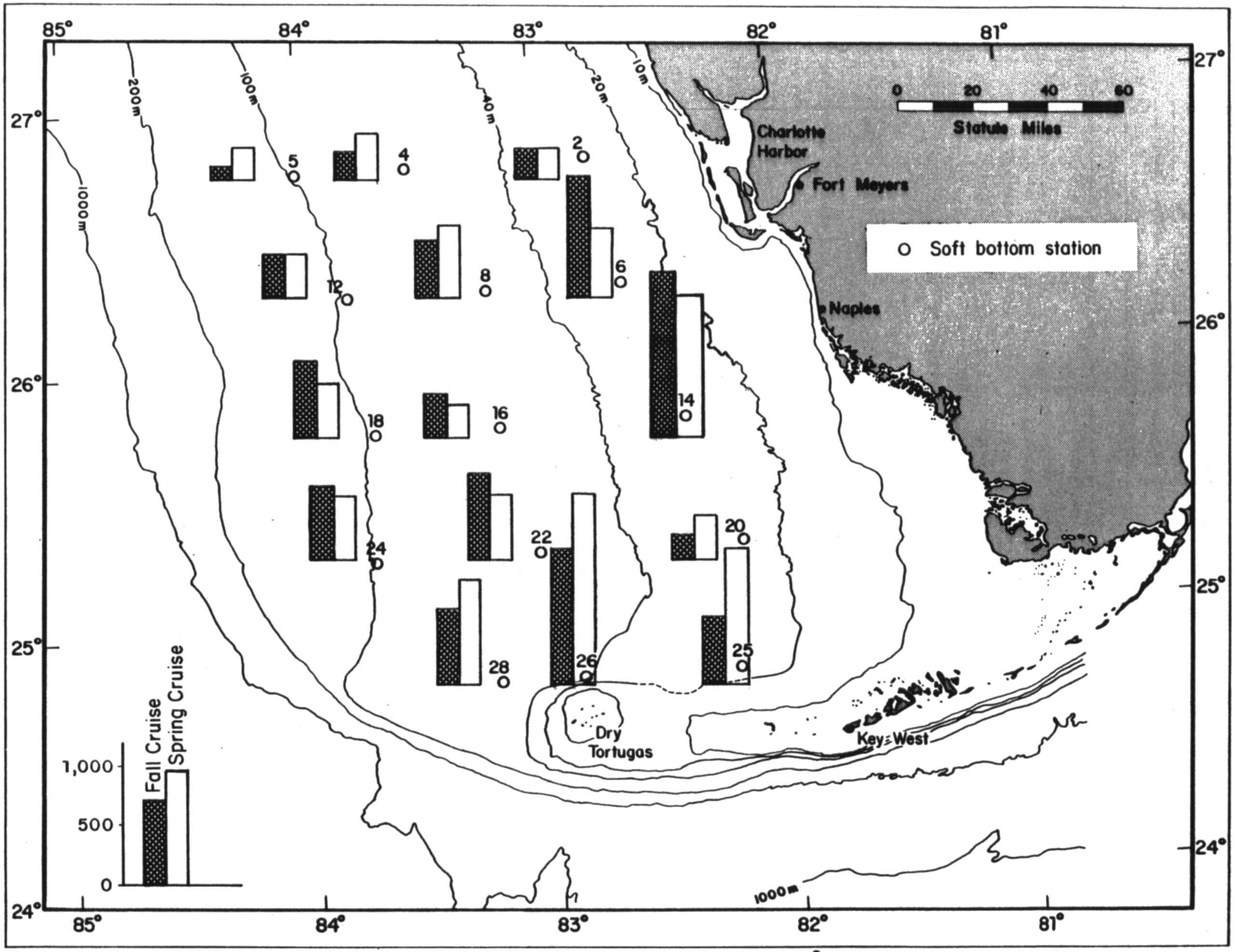


Figure 10-23. Total density of molluscs (individuals per m^2) collected by box core.

Table 10-16. Selected macroinfaunal community parameters from Fall and Spring Cruises (excluding nematodes, copepods, and ostracods).

STA.#	# of TAXA	MARG.INX.	S&W H'	S&W H"	SIMP.DM.	GINI	EQU.J'
			FALL CRUISE				
2	172	23.11	3.93	3.88	0.05	0.95	0.76
4	135	20.20	4.13	4.04	0.03	0.97	0.84
5	115	17.69	3.67	3.58	0.08	0.92	0.77
6	111	14.00	3.19	3.17	0.08	0.92	0.68
8	111	15.19	3.21	3.17	0.09	0.91	0.68
12	128	18.58	3.79	3.73	0.06	0.94	0.78
14	117	14.77	3.59	3.57	0.05	0.95	0.75
16	175	24.34	4.17	4.10	0.03	0.97	0.81
18	135	19.23	3.52	3.46	0.08	0.92	0.72
20	130	17.48	3.87	3.83	0.04	0.96	0.80
22	168	22.21	3.68	3.63	0.06	0.94	0.72
24	130	18.47	3.67	3.61	0.06	0.94	0.75
25	66	8.76	3.07	3.05	0.07	0.93	0.73
26	74	10.04	3.09	3.06	0.07	0.93	0.72
28	188	25.38	4.26	4.21	0.03	0.97	0.81
			SPRING CRUISE				
2	108	13.95	2.99	2.96	0.10	0.90	0.64
4	198	27.35	4.35	4.27	0.03	0.97	0.82
5	160	22.81	4.10	4.02	0.05	0.95	0.81
6	84	12.26	3.04	2.99	0.10	0.90	0.69
8	122	16.90	3.60	3.56	0.05	0.95	0.75
12	149	21.18	3.73	3.66	0.07	0.93	0.75
14	133	17.05	3.49	3.46	0.06	0.94	0.71
16	198	25.97	4.02	3.97	0.04	0.96	0.76
18	188	25.91	3.92	3.85	0.06	0.94	0.75
20	152	20.51	3.85	3.81	0.04	0.96	0.77
22	208	26.51	3.99	3.95	0.04	0.96	0.75
24	178	25.02	3.88	3.81	0.06	0.94	0.75
25	94	11.84	3.30	3.28	0.06	0.94	0.73
26	122	15.43	3.43	3.40	0.06	0.94	0.71
28	213	28.10	4.60	4.54	0.02	0.98	0.86

NOTE:

MARG. INX.: Margalef's Index (Margalef, 1958).
S&W H': Shannon-Weaver Index (Shannon and Weaver, 1963).
S&W H": Shannon-Weaver Index with Basharin's correction (Basharin, 1959).
SIMP.DM: Simpson's Dominance Diversity (Simpson, 1949).
GINI: Gini's Diversity Index (Gini, 1912).
EQU.J': Pielou's Equitability Index (Pielou, 1966).

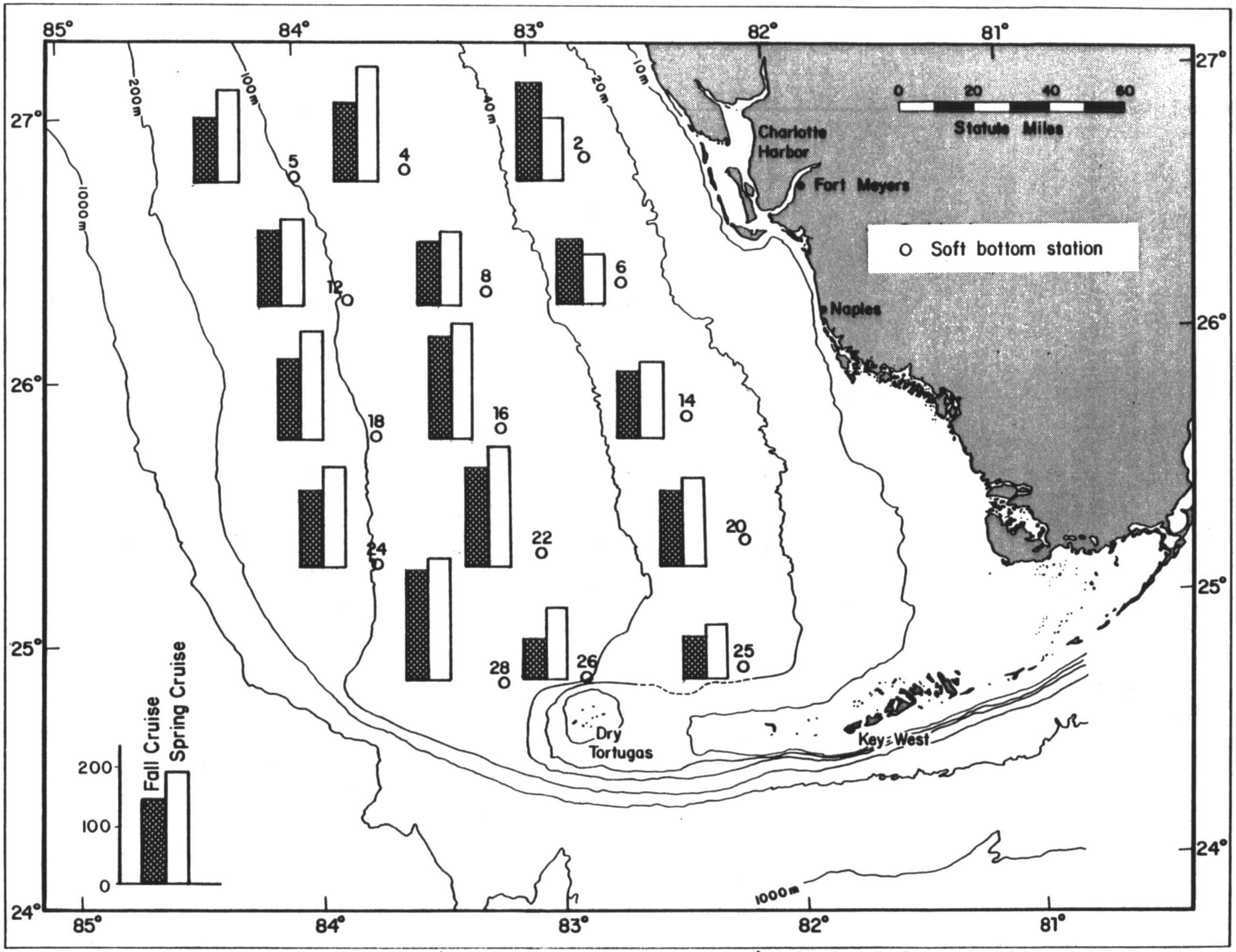


Figure 10-24. Taxonomic richness (number of taxa per station) of macroinfauna collected by box core.

from 3.07 (Station 25) to 4.26 (Station 28) for the Fall Cruise and from 2.99 (Station 2) to 4.60 (Station 28) for the Spring Cruise. Pielou's equitability index ranged from 0.68 (Station 8, Fall Cruise) to 0.86 (Station 28, Spring Cruise). No distinct relationship with distance from shore or geographical boundaries was evident from these data (Figure 10-25). Temporal and spatial variations in both taxonomic diversity and equitability were minimal.

10.3.3.8 Faunal Similarity

Faunal similarity analyses for each cruise using Morisita's index (Morisita, 1959) were conducted using the complete data base after excluding all meiofaunal components (nematodes, copepods, and ostracods).

Trellis diagrams showing faunal similarity comparisons (excluding meiofaunal components) for the Fall and Spring Cruises are presented in Tables 10-17 and 10-18, respectively. A combined Morisita's index analysis (both cruises) is presented in Table 10-19. The geographical distribution of the higher values of Morisita's index of similarity (>0.7) for the Fall Cruise is shown in Figure 10-26. Clearly, these results indicated that the offshore middle shelf stations were closely related to each other; these stations were also similar to Stations 4, 16, and 22 (inshore middle shelf). The geographic distribution of the higher values of Morisita's index of similarity (>0.7) for the Spring Cruise are presented in Figure 10-27. Two groups of stations were revealed in this analysis. The first group was composed of the offshore middle shelf stations (5, 12, 18, and 24). The second group was composed of the northern inner shelf and inshore middle shelf stations (2, 6, 8, 14, 16, 20, and 22). The composition at Station 4 was revealed to be intermediate between member stations of these two groups. Spatially, faunal similarity analysis identified an offshore homogeneity in fauna. Similarities between nearshore stations were variable with season.

Values of Morisita's index for comparisons between the two cruises at the individual stations are presented in Figure 10-28. Comparisons of dominant taxa at individual stations are presented in Table 10-20. Generally, the stations were similar between the two seasons (except for Station 2). The affinity was somewhat stronger at the offshore middle shelf stations. These

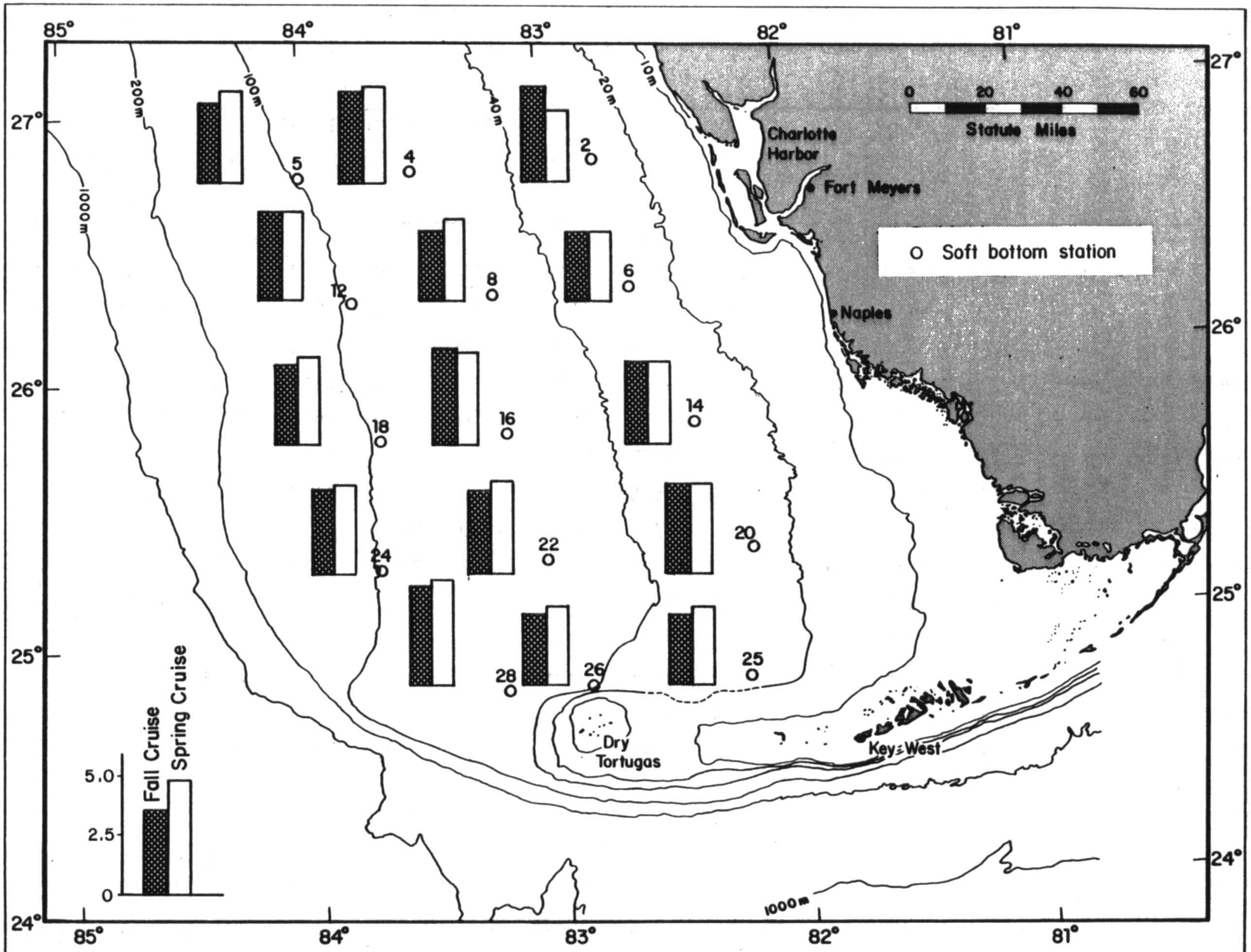


Figure 10-25. Taxonomic diversity (Shannon-Weaver index) of macroinfauna collected by box core.

Table 10-17. Faunal similarity matrix for the Fall Cruise (excluding nematodes, copepods, and ostracods).

Station	2	4	5	6	8	12	14	16	18	20	22	24	25	26	28
2	/	----	..	..	++++	..	----	++++	..	++++	++++	..	----	++++	++++
4	0.37	/	++++	..	----	XXXX	..	++++	++++	----	++++	++++	----	..	++++
5	0.16	0.68	/	..	..	XXXX	..	++++	XXXX	..	++++	XXXX	..	..	----
6	0.29	0.19	0.13	/	----	..	----	----	..	..	----	..	..	----	----
8	0.60	0.31	0.20	0.48	/	----	XXXX	++++	..	++++	XXXX	----	----	----	++++
12	0.30	0.71	0.89	0.25	0.43	/	----	XXXX	XXXX	..	XXXX	XXXX	----	..	++++
14	0.49	0.22	0.14	0.46	0.72	0.31	/	----	..	++++	++++	..	----	----	++++
16	0.52	0.68	0.60	0.31	0.56	0.71	0.44	/	++++	++++	XXXX	++++	++++	----	XXXX
18	0.16	0.56	0.85	0.12	0.21	0.83	0.19	0.61	/	..	++++	XXXX	----	..	----
20	0.64	0.42	0.15	0.29	0.55	0.26	0.53	0.55	0.19	/	++++	..	----	++++	++++
22	0.58	0.64	0.65	0.42	0.79	0.81	0.65	0.82	0.66	0.52	/	XXXX	----	----	XXXX
24	0.24	0.61	0.84	0.14	0.32	0.87	0.26	0.65	0.96	0.24	0.73	/	----	..	++++
25	0.38	0.32	0.27	0.26	0.48	0.37	0.39	0.51	0.31	0.42	0.50	0.30	/	++++	----
26	0.50	0.26	0.12	0.33	0.49	0.22	0.44	0.41	0.23	0.51	0.49	0.24	0.57	/	----
28	0.54	0.61	0.46	0.33	0.59	0.58	0.55	0.85	0.47	0.54	0.79	0.53	0.45	0.46	/

<u>Where</u>: XXXX denotes high similarity ($C\lambda > 0.7$)

++++ denotes moderate similarity ($0.5 < C\lambda < 0.7$)

---- denotes low similarity ($0.3 < C\lambda < 0.5$)

.. denotes very low similarity ($C\lambda < 0.3$)

Faunal similarity values are based on Morisita's (1959) formula.

Table 10-18. Faunal similarity matrix for the Spring Cruise (excluding nematodes, copepods, and ostracods).

Station	2	4	5	6	8	12	14	16	18	20	22	24	25	26	28
2	/	----	..	++++	++++	..	XXXX	XXXX	..	++++	++++	..	++++	++++	..
4	0.36	/	XXXX	----	----	++++	----	++++	++++	++++	XXXX	++++	----	----	++++
5	0.17	0.70	/	..	..	XXXX	..	----	XXXX	..	++++	XXXX	..	..	----
6	0.64	0.35	0.15	/	XXXX	..	++++	..	..	----	----	..	..	----	----
8	0.65	0.45	0.20	0.71	/	----	XXXX	++++	..	++++	++++	..	----	----	++++
12	0.27	0.67	0.89	0.26	0.32	/	..	----	XXXX	..	++++	XXXX	..	..	----
14	0.86	0.41	0.19	0.66	0.79	0.29	/	XXXX	..	XXXX	++++	..	++++	++++	----
16	0.72	0.61	0.43	0.29	0.57	0.43	0.73	/	----	++++	XXXX	----	++++	++++	----
18	0.23	0.66	0.86	0.17	0.28	0.88	0.26	0.42	/	----	++++	XXXX	..	..	----
20	0.65	0.52	0.24	0.40	0.56	0.30	0.71	0.69	0.32	/	++++	..	++++	++++	----
22	0.57	0.73	0.54	0.40	0.65	0.59	0.62	0.84	0.54	0.61	/	++++	----	----	++++
24	0.20	0.68	0.88	0.18	0.25	0.93	0.22	0.39	0.92	0.26	0.53	/	..	..	----
25	0.54	0.35	0.27	0.27	0.45	0.30	0.64	0.64	0.26	0.52	0.47	0.24	/	++++	..
26	0.63	0.43	0.16	0.36	0.47	0.18	0.65	0.63	0.21	0.58	0.46	0.20	0.57	/	..
28	0.25	0.57	0.36	0.30	0.56	0.37	0.40	0.47	0.36	0.40	0.64	0.35	0.28	0.25	/

<u>Where</u>: XXXX denotes high similarity ($C\lambda > 0.7$)

++++ denotes moderate similarity ($0.5 < C\lambda < 0.7$)

---- denotes low similarity ($0.3 < C\lambda < 0.5$)

.. denotes very low similarity ($C\lambda < 0.3$)

Faunal similarity values are based on Morisita's (1959) formula.

Table 10-19. Faunal similarity (Morisita's Index) matrix for Fall and Spring Cruises combined (excluding nematodes, copepods, and ostracods).

FALL CRUISE STATIONS	SPRING CRUISE STATIONS														
	2	4	5	6	8	12	14	16	18	20	22	24	25	26	28
2	0.47	0.41	0.22	0.27	0.38	0.25	0.50	0.41	0.27	0.55	0.42	0.22	0.30	0.54	0.28
4	0.24	0.69	0.71	0.19	0.27	0.67	0.28	0.45	0.64	0.32	0.48	0.64	0.29	0.31	0.36
5	0.14	0.62	0.91	0.14	0.18	0.91	0.14	0.40	0.79	0.16	0.54	0.86	0.24	0.12	0.31
6	0.45	0.33	0.14	0.73	0.52	0.22	0.51	0.22	0.15	0.37	0.32	0.15	0.23	0.28	0.26
8	0.74	0.37	0.22	0.61	0.79	0.38	0.79	0.53	0.34	0.61	0.54	0.30	0.43	0.53	0.41
12	0.29	0.67	0.87	0.27	0.34	0.92	0.32	0.45	0.82	0.33	0.59	0.84	0.32	0.18	0.40
14	0.46	0.31	0.15	0.57	0.71	0.26	0.69	0.34	0.25	0.46	0.42	0.22	0.37	0.43	0.43
16	0.49	0.72	0.63	0.32	0.48	0.61	0.56	0.66	0.59	0.58	0.64	0.58	0.47	0.46	0.50
18	0.14	0.51	0.76	0.13	0.15	0.78	0.15	0.30	0.67	0.13	0.39	0.74	0.23	0.13	0.26
20	0.51	0.41	0.17	0.28	0.42	0.20	0.53	0.51	0.22	0.58	0.43	0.17	0.35	0.59	0.29
22	0.53	0.63	0.65	0.48	0.62	0.75	0.63	0.54	0.68	0.56	0.65	0.67	0.42	0.46	0.50
24	0.20	0.59	0.80	0.16	0.24	0.83	0.22	0.36	0.77	0.19	0.48	0.81	0.23	0.18	0.33
25	0.53	0.35	0.27	0.27	0.42	0.32	0.61	0.59	0.28	0.47	0.45	0.26	0.85	0.57	0.26
26	0.42	0.30	0.13	0.32	0.36	0.17	0.48	0.38	0.16	0.44	0.33	0.14	0.47	0.70	0.22
28	0.36	0.60	0.50	0.35	0.52	0.50	0.50	0.48	0.49	0.47	0.54	0.47	0.37	0.48	0.60

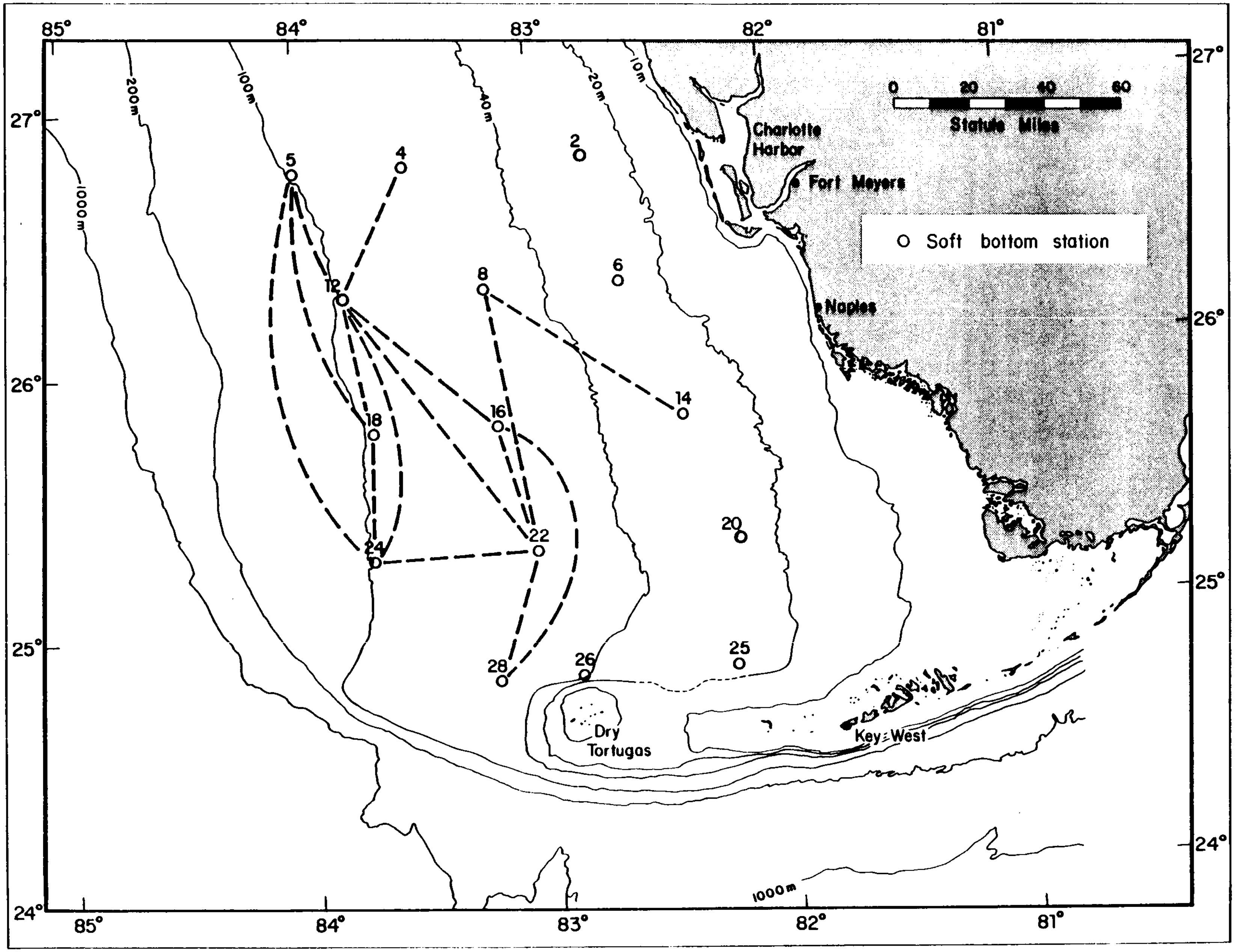


Figure 10-26. Similarities (Morisita's index > 0.7) among soft bottom stations - Fall Cruise macroinfauna.

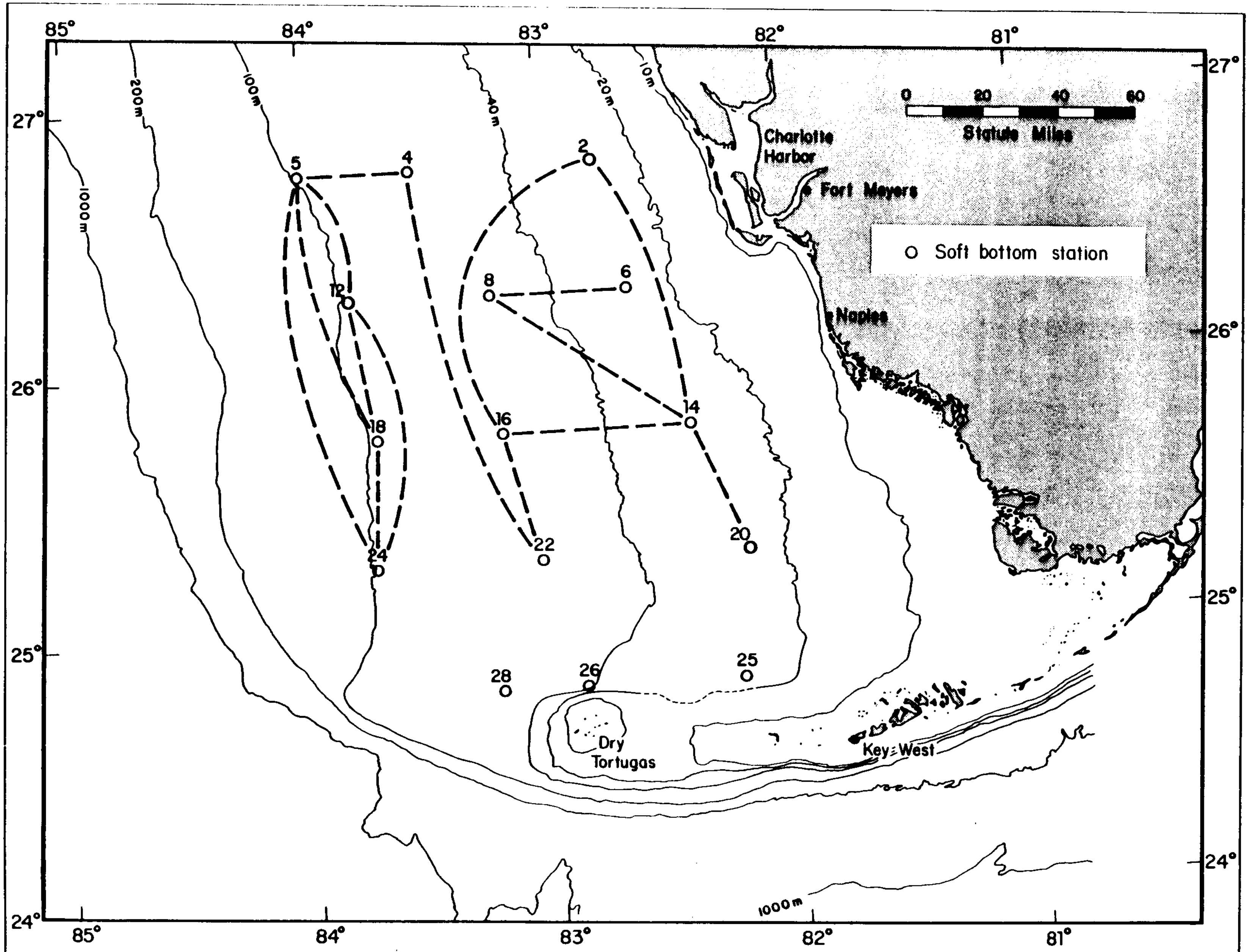


Figure 10-27. Similarities (Morisita's index > 0.7) among soft bottom stations - Spring Cruise macroinfauna.

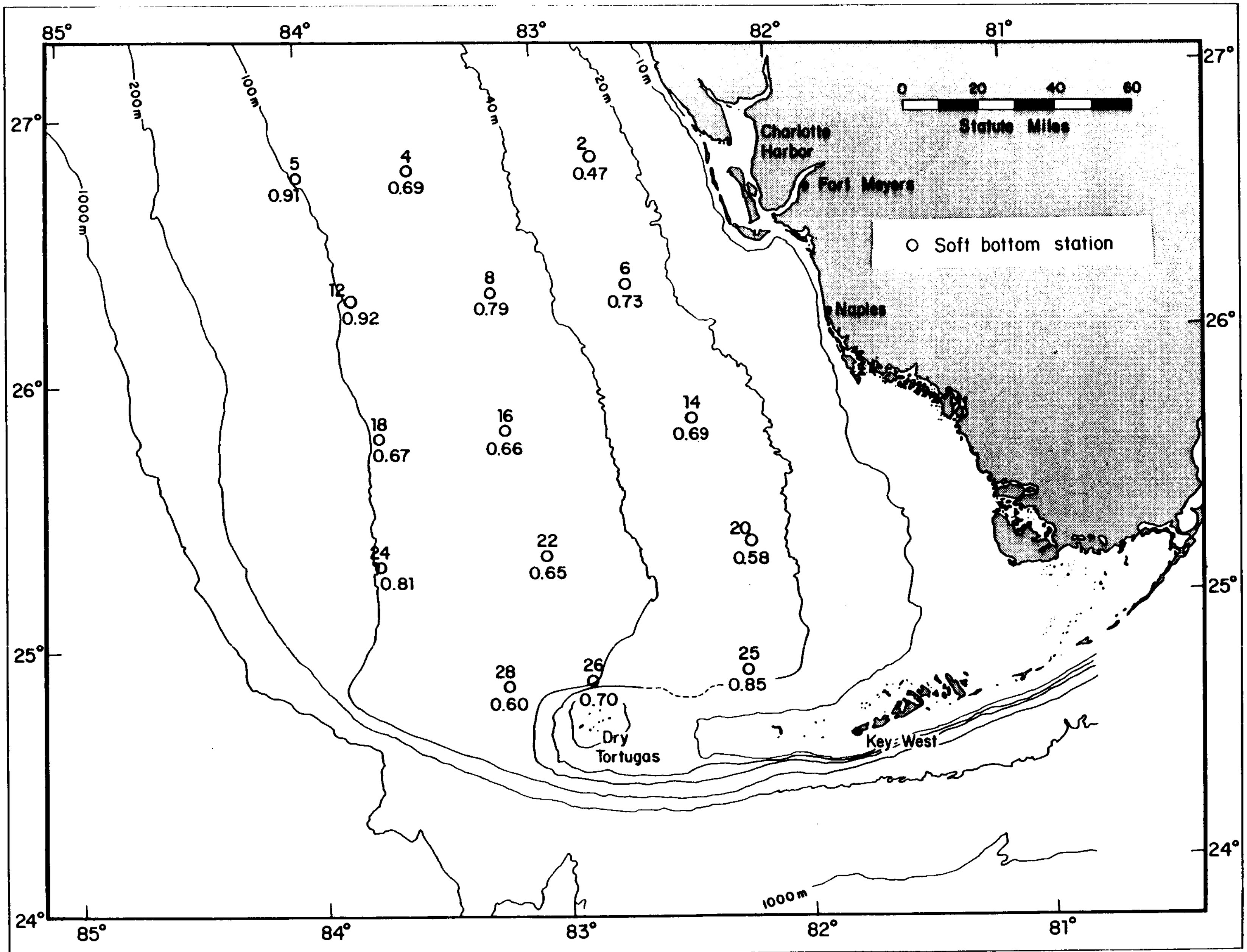


Figure 10-28. Morisita's index values for comparison of Fall and Spring Cruise macroinfauna data.

Table 10-20. Temporal variation in dominant taxa.

Transect	Station	DOMINANT TAXA Fall Cruise	Spring Cruise
A	2	Oligochaeta	Oligochaeta
		Paraonidae	Paraonidae
		<u>Eunice vittata</u>	<u>Fabricia</u> sp.
		<u>Synelmis albini</u>	<u>Prionospio cristata</u>
	4	<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Oligochaeta	<u>Sphaerosyllis</u> sp.
	5	<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Paraonidae	Paraonidae
B	6	<u>Fabricia</u> sp.	<u>Fabricia</u> sp.
		<u>Prionospio cristata</u>	Paraonidae
	8	Paraonidae	Paraonidae
		<u>Lucina radians</u>	<u>Lucina radians</u>
	12	<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Paraonidae	Paraonidae
C	14	Paraonidae	Paraonidae
		<u>Lucina radians</u>	<u>Lucina radians</u>
			<u>Prionospio cristata</u>
	16	Paraonidae	Paraonidae
		<u>Synelmis albini</u>	<u>Prionospio cristata</u>
		Oligochaeta	Nemertina
	18	<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Bivalvia	<u>Minuspio cirrifera</u>
D	20	Oligochaeta	Oligochaeta
		Paraonidae	Paraonidae
		<u>Lembos</u> sp. A	Nemertina
		<u>Apseudes</u> sp. A	<u>Prionospio cristata</u>
	22	Paraonidae	Paraonidae
		<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Oligochaeta	<u>Ampharete acutifrons</u>
	24	<u>Synelmis albini</u>	<u>Synelmis albini</u>
		Bivalvia	Veneridae
		Paraonidae	Paraonidae
E	25	<u>Minuspio cirrifera</u>	<u>Minuspio cirrifera</u>
		Oligochaeta	<u>Magelona pettibonae</u>
		<u>Prionospio cristata</u>	<u>Prionospio cristata</u>
	26	Oligochaeta	Oligochaeta
		<u>Caecum pulchellum</u>	<u>Prionospio cristata</u>
		<u>Sigambra tentaculata</u>	<u>Sigambra tentaculata</u>
		Paraonidae	Paraonidae
	28	Paraonidae	Paraonidae
		<u>Synelmis albini</u>	<u>Lucina radians</u>
		Oligochaeta	<u>Maera</u> sp.
		<u>Ampharete acutifrons</u>	<u>Ampharete acutifrons</u>

results indicated less temporal variability at these offshore middle shelf stations than at the inshore middle shelf and inner shelf sampling locations.

Faunal similarity was also assessed using normal and inverse clustering analysis with the Bray-Curtis index (Smith, 1976). Results of the Morisita's index analyses and the clustering analyses were not directly comparable because data used in the calculation of the Morisita's index differed from those in the clustering analyses. Only the more frequently occurring taxa for which taxonomic identifications were certain were used in the clustering analyses of the macroinfaunal data. Taxa which did not have three positive occurrences were not included in the clustering analysis. The entire data set was used in the calculation of Morisita's index.

The results of the normal clustering analysis of the macroinfaunal data for the Fall Cruise are presented in Figure 10-29. The associated dendrogram for this analysis is presented in Figure 10-30. Five groups of stations were distinguished by this analysis. The first group (I) of stations was composed of the offshore middle shelf stations (5, 12, 18, and 24) and one inshore middle shelf station (4). Although many of the taxa found at these stations were found at stations in other groups, the polychaetes Glycera papillora, Prionospio spp., Synelmis albini, and Terebellides stroemii were predominantly found at the stations in this group. The second group (II) of stations was composed of four inshore middle shelf stations (8, 16, 22, and 28). Taxa which had their predominant abundances at the stations in this group were the polychaetes Magelona sp. A, Ceratocephale oculata, Schistomeringos rudolphi, and Tharyx annulosus, and the bryozoans Selenaria spp. Stations 25 and 26 formed the third group (III) of stations. The taxa which were found predominantly at these stations were the polychaetes Cossura delta, Sigambra tentaculata, Magelona spp., Prionospio cirrifera, Paraprionospio pinnata, and Magelona pettiboneae. The two inner shelf stations on Transects B and C (Stations 6 and 14) formed the fourth group (IV) of stations. Taxa which were found predominantly at these two stations were Lumbrineris ernesti (polychaete), Cyclaspis sp. A (cumacean), unidentified Aoridae (gammarids), Photis sp. A (gammarid), and Phtisica marina (caprellid). The two inner shelf stations on Transects A and D (Stations 2 and 20) formed the fifth group (V) of stations on the Fall Cruise. Taxa which were found predominantly at these

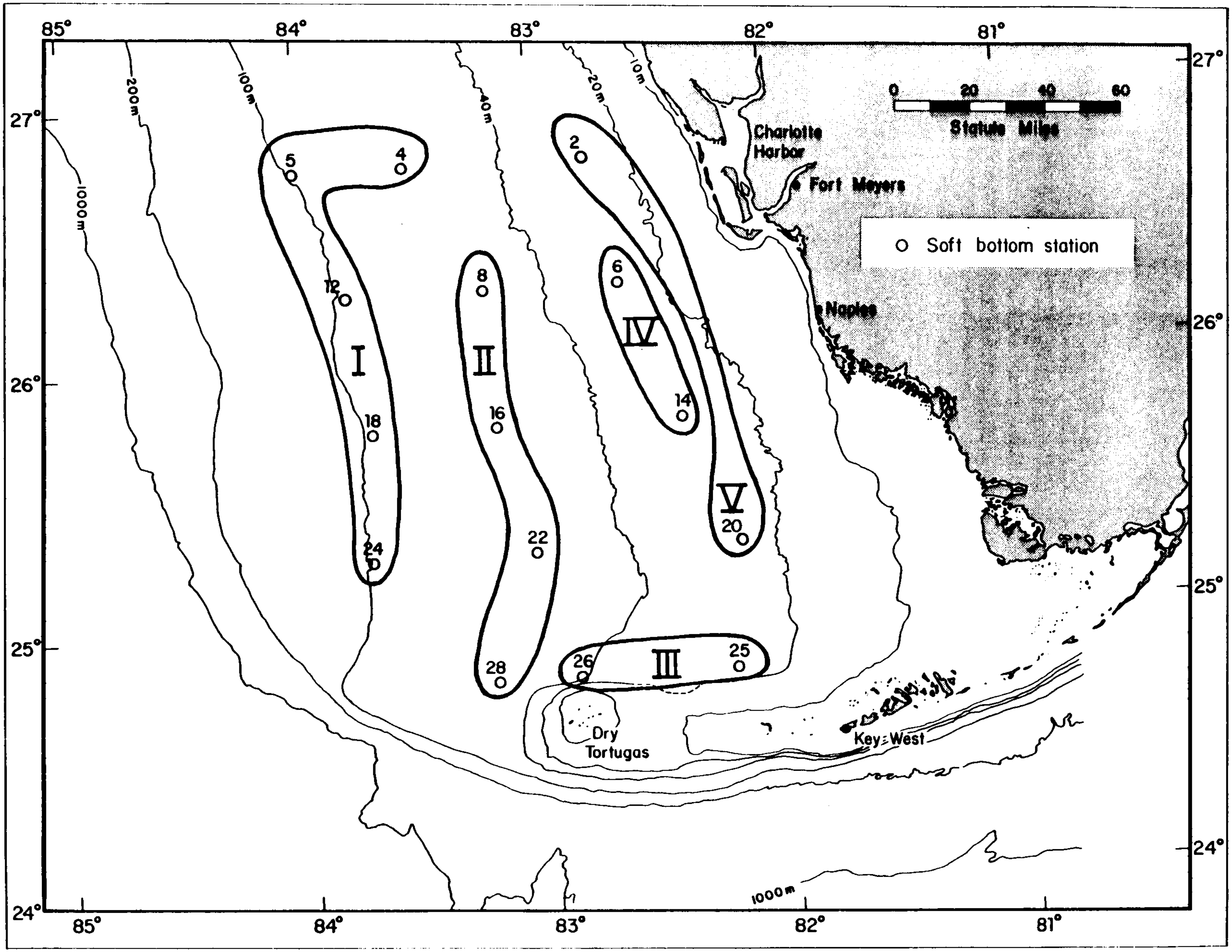


Figure 10-29. Results of normal clustering analysis of Fall Cruise macroinfauna data.

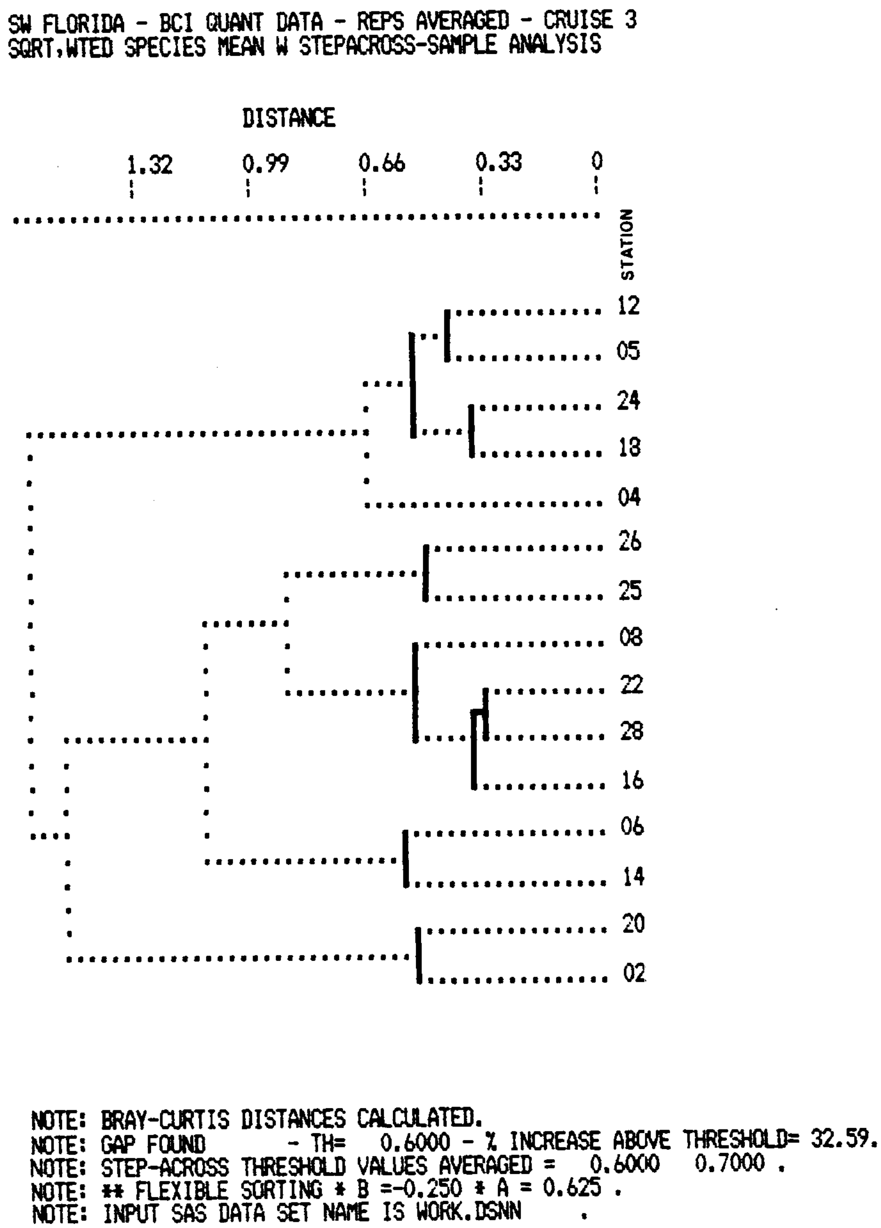


Figure 10-30. Dendrogram for normal clustering analysis of Fall Cruise macroinfauna data.

stations were the polychaetes Vermiliopsis spp., Hydroides crucigara, Goniadides carolinae, Pisione remota, and Ehlersia cornuta, and the gammarid amphipod Maera sp. A.

The results of the normal clustering analysis of the macroinfaunal data for the Spring Cruise are presented in Figure 10-31. The associated dendrogram for this analysis is presented in Figure 10-32. Groups formed in this analysis reflected a general onshore-offshore trend with the obvious exception of Stations 6, 8, and 12, which were located on Transect B. The taxa which were found at the stations in this group (I) were not unique to these stations, rather this group was characterized by having fewer of the more widely distributed taxa. Taxa which were found in higher abundances at the stations in this group included Lucina radians (bivalve), Nuculana spp. (bivalve), and Harbansus spp. (ostracods). The second group (II) of stations was composed of three offshore middle shelf stations (5, 18, and 24). Taxa which were found predominantly at these stations included the polychaetes Prionospio cirrobranchiata and Pionosyllis procera, the anomuran Callianassa marginata, and the brachiopod Platidia clepsydra. The third group (III) of stations was composed of four inshore middle shelf stations (4, 16, 22, and 28) and one inner shelf station (20). Predominant taxa at these stations included the polychaetes Gyptis brevipalpa and Fabricia spp., the bivalves Tellina spp., and the bryozoans Selenaria spp. The fourth group (IV) of stations was composed of Stations 25 and 26. The polychaetes, Sigambra tentaculata and Magelona spp., and the bivalve Tellina sybaritica were among the predominant taxa at the stations in this group of stations. The two inner shelf Stations 2 and 14 composed the fifth group (V) of stations, which clustered closely with the fourth group. The taxa Prionospio cristata (polychaete), Mediomastus spp. (polychaete), Paraprionospio pinnata (polychaete), and unidentified Nemertina were among the taxa common to the fourth and fifth groups. Species such as Cyclaspis sp. A (cumacean) and Synchelidium americanum (amphipod) were found at stations in the fifth group but not in the fourth group.

Normal clustering analysis of the macroinfaunal data for the two cruises combined revealed that the greatest temporal variability occurred at the stations on Transect B. The least temporal variability occurred at the stations on the most southerly Transect E.

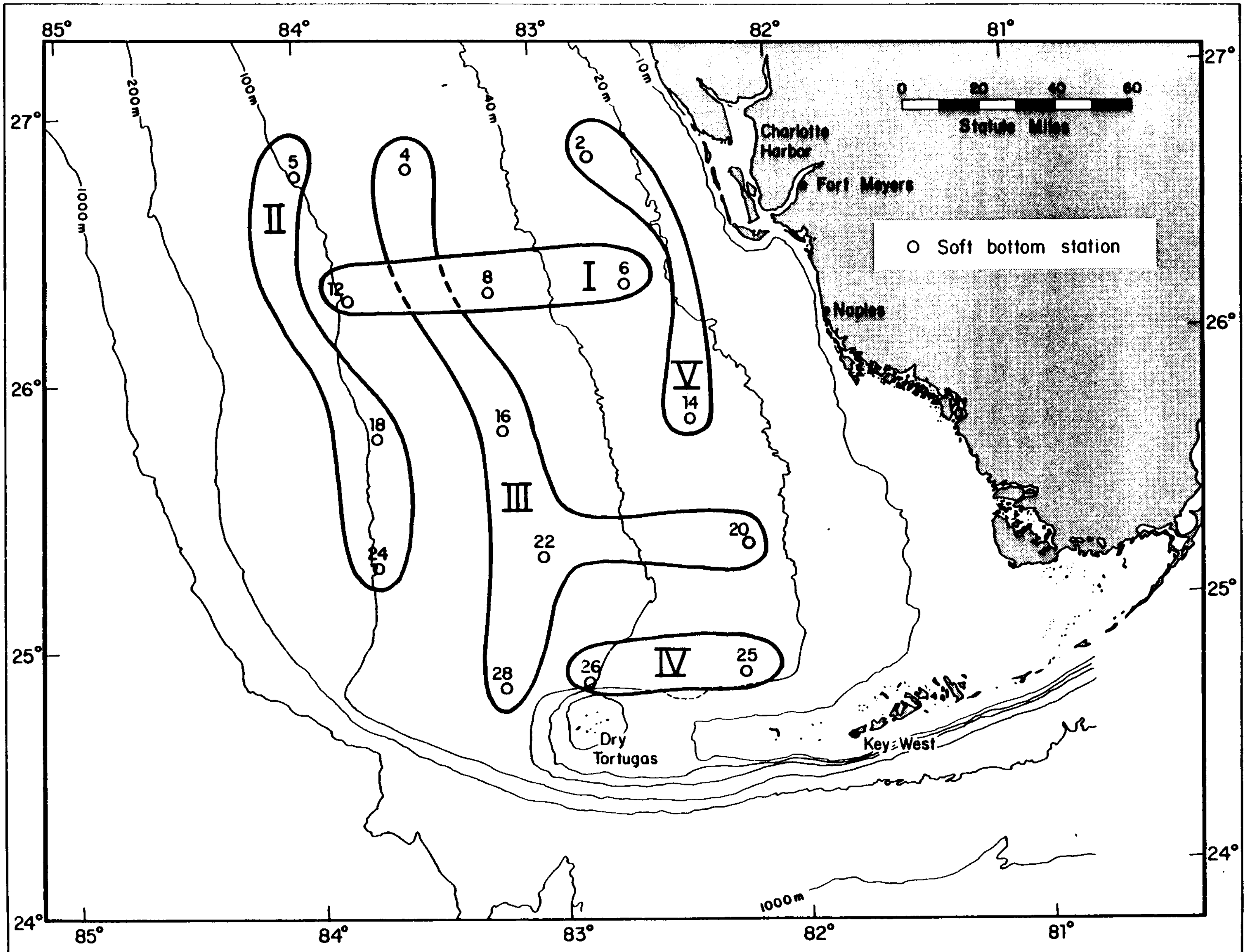
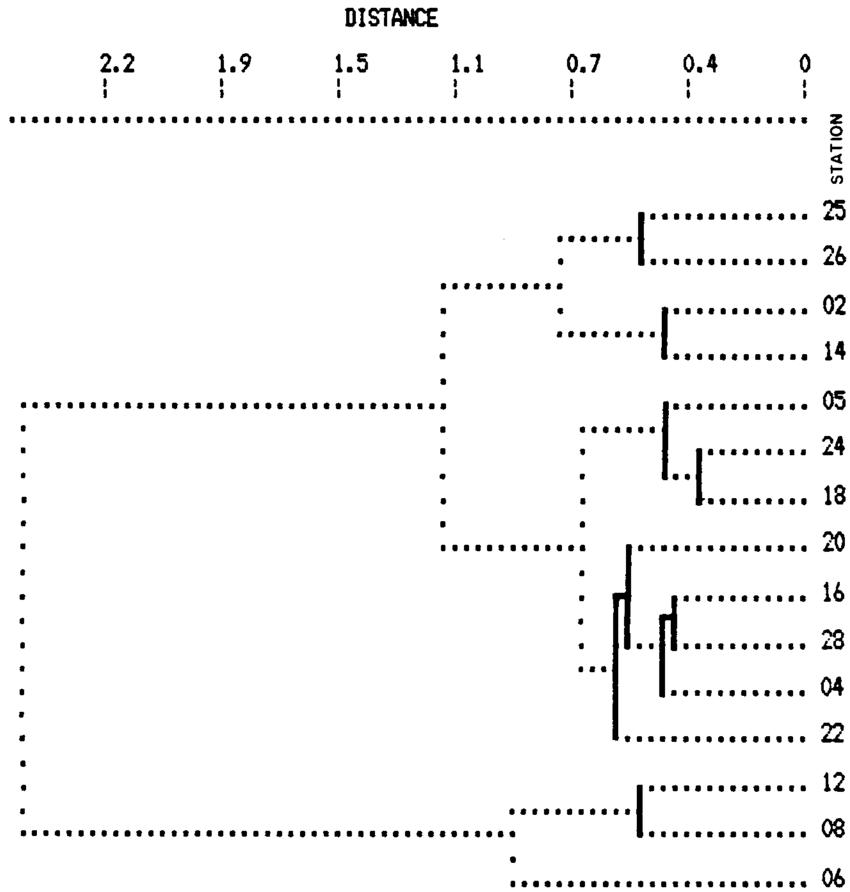


Figure 10-31. Results of normal clustering analysis of Spring Cruise macroinfauna data.

SW FLORIDA - BCI QUANT DATA - REPS AVERAGED - CRUISE 4
SQRT;WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.7000 - % INCREASE ABOVE THRESHOLD= 33.12.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.7000 0.8000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .

Figure 10-32. Dendrogram for normal clustering analysis of Spring Cruise macroinfauna data.

10.3.3.9 Epifauna/Infauna Relationship

Since epifauna can reduce (by predation) or increase infaunal abundance (by providing microhabitats), data from the bottom photographs were analyzed to estimate epifaunal abundance. Results are summarized in Table 10-21. Percentage incidence of epifauna was used as an index for abundance and plotted with infaunal density and taxonomic richness (Figure 10-33). Only data from the Fall Cruise were utilized for this comparative analysis. In general, infaunal density increased with an increase in epifaunal incidence (and vice versa). Along Transect A, however, the reverse trend was evident, i.e., a decrease in infaunal density was accompanied by an increase in epifaunal abundance. Infaunal taxonomic richness did not appear to be correlated to epifaunal abundance.

10.3.3.10 Sediment/Infauna Relationship

Substrate is generally considered the most important factor in determining the distributional patterns of infaunal species. Detailed description of the sediment types and characteristics in the study area is provided in Section 7.0. Sediment parameters considered most relevant to the benthos are summarized in Table 10-22 and graphically depicted in Figures 10-34 and 10-35. Mean grain size ranged from 0.77 (Station 5) to 4.15 (Station 25). Highest mean grain size (range: 4.03-4.15) was encountered at Stations 25 and 26. Lowest mean grain size (range: 0.77-1.21) was encountered at all of the stations in Transect A (Stations 2, 4, and 5) and Station 20. Temporally, mean grain size showed the greatest change at Station 2 (where temporal faunal similarity was also low). Visual observations at Station 2 indicated that sediments ranged from very coarse shell material to fine sand. Therefore, it is possible that different locations within the station could have been sampled during the two cruises. Silt/clay content ranged from 1.06% at Station 20 to 78.63% at Station 26. Silt/clay content was highest at Stations 25 and 26 (69-78%), high at Stations 6, 8, 12, 14, and 22 (>15%), moderate at Stations 16 and 28 (>10%, <15%), low at Stations 2, 4, 5, 18, and 24 (>3%, <13%) and very low at Station 20 (<2%). These station groupings do not correspond with the faunal cluster groups (see Section 10.3.3.8) except for the station grouping 25

Table 10-21. Percent incidence of epifauna from bottom photographs (Fall Cruise).

Transect	Station No.	No. of Photos Analyzed	% Photos in Which Epifauna Were Observed	% Sponges	% Crabs	% Urchins	% Holothurians
A	2	172	39.53	7.50	0	16.86	0.58
	4	229	58.52	24.89	0	16.59	0
	5	190	70.00	6.32	37.89	8.42	1.58
B	6	182	80.77	0	9.89	75.27	0
	8	208	33.81	18.75	0.96	0	0
	12	198	34.34	0	10.10	2.02	6.57
C	14	157	88.54	0	0	88.64	1.27
	16	173	28.32	3.47	0.58	1.16	6.36
	18	173	24.86	2.31	1.73	4.05	3.47
D	20	194	74.74	67.01	0	9.28	0
	22	321	63.24	51.40	0	0	0
	24	138	50.00	0	0	46.10*	2.17
E	25		Visibility low due to turbidity - no data				
	26	179	9.50	0	0.56	0	0
	28	156	67.95	57.69	1.92	4.49	0

* Ophiuroids.

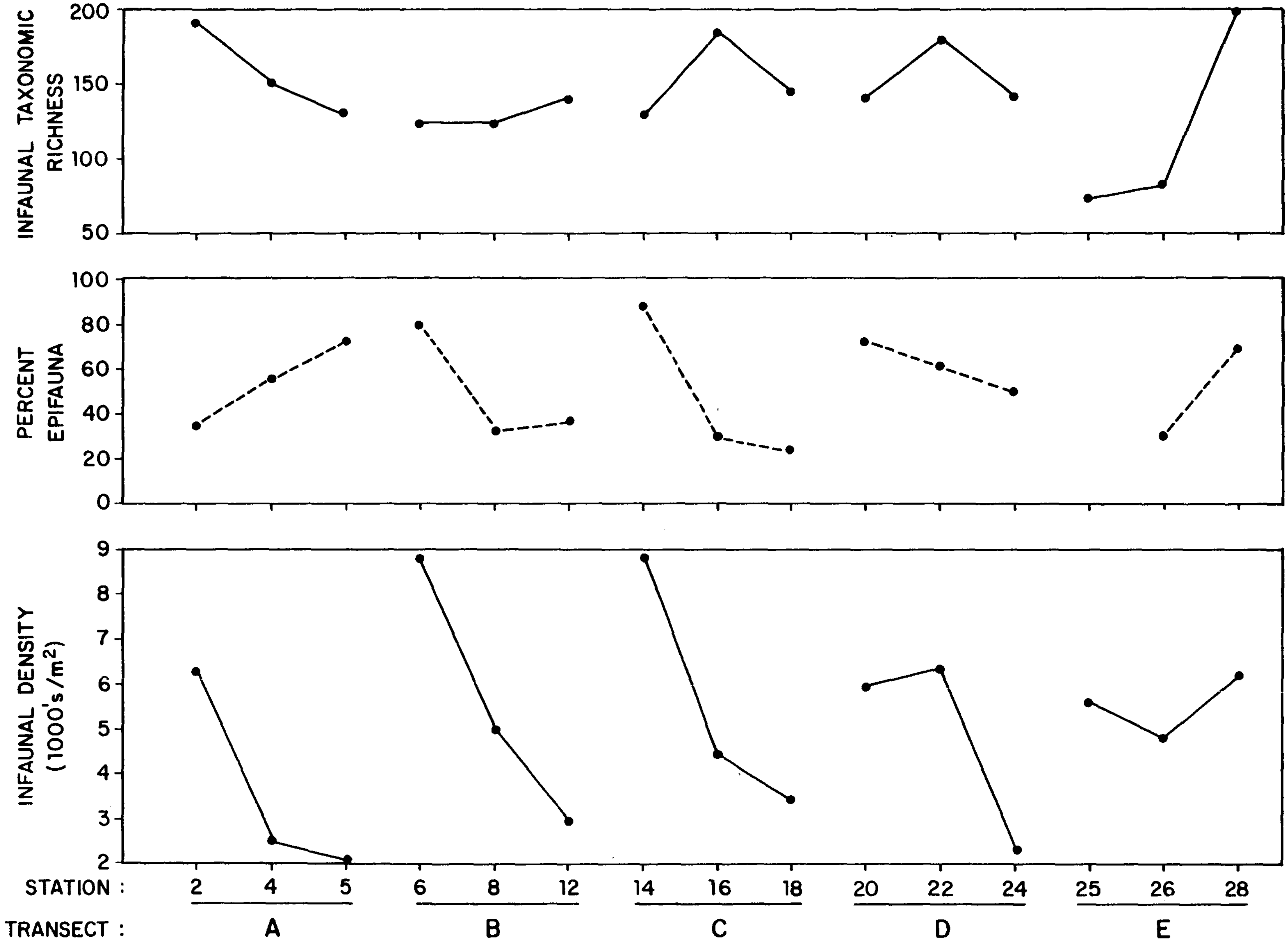


Figure 10-33. Comparison of the percent incidence of epifauna with infaunal taxonomic richness and density (no photographic data at Station 25).

Table 10-22. Selected sediment parameters.

Station	Mean Grain Size (Φ)		% Silt/Clay		% Carbonate	
	Fall	Spring	Fall	Spring	Fall	Spring
2	1.21	2.69	4.55	4.76	72.04	40.58
4	0.91	1.47	7.91	12.41	98.88	97.27
5	0.88	0.77	5.47	5.04	97.09	94.02
6	3.26	3.11	23.74	17.83	85.93	82.60
8	2.51	2.77	14.73	19.51	95.92	93.24
12	2.56	2.20	21.09	17.46	96.69	96.15
14	2.87	3.25	16.83	27.98	96.44	93.59
16	1.87	2.09	14.66	11.60	95.70	95.04
18	1.48	1.66	5.26	3.95	98.16	99.45
20	0.96	1.06	1.43	1.06	98.58	98.29
22	1.84	2.01	16.71	18.87	94.35	95.91
24	1.71	1.64	7.91	7.33	96.26	98.32
25	4.15	4.09	74.86	69.38	90.30	91.10
26	4.05	4.03	78.63	71.25	92.59	91.24
28	2.09	2.26	12.16	10.96	98.50	93.91

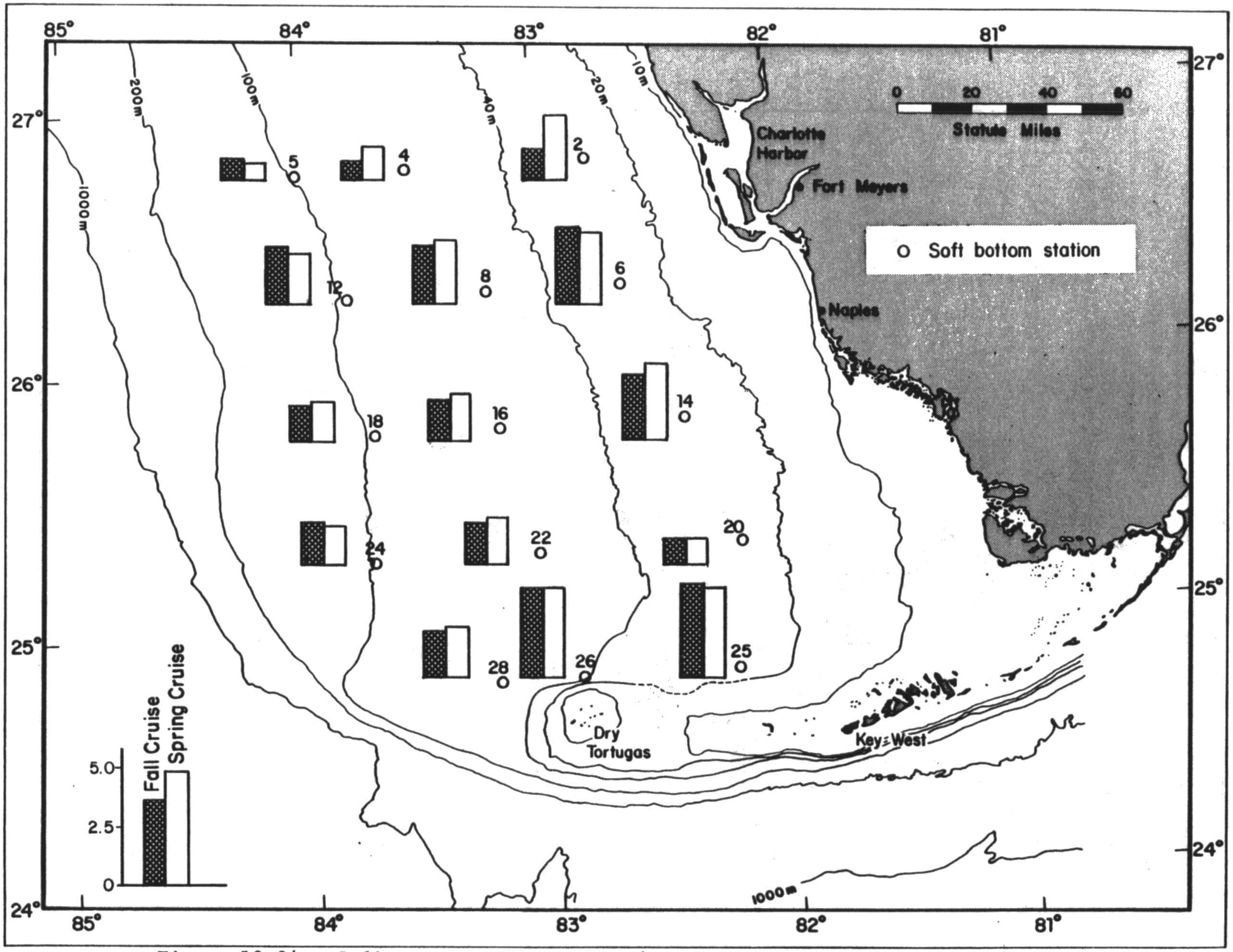


Figure 10-34. Sediment mean grain size (phi units) at soft bottom stations.

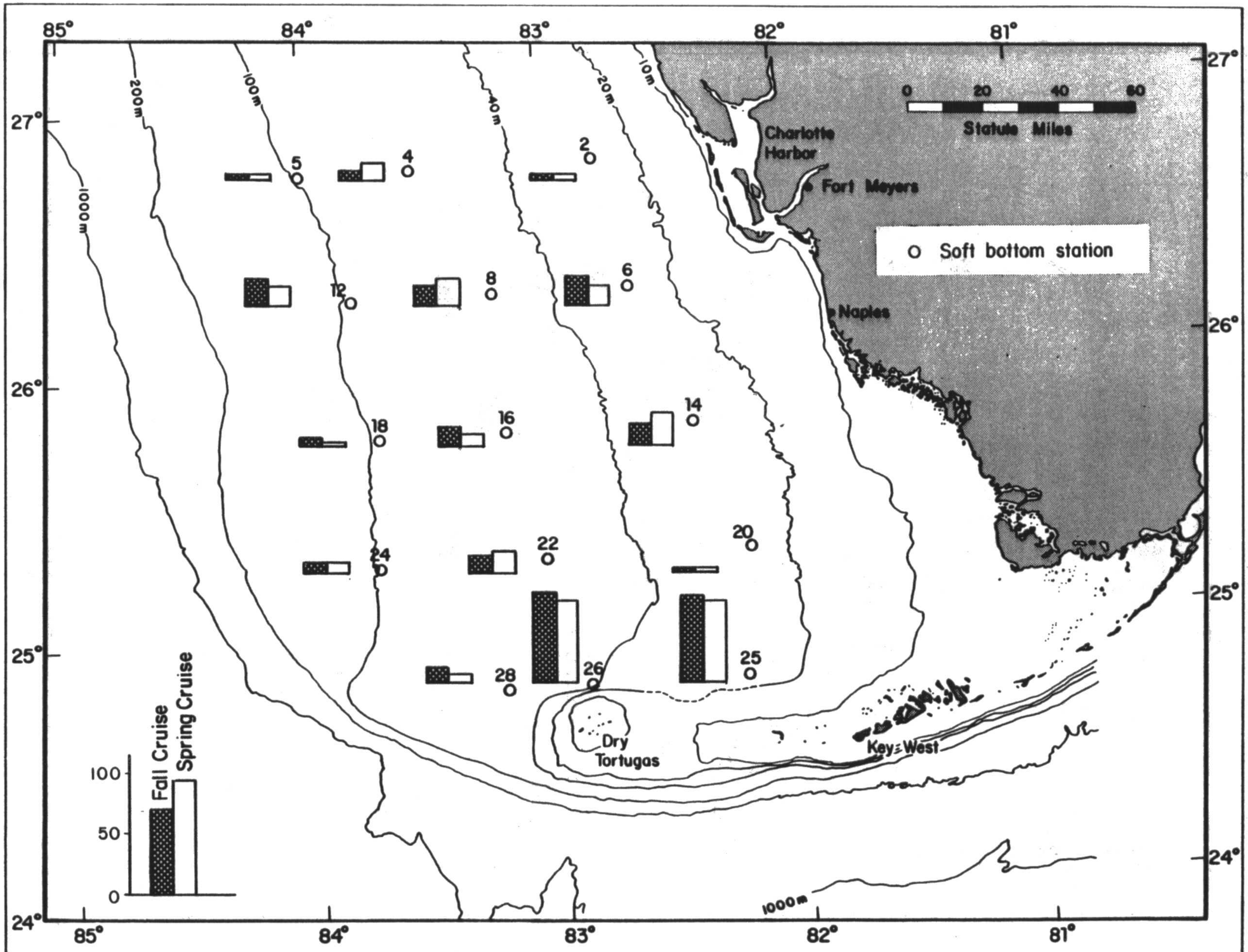


Figure 10-35. Percent silt/clay content in sediments at soft bottom stations.

and 26. Sediments in the study area were high in carbonate content. Stations 2 and 6 contained lower percent carbonates; both these stations are nearshore.

In general (Figure 10-34), mean grain size decreased with increasing depth. Silt/clay content did not exhibit any specific pattern. Temporal variations were minimal in both parameters. Considering carbonates with the mean grain size and silt/clay content, the southernmost transect nearshore stations (25 and 26) were comprised primarily of carbonate mud while the other stations derived their carbonate from coarser shell material. No significant statistical correlations were found between these sediment parameters and community characteristics such as faunal density and taxonomic richness. However, it appears from visual inspection of Figures 10-20 and 10-34 that a reduction in faunal density may be related to a reduction in mean grain size. Sediment preference of the eight most abundant taxa in the study area is presented in Table 10-23. Nemertina and Oligochaeta appeared to have a wide tolerance for grain size and silt/clay content. Since several species may have been lumped together in these taxa, this trend may be an artifact. The polychaetes *Synelmis albini* and Paraonidae spp. also exhibited a wide tolerance for mean grain size and silt/clay content. Factors which vary with depth, at least in this case, appear to be important in determining the abundance patterns of these taxa (see Figures 10-14 and 10-15). The polychaetes *Fabricia* sp., *Prionospio cristata* and *Ampharete acutifrons* and the bivalve *Lucina radians* were restricted in abundance within a small range of mean grain size and silt/clay content. These species appear to be influenced by sediment characteristics.

10.4 Discussion

10.4.1 Epibiota

Only three of the soft bottom stations lacked any evidence of macrophytes. No pattern for the dispersion of algae was apparent since all transects and depths contained stations with algae.

Table 10-23. Sediment/animal relationships.

Species/Taxa	Abundant in Range of Mean Grain Size (Φ)	Abundant in Range of Silt/Clay Content (%)	Maximum Abundance in Mean Grain Size (Φ)	Maximum Abundance in Silt/Clay Content (%)
1. Oligochaeta	0.96-4.05	1.06-78.63	4.03	71.25
2. Nemertina	0.96-4.15	1.06-74.86	1.06	1.06
3. *Synelmis albini*	0.77-2.56	3.95-21.09	1.66	3.95
4. Paraonidae spp.	0.91-2.77	4.55-19.51	2.69	4.76
5. *Fabricia* sp.	2.69-3.26	4.76-23.74	3.26	23.74
6. *Prionospio cristata*	2.69-3.26	4.76-27.98	2.69	4.76
7. *Lucina radians*	2.51-3.26	14.73-27.98	2.87	16.83
8. *Ampharete acutifrons*	1.84-2.26	10.96-18.87	2.01	18.87

The flora obtained in the sampling of the soft bottom stations was limited by comparison to Dawes, Earle, and Crowley (1967); Dawes and Van Breedveld (1969); Dawes (1974); Earle (1969); Humm and Taylor (1961); Phillips and Springer (1960); or Taylor (1966). The soft bottom algae collections were only made on soft unconsolidated sediments. Soft sandy substrates generally lack high concentrations of algae as they do not offer a firm attachment site (Dawson, 1966; Dawes and Van Breedveld, 1969), required by many forms of marine algae. Soft bottom station locations were chosen after review of video coverage. Areas exhibiting a conspicuous attached epibiota were not considered to be appropriate soft bottom locations. These areas included limestone outcroppings, coarse shelly bottoms and thin sandy or shelly material overlying a limestone base, substrates most likely to support a rich algal growth.

Sampling gear and methodology may have caused a slight underestimation of the flora present at the soft bottom stations. Core samples were not expected to contain significant amounts of epibiota unless very high densities were present, as five replicate core samples covered an area of only 0.325 m^2 (1 core = 0.065 m^2). Additionally, representative biota were sorted from the trawls, but the entire sample was never sorted and preserved. Therefore, the dominant flora was sampled, but the less abundant species may not have been identified.

In collections made by the Florida Department of Natural Resources during the Hourglass Cruises (Dawes and Van Breedveld, 1969), a total of 152 species of green, brown, and red algae was collected, with three species of seagrasses. Eighteen of the Hourglass Cruise algae were new records for Florida, including nine range extensions. Differences between Hourglass and these results were attributed to sampling methodology (dredge vs. box corer and trawl), sampling effort (monthly for 28 months vs. twice), and recovery of satisfactory amounts of whole plants. Although the number of species of algae collected at the soft bottom stations was limited, 103 species of macroalgae were collected at the live bottom and soft bottom stations combined. Four species of seagrasses were also collected. The total number of plant species collected during this study was comparable to the number collected during the more extensive Hourglass Cruises. Seasonality reported by the earlier studies was not observed during the present investigation.

Background fish surveys relevant to the study area have been reported by Hastings et al. (1976), Hoese and Moore (1977), Shipp (1978), Shipp and Bortone (1979), Smith (1976), and Smith et al. (1975). Shipp and Bortone (1979) collected 292 species of fish during the MAFLA surveys. Their study area (much larger than the present study area) ranged from south-central Florida to Mississippi with one transect lying in the present study area (between Transects A and B). During the present study, which encompasses an area from offshore Port Charlotte south to the Dry Tortugas, a total of 120 taxa were collected, or roughly 40% of the demersal shelf species identified by Shipp and Bortone (1979).

Some changes in taxonomic composition occurred between cruises. The Fall Cruise accounted for 99 taxa of fish, while the Spring Cruise accounted for 77 taxa, a difference of 22. There were 58 taxa collected in common on both the Fall and Spring Cruises.

With the exception of Bollmannia communis, which occurred only at Stations 25 and 26, most of the abundant taxa were found throughout the sampling area, and faunal composition was fairly similar from area to area. Little seasonal variation in faunal composition was detected between the two sampling periods.

The soft bottom epifauna collected by otter trawl should not be considered quantitative (Appendix B-6). It was not thought valid to quantify trawl samples for this study. Trawling duration was generally comparable among stations and sampling periods, but, normally only a subsample of the catch was retained for identification. Entire small-sized samples were only occasionally saved. The data presented in Appendix B-6 are strictly records of catch, documenting the numbers of various organisms collected. Quantities listed can be considered as roughly equivalent to the proportions present in trawl samples, but the species list cannot be considered as a complete census. All quantitative analyses and comparisons must, therefore, be approached with caution and are useful only for distinguishing general trends. The data, however, possess value for describing the general patterns of faunal distribution. The presence of sponges in the otter trawl collections indicated sampling over scattered live bottom patches.

Clustering analysis results indicated little latitudinal variation in epifaunal composition; but distinct bathymetric patterns were observed. Offshore middle shelf stations consistently grouped together and with the inshore middle shelf Stations 8 and 16. Inshore middle shelf Stations 22 and 28 grouped with the offshore middle shelf stations on the Fall Cruise and with Stations 2, 4, and 20 on the Spring Cruise. This may have simply been an artifact of a single otter trawl collection at each station on the two cruises or may have been due to a real shift in faunal composition, although temporal variability at Stations 22 and 28 was not evident. Differences in the clustering of the remaining stations may have also been due to the small sample size at each station, but these groupings did indicate onshore-offshore differences in faunal distributions.

10.4.2 Macroinfauna

10.4.2.1 Study Design Considerations

For the purposes of this study, macroinfauna are classified as those organisms that are retained in a 0.5-mm sieve (Mare, 1942). Because several investigations have also utilized (or recommended) a 1.0-mm sieve as the size separating macroinfauna (e.g., Josefson, 1981; Lie, 1968; Swartz, 1978; Tamai, 1982; Word et al., 1976), the faunal differences observed between the two sieve sizes were evaluated. Results (see Section 10.3.3.3) clearly show that the 1.0-mm separation would lose substantial faunal information (in terms of species composition, richness, and density), although it would save considerable sorting and identification time. Hence, the 0.5-mm level separation (as used in the present study) was necessary for the study area. Reish's (1959) classical study and a more recent study by Mahadevan and Patton (1979) on sieve size effects supported these findings.

Since benthic infauna are vertically distributed in the sediment, the depth of penetration of the sampling device should be well below where the majority of fauna are distributed. Most investigators claim that a majority of the infauna are found within the top 10 cm of the sediment (Holme, 1964; Johnson, 1967; Keith and Hulings, 1965; Lie and Pamatmat, 1965). The texture of the sediment is probably the most important factor in determining the distributional depth of the infauna. Recent studies (Christie, 1976; Culter and Mahadevan, 1978) have shown that considerable numbers of taxa and individuals may be distributed below sediment depths of 10 cm. The box core used in this study can penetrate to a depth of 30 cm into the sediment. Only the upper 15 cm of the box core sample was processed in order to save sorting time and to reduce the bulk of material to be handled. The upper 15 cm and lower 15 cm of the box core sediments at two stations were analyzed to evaluate this decision in terms of the adequacy of the sample. The results (see Section 10.3.3.2) showed clearly that the lower 15-cm fraction provided insignificant additional faunal information. Therefore, the 15-cm depth of box core penetration used in the present study was adequate to sample the macroinfaunal communities in the study area.

Replication is extremely important for quantitatively describing the benthic macroinfauna (Holme, 1964; Holme and McIntyre, 1971; Lie, 1968; Mahadevan, 1979; Simon, 1978). Taxon saturation curves (Gleason, 1922; Holme, 1953; 1964; Jones, 1956; Longhurst, 1959) provide a simple method for determining adequacy of replication. The assumption of the taxon saturation curve is that an environment is adequately sampled when no more new taxa are added in consecutive replicates, i.e., when cumulative numbers of taxa are plotted versus cumulative number of replicates, an asymptote should be reached. For practical reasons, a less than or equal to 10% increase in consecutive replicates is considered adequate to sample the majority of the taxa in a habitat (Mahadevan et al., 1977). This 10% cutoff, although arbitrary, provides consistent results. Once enough replicates are collected to reach the 10% increase criterion, additional replicates add taxa very slowly, thereby requiring an enormous number of replicates to reach the asymptote (Lie, 1968). Therefore, to collect a majority of the taxa (ca. 90%) in a habitat, saturation to the $\leq$10% increase level, is considered adequate. As described in the results (Section 10.3.3.1), the five replicates collected at each station during the present study can be considered generally adequate. However, taxonomic richness values presented in this report must be considered conservative because of the 10% criterion used in determining sampling adequacy. The error introduced by this level of replication, for all other community parameters, is considered minimal, since additional replicates would not have dramatically altered the proportions of the dominant taxa.

10.4.2.2 Faunal Composition

Composition and distributional patterns of selected taxa are described in the results (Section 10.3.3.4). The enormous number of taxa (1,033) identified during this study is a reflection of the diversity and heterogeneity of macroinfaunal communities in the study area. Previous studies in this shelf region (Dames and Moore, 1979; Lyons, 1980; Lyons and Collard, 1974; Mahadevan, 1981) have similarly concluded that the shelf region is extremely diverse. Twenty-nine taxa were considered dominants and their distributional patterns showed (see Section 10.3.3.4) that faunal zonation was present but not clear cut as those described by Dames and Moore (1979) and Lyons (1980). A Synelmis albini (polychaete) dominated zone was present between 60 and 90-m depths of the study area. This zone can be considered similar to the zone described as the "100-m cluster" by Dames and Moore (1979). Temporal variation in this zone was less in comparison to the shallower stations. The mid-depth stations (40-60 m) of the study region, although somewhat similar to each other, were not clearly demarcated as a zone. Lyons (1980) classified similar depths (55-73 m) as a distinct "Middle Shelf I Zone" and Dames and Moore (1979) classified similar depths (40-60 m) as the "40-m cluster". Lyons (1980) and Dames and Moore (1979) also recognized a nearshore faunal zone at the 20-m depth contour areas. The absence of such clear cut shallow faunal zones from the data of the present study is probably a reflection of the difference in sampling efforts between the studies (i.e., spatially and temporally more extensive sampling may reveal such shallow faunal zones as identified in the above cited studies). Also, spatial heterogeneity is extremely common in shallow water macroinfaunal communities (Mahadevan, 1981) and is probably related to a variety of factors such as: 1) the influence of nearby bays and estuaries; 2) the presence of patchy hard-bottom habitats; 3) heterogeneity of sediment; 4) influence of natural factors such as storms and red tides; 5) biological factors such as predation by epifauna and competition by other infauna.

10.4.2.3 Taxonomic Richness and Diversity

As discussed earlier (Section 10.4.2.1), estimates of taxonomic richness from the present study are essentially conservative for two major reasons:

1) Additional replication would have added considerable number of "rare" species.

2) Certain groups, such as nemertines, oligochaetes and paraonids (polychaete) were not separated to the species level (because of taxonomic limitations); this separation would have added several species.

In spite of the conservativeness, taxonomic richness at stations in the study area was extraordinarily high (see Results Section 10.3.3.6). On an average, taxonomic richness values reported in the present study were twice as much as those reported by Dames and Moore (1979). In general, the deeper stations (>60 m) and the southernmost stations (near Dry Tortugas) exhibited the highest taxonomic richness (probably receiving an influx of Caribbean species). Temporal variations in taxonomic richness were minimal. In comparison to previous studies from the study region, taxonomic richness was considerably higher in the present study (Table 10-24).

Data on taxonomic diversity (Shannon-Weaver index, Shannon and Weaver, 1963) and equitability (Pielou's index, Pielou, 1966) indicated that the spatial and seasonal variations for these parameters in the study area were minimal (see Results Section 10.3.3.7). The usefulness of diversity indices in ecology has been questioned by Hurlbert (1971) and Peet (1975), while other authors (Boesch, 1972; Pearson, 1975; Swartz, 1972) have recommended its use for detecting ecological change. The arguments and indices are so numerous that confusion is rampant (reviews in Fager, 1972; Hairston, 1964; Hurlbert, 1971; Peet, 1974; Pielou, 1975; Sanders, 1968; Smith et al., 1979; Whittaker, 1972; etc.). Whatever the arguments and personal preference of indices are, most investigators agree that a diversity index should be a measure that somehow reflects the species richness and evenness of a community. The Shannon-Weaver index purports to reflect these characteristics. Higher species diversity

Table 10-24. Comparison of average species richness (number of species/station) and faunal density (number of organisms per m^2) between the present study and past benthic studies in southwest Florida.

	Locality	Depth (m)	Average Species Richness	Average Faunal Density	Source
1.	Hillsborough Bay	1 - 5	29	73,400	Simon, 1978
2.	Mid-Tampa Bay	2 - 8	54	23,160	Mahadevan et al., 1980
3.	Lower Tampa Bay	2 - 5	88	11,061	Mahadevan, 1976
4.	Anclote Sound	1 - 3	90	12,090	Mahadevan and Patton, 1979
5.	Gulf of Mexico (off Anclote to Clearwater)	2 - 15	65	6,513	Mahadevan, 1981
6.	Charlotte Harbor	1 - 2	80	3,170	Texas Instruments, Inc., 1978
7.	Offshore Charlotte Harbor	20 - 100	59	2,299	Dames and Moore, 1979
8.	Offshore Charlotte Harbor	25 - 90	156*	4,998*	Present Study (Transect A)
9.	Naples Bay	1 - 3	38	6,702	Yokel, 1979
10.	Offshore Naples Bay	25 - 90	165*	6,068*	Present Study (Transect C)
11.	Southwest Florida Shelf	25 - 90	150*	5,749*	Present Study (Transects A-E)

NOTE: These comparative data should be viewed with caution, because of the different sampling methodologies, sampling frequencies, and number of stations sampled by the investigators; sieve size used in the studies was 0.5 mm.

* Data from Tables 10-11 and 10-13. Richness values presented represent "taxonomic" rather than true "species" richness.

values are generally construed to be ecologically desirable. For example, organically enriched areas and other polluted areas (where dominance by few opportunistic species occurs) exhibit low species diversities when compared to similar unpolluted habitats. Taken in this context, the diversity values in the study area are extremely high and could reflect clean habitat conditions. This statement should, however, be viewed with caution, since at times polluted areas where pioneer communities exist, such as areas that receive thermal discharges, have been shown to exhibit high diversity (Logan and Maurer, 1975; Mahadevan et al., 1977).

In comparison to the study by Dames and Moore (1979), diversity values reported in the present study are considerably higher.

10.4.2.4 Faunal Density

Abundance of macroinfauna is considered a measure of benthic standing crop (Holme, 1964) particularly in areas where epifauna and algae are relatively scarce. Therefore, comparisons of faunal density can provide an understanding and delineation of faunal zones. Faunal density results are described in Section 10.3.3.5. Faunal density appears to be inversely related to depth, i.e., deeper stations generally exhibited lower faunal densities. Dames and Moore (1979) found a similar trend in their studies of the Eastern Gulf of Mexico (MAFLA program). Temporal variations in faunal density were occasionally pronounced. Polychaetes accounted for about 60% of the fauna; this is consistent with the findings of Dames and Moore (1979). In comparison to other benthic studies in the region, density from the present study was about the same or lower (Table 10-24).

10.4.2.5 Faunal Similarity

Overlap coefficients or indices of faunal similarity are extremely useful in detecting spatial and seasonal changes in macroinfaunal communities. The obvious advantage of these types of indices over diversity indices is that taxa in common and the number of individuals shared between two samples, seasons, or stations can be compared and reduced to a single similarity value. Use of cluster analysis (Clifford and Stephenson, 1975; Stephenson et al., 1972) can differentiate groups of stations or seasons that are similar. Faunal similarity analyses for the whole set of data were conducted using the Morisita's index (Morisita, 1959) and results are described in Section 10.3.3.8. Using only the more frequently occurring taxa (Stephenson and Cook, 1980), faunal similarity was also assessed using normal and inverse clustering analyses with the Bray-Curtis Index (Bray and Curtis, 1957; Smith, 1976). Results are described in Section 10.3.3.8. Both methods identified an offshore faunal zone dominated by Synelmis albini (depths: 60 to 90 m) and detected no pronounced seasonal changes in any of the stations (except Station 2 where a concomitant change in sediments also occurred; see also Section 10.3.3.10). The clustering analysis identified a faunal zone (nearshore <50 m) in the southernmost area of the study region (near Dry Tortugas). Some nearshore groupings of stations (ca. 20-m depth) and mid-depth station groupings (ca. 50-m depth) were also evident from the cluster analysis. These groupings were, however, not as distinct as the offshore group of stations. Therefore, in terms of faunal zonation, only the offshore faunal zone (60 to 90-m depth) is clearly distinct and compares well with faunal zones previously described by Dames and Moore (1979) and Lyons (1980).

10.4.2.6 Factors Influencing Infaunal Distribution

Data obtained from the present study indicate that at least three groups of factors influence the distributional patterns of macroinfaunal communities in the study area:

1) Depth-Related Factors: Evidence for the influence of factors related to depth on infaunal distribution comes from the examination of faunal density (Section 10.3.3.5), abundance patterns of dominant species (Section 10.3.3.4), and the faunal similarity analyses (Section 10.3.3.8). On the southwest Florida shelf, water depth is closely related to distance from shore; therefore, factors which are related to water depth are also related to distance from shore. Factors of this nature include the abundance and composition of organic material in the sediment, sediment grain size, and turbidity. Previous studies in the area (Dames and Moore, 1979) also have arrived at a similar conclusion.

2) Sediment Characteristics: Sediment grain size and silt/clay content appear to influence the distribution of certain dominant taxa (Section 10.3.3.10). Similarly, it appears to influence faunal density, with finer grain size habitats having a greater density. Although no statistical validity can be attached to this finding, it is contrary to Dames and Moore's (1979) findings, where density was inversely related to fine grain sediments. The importance of sediment characteristics to infaunal distribution has been well documented in literature (Bloom et al., 1972; Gray, 1974; Nichols, 1970; Pearson, 1975; Sanders, 1958; Thorson, 1957). In the study area, bathymetry and sediment type appear to be related (except in the southernmost transect). This inter-relationship and the obvious influence of sediment type at Station 2 (Section 10.3.3.10) and the southernmost transect nearshore stations (25 and 26), suggest that sediment characteristics, especially substantial changes, are as important as factors related to depth and distance from shore in influencing infaunal distribution.

3) Epifaunal Abundance: Varying types and abundance of epifauna could impart different influences on infaunal distribution. For example, sponges, while providing microhabitats for certain infaunal species, can interfere with larval settlement; large deposit feeders such as holothurians can "crop" large areas and considerably reduce the abundance of infaunal species. Although these relationships are extremely complex, a simple comparison of epifaunal abundance to infaunal abundance showed that a direct relationship may exist (Section 10.3.3.9). Though preliminary, it appears that epifaunal abundance may also be an important factor in the distribution of macroinfaunal communities in the study area.

10.4.2.7 Overview

The macroinfaunal communities in the study area were diverse; both taxonomic richness and equitability were relatively high. Faunal densities were moderate and oligomixity (dominance by few species) low. An offshore faunal zone (60 to 90-m depth) dominated by the polychaete *Synelmis albini* was the most distinct zone that was comparable to previous studies. Spatial and temporal variations were pronounced in the nearshore areas, thereby negating any distinct faunal zones. Factors related to depth and distance from shore, sediment characteristics and epifaunal abundance appear to influence infaunal distribution in the study area.

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11.0 LIVE BOTTOM BIOTA

11.1 Introduction

Live bottom stations were sampled in the course of the Southwest Florida Shelf Ecosystems Study Year I effort to characterize live bottom areas which may be susceptible to damage from gas and oil development activities. This effort was conducted to provide preliminary information for decisions on leasing activities and environmental stipulations by the Minerals Management Service.

Fifteen live bottom stations were chosen in the course of the sampling effort to provide the needed information (see Section 3.0). Sampling was performed using a variety of techniques, involving both visual and actual collection of specimens, to allow characterization of the epibiota of the southwest Florida shelf.

11.2 Methods and Materials

11.2.1 Field Methods

The methods of collection at live bottom stations are described in Section 5.0.

11.2.2 Shipboard Processing

The complete contents of all trawls and dredges were photographed prior to sorting. Photographs were also made of the dominant species (particularly sponges) to aid in the identification of the species observed in the underwater still photographs. The biological specimens collected in the dredges and trawls were then rough-sorted from all non-living material. Crustaceans and echinoderms were immediately placed into containers with a 15% solution of $MgSO_4$. They were anesthetized for 20 to 30 min to reduce loss of appendages. All specimens were then preserved in either 10% buffered formalin or 70% ethanol depending on the taxon. Labels were placed on both the inside and outside of all specimen containers. Specimens that were photographed on deck for later comparison with underwater still camera slides were labeled and identified with a distinctive identification number.

11.2.3 Laboratory Analysis

All samples were returned to the laboratory, sorted to the lowest possible taxonomic level, and identified to the species level whenever feasible. Representative individuals of the sorted specimens were then sent to consulting taxonomic experts for identification or verification of identifications. Following final identifications, species lists were developed for each station and all data were computerized to facilitate further statistical analysis. A voucher collection was assembled and will be forwarded to the U.S. National Museum. Figure 11-1 shows a flow chart for the processing of live bottom station biological samples.

11.2.4 Quantitative Slide Analysis

All color 35-mm still photographs were initially reviewed in their original roll form using a Dukane Model 27A25 microreader. Slides taken at each station with images of epibiota in at least five percent of the area covered in a slide were selected for analysis. Estimates of the coverage of the epibiota were, therefore, of biotal coverage within live bottom patches at the stations. These data supplemented the television data (Section 3.0) which provided estimates of live bottom coverage by the patches at the stations. 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.

One hundred slides per station were randomly chosen from all of the slides containing suitable epifaunal images for quantitative slide analysis. All suitable slides were analyzed at stations where less than 100 acceptable photographs had been taken. The Fall Cruise stations for which 100 slides were not examined were Stations 1 (99 slides), 3 (36 slides), 7 (28 slides), 13 (82 slides), 17 (42 slides), 19 (64 slides), 21 (98 slides), and 27 (31 slides). Spring Cruise locations for which 100 slides were not examined were Stations 1 (99 slides), 3 (68 slides), 7 (56 slides), and 23 (99 slides).

Quantitative slide analyses were performed to estimate the percentage cover of the various species, genera, species-groups, and/or substrate types that could

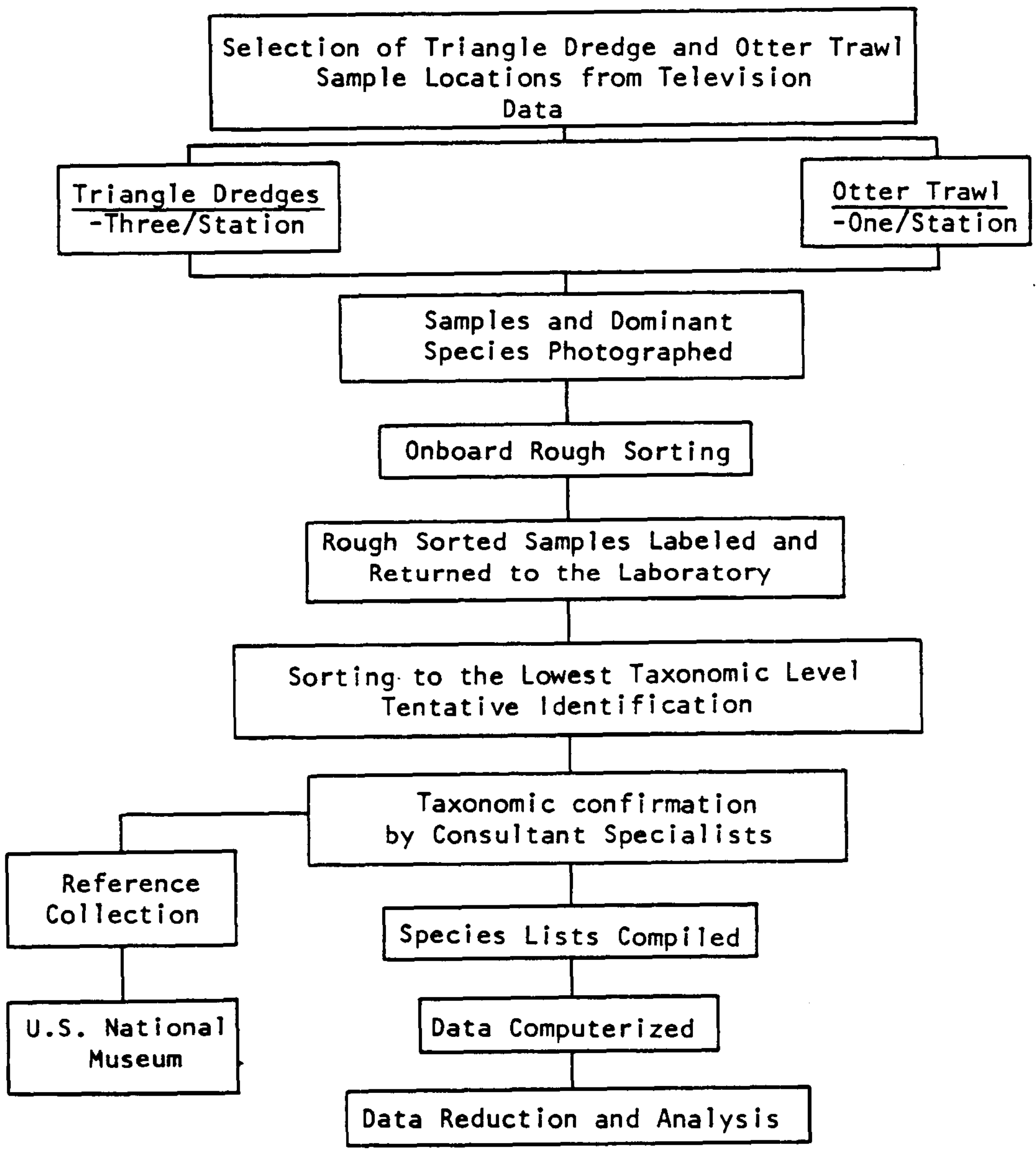


Figure 11-1. Live bottom station biological sample analysis methodology.

be identified at each station. Using an acetate overlay, 100 randomly selected points were superimposed over each slide while it was projected onto the screen of the microreader. The number of points that covered each of the biotal and/or substrate types was recorded for every slide. All of the biota was identified to the lowest taxonomic level possible, and all 100 slides, or all available slides less than 100, per station were analyzed using this method.

Taxon-area curves were then plotted for every station sampled (Figure 11-2). In all cases, 100 slides per station were adequate for these curves to become nearly level. This indicated that a majority of the species identifiable by this method had been sampled at each station. For most stations, the analysis of 50 to 60 slides (25 to 30 m^2) per station was sufficient. The data were computerized for further analysis.

The percentage cover of each distinguishable biotal or substrate type was proportional to the number of points lying over that particular image. These percentages were calculated and then converted to the absolute area covered by each of the faunal or substrate types at each station. These analyses of the still photos provided a quantitative estimate of the epifauna, macroalgae, and substrate types present at each station. Figure 11-3 shows a flow chart for the quantitative slide analysis.

11.3 Results

11.3.1 Species Richness

Species richness (total number of species) values for the live bottom stations are presented for the otter trawls (Figure 11-4) and the triangular dredge samples (Figure 11-5). Comparison of the species richness values of the two sampling methods revealed that the triangular dredge samples had higher values than the otter trawls in 25 of 29 comparisons. This was due, in large part, to three triangular dredge samples and only one otter trawl sample being collected at each station, as well as the differences in types of biota collected. Trawls collected fish species and larger epibiota while the triangular dredges collected the smaller epibiota.

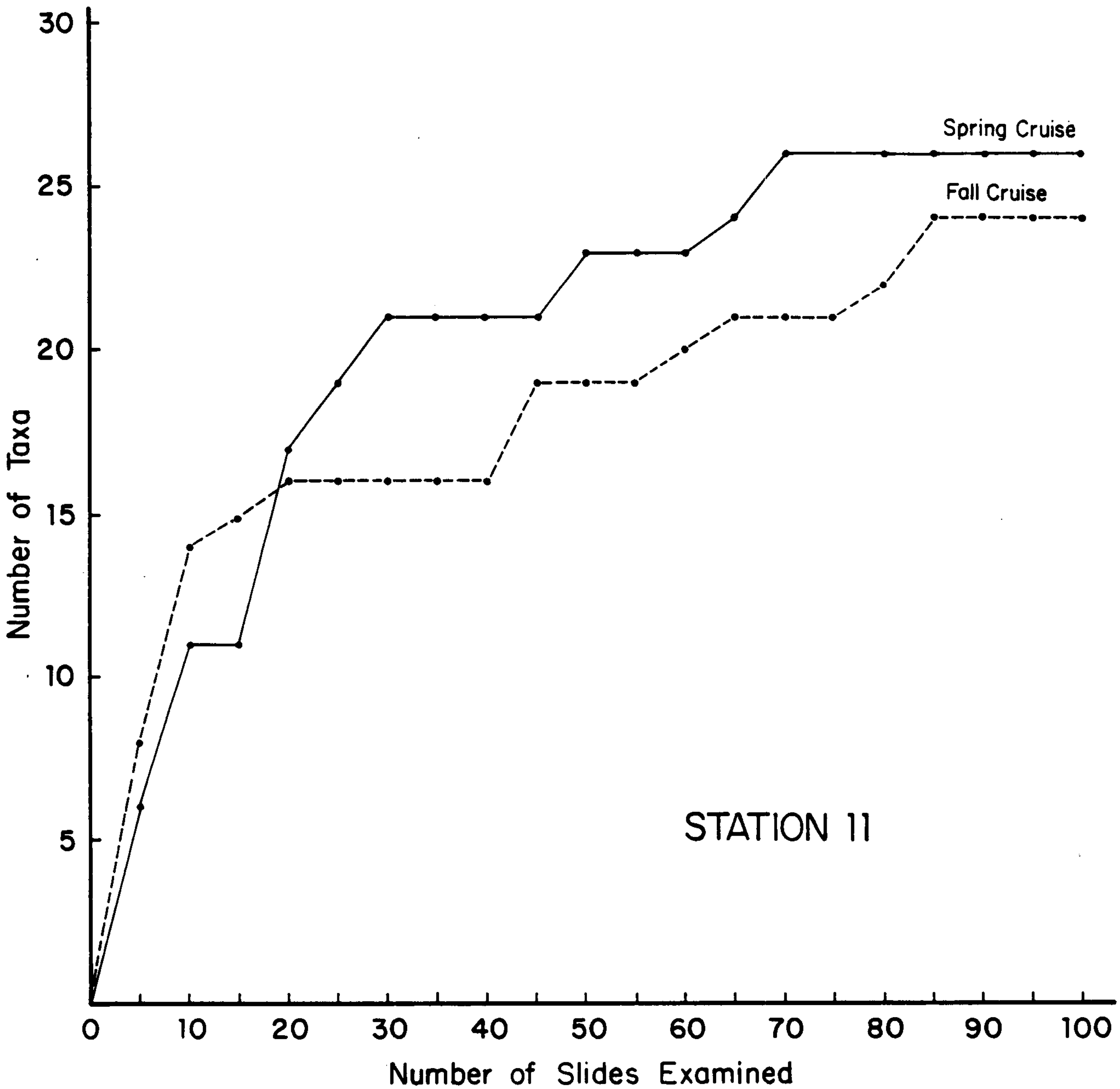


Figure 11-2. Example of taxon-area curve plotted for quantitative slide analysis data (each slide represents 0.5 m^2 of sea floor).

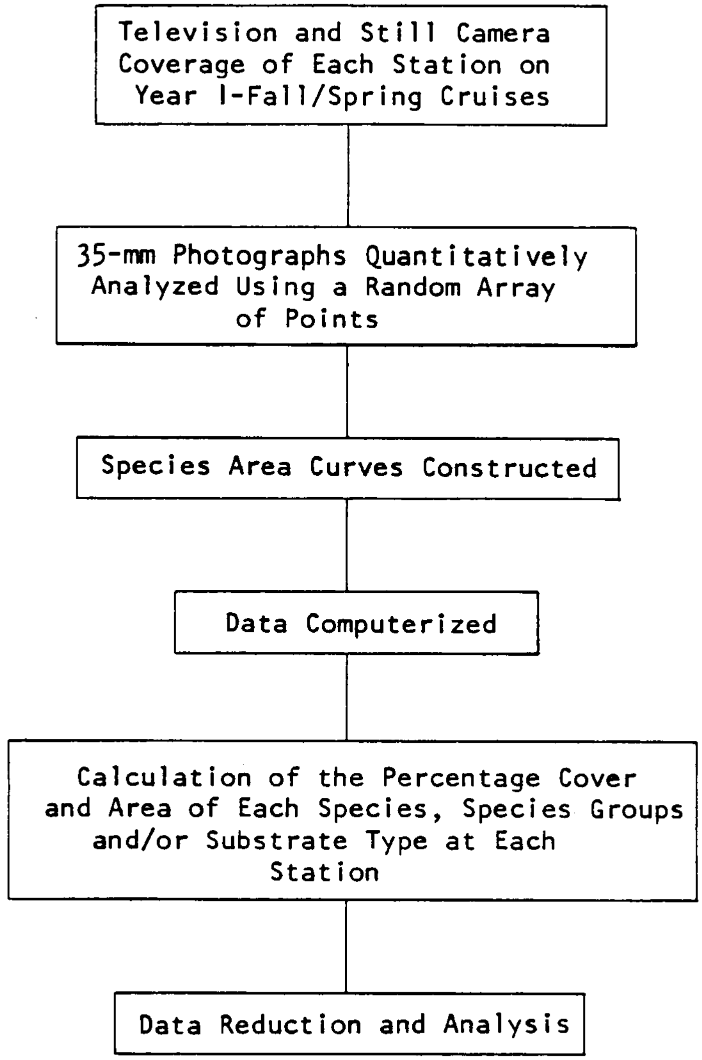


Figure 11-3. Summary of quantitative slide analysis methodology.

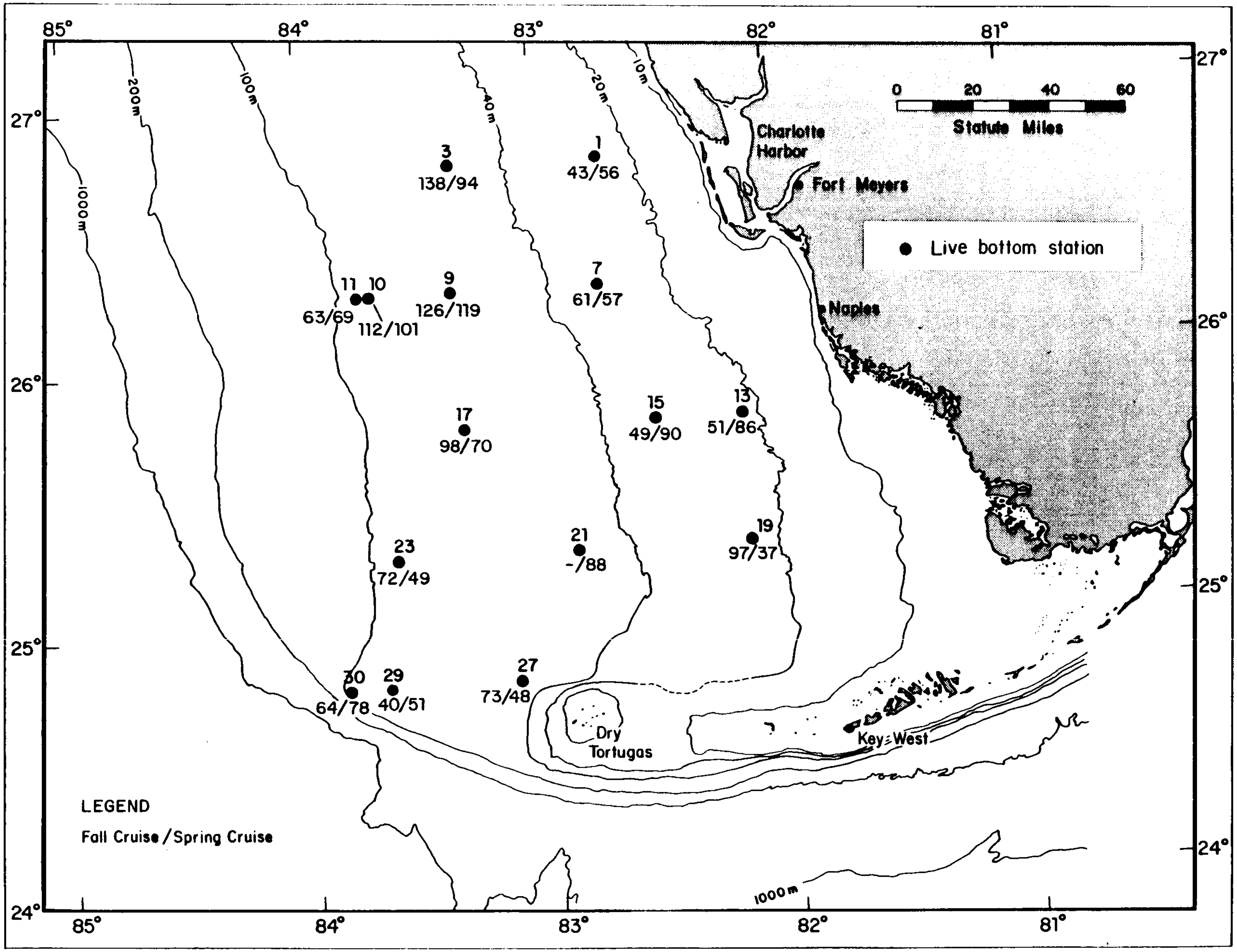


Figure 11-4. Species richness values from Fall and Spring Cruise trawl samples.

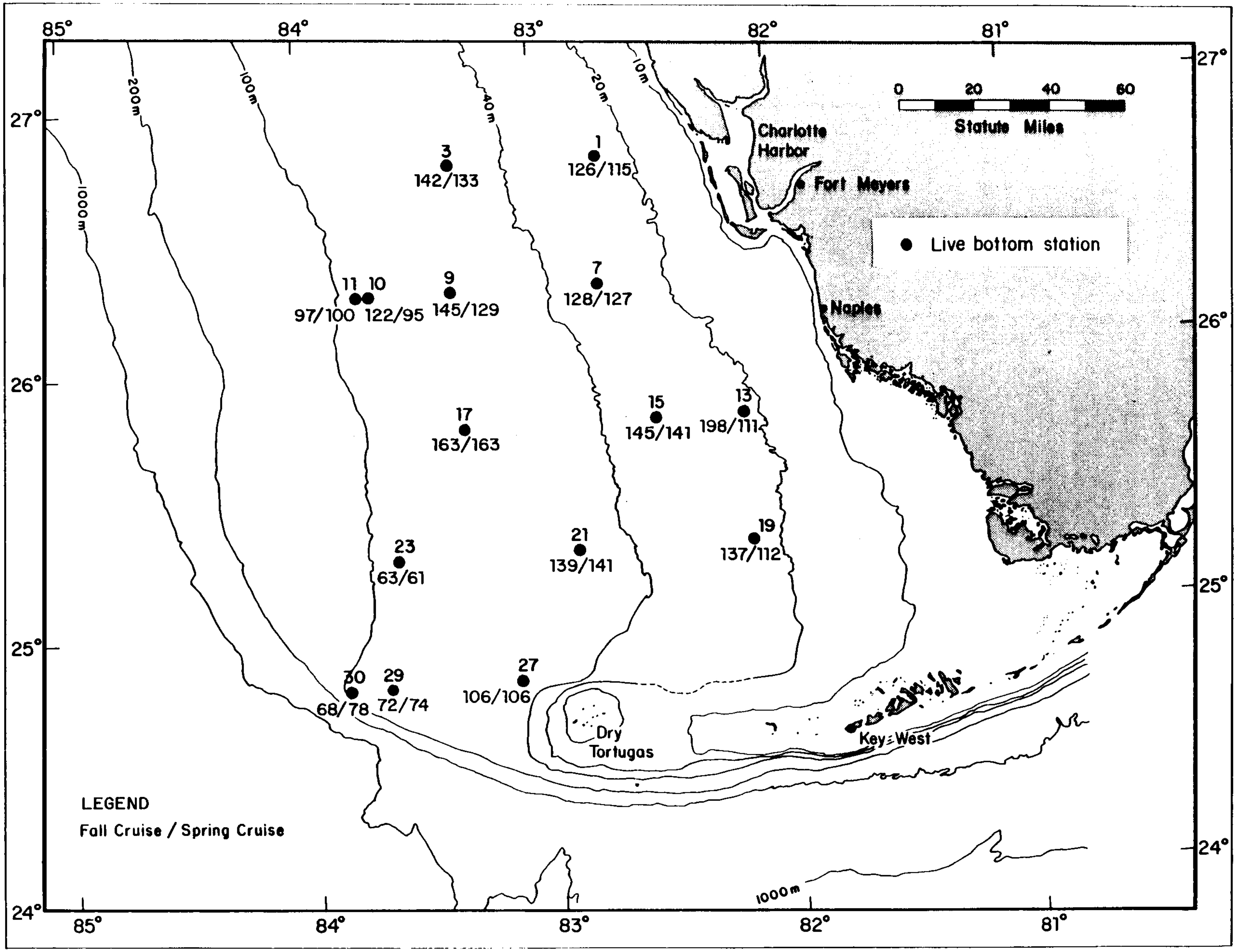


Figure 11-5. Species richness values from Fall and Spring Cruise dredge samples.

Values of species richness for the otter trawls ranged from 40 (Station 29, Fall Cruise) to 138 (Station 3, Fall Cruise). Comparison of the species richness values showed the Fall Cruise values exceeded the Spring Cruise values at 8 of 14 stations. Species richness values varied temporally over a wide range. Values for the Fall Cruise were 162% greater than the values for the Spring Cruise at Station 19 while values for the Fall Cruise were 41% and 46% less than values for the Spring Cruise at Stations 13 and 15, respectively.

Species richness values for the triangular dredge samples ranged from 61 (Station 23, Spring Cruise) to 198 (Station 13, Fall Cruise). Fall Cruise values exceeded Spring Cruise values at 9 of 15 stations. As was true for the otter trawl data, species richness values for the triangular dredge samples varied between the Fall and Spring Cruises. At Station 13, the values from the Fall Cruise were 78% greater than the values for the Spring Cruise while the Fall Cruise values were 13% less than the Spring Cruise values at Station 30. The lowest values of species richness were found at Stations 23, 29, and 30. Depth may have contributed to these low values as diversity decreases with increasing depth on the continental shelf. These low values may also have been due to decreased sampling efficiency over the substrate at the stations. This substrate was predominated by coralline algal nodules at Station 23 and an algal nodule pavement with *Agaricia* (hard coral) accumulations at Stations 29 and 30. The nature of these substrata may have inhibited effective sampling of the epibiota at these stations.

11.3.2 Percent Coverage

11.3.2.1 Total Epibiota

The percent coverages of the biota within live bottom patches at the live bottom stations on the Fall and Spring Cruises, measured by means of the quantitative slide analysis, are presented in Figure 11-6. Low coverages of biota were found over the majority of the live bottom stations on the southwest Florida continental shelf. Since the slides chosen for quantitative analysis were within the actual live bottom areas at the individual stations, it was concluded that, upon close examination, live bottom coverage was relatively sparse at these stations.

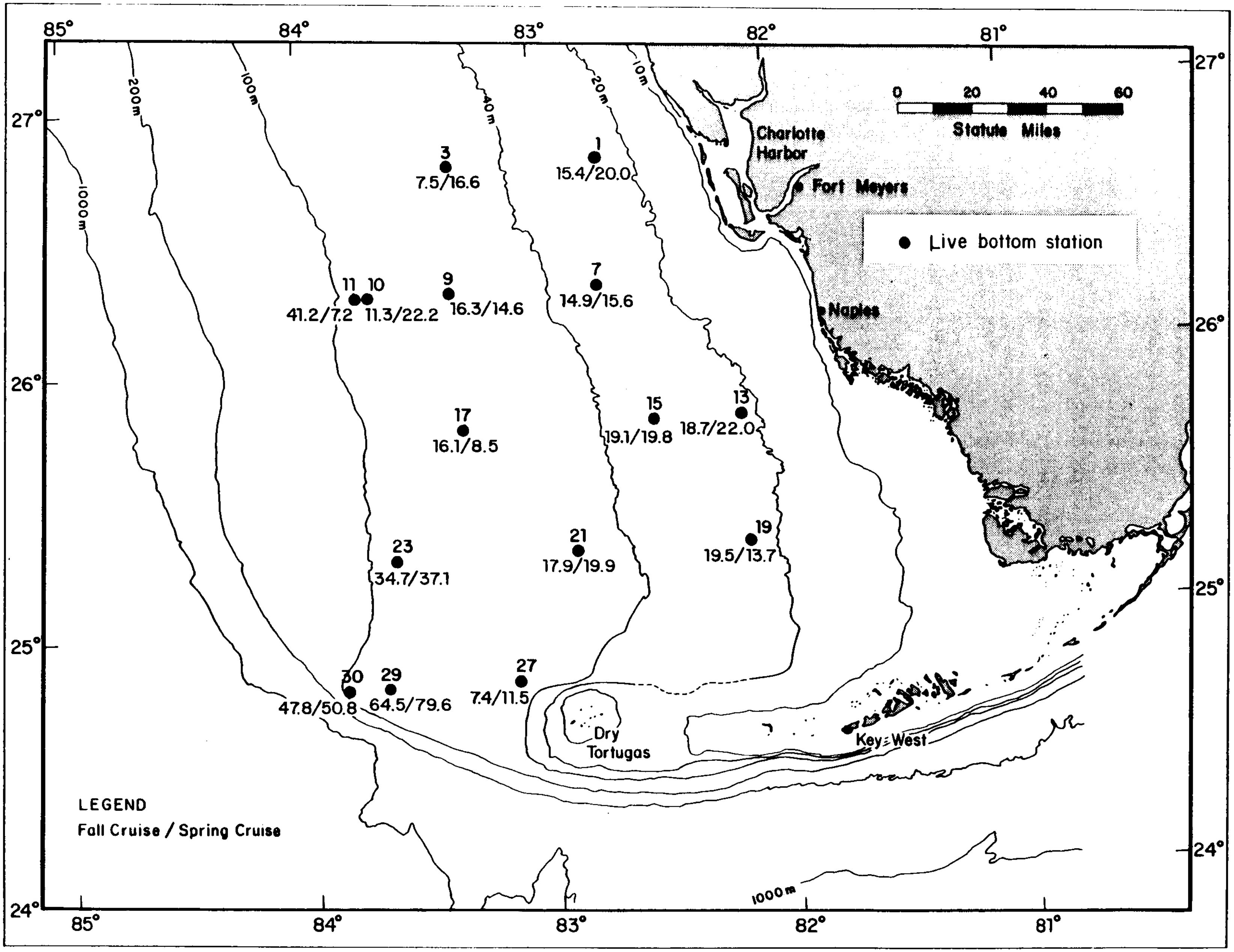


Figure 11-6. Percent coverage of biota within sample station live bottom patches.

Exceptions to this generalization of sparse coverage were found in the course of the survey. The first exception was the large discrepancy of percent coverage at Station 11 between the two cruises. During the Fall Cruise (October-November), 41% of the live bottom patches were found to be covered by biota while only 7% were covered by biota on the Spring Cruise (April-May). This difference is primarily due to high percent coverage by Halimeda spp. (green algae) on Cruise III, and low percent coverage by this taxon on Cruise IV.

Higher percent coverages were also found in the southwestern portion of the study area. Higher percents of Anadyomene menziesii (green alga), the order Cryptonemiales (coralline algae), and Peyssonnelia simulans (coralline alga) were found at Stations 23, 29, and 30 than at the other stations (Tables 11-1 and 11-2). The highest value of percent coverage was found at Station 29. In addition to the three taxa which were present in greater abundance at all three of the southwestern stations, Agaricia spp. (hard coral) were also present in a higher density at Station 29.

Percent coverages of the taxa identified in the quantitative slide analysis are presented in Appendix B-10.

11.3.2.2 Epiflora

The percent coverages of the epiflora at the live bottom stations are presented in Figure 11-7. The lowest percentages of the total epibiotal coverage were associated with epiflora at Stations 3, 7, 15, 19, 21, and 27. The relatively high coverage at Station 1 was due to the presence of Phaeophycophyta (brown algae) during fall and spring and the presence of Chlorophycophyta (green algae) during fall. Station 13, the other inner shelf station with high epifloral coverage, had a higher percentage of epiflora only on the Fall Cruise. During this survey, Phaeophycophyta were the predominant epiflora with a lesser contribution from Caulerpa spp. (green algae).

The epiflora dominated the percent coverage of the epibiota at Stations 9, 10, and 11. Phaeophycophyta and Halimeda spp. (green algae) were the primary contributors to the epifloral coverage at Station 9 on both cruises.

Table 11-1. Average percent cover of dominant taxa* in quantitative slide analysis on the Fall Cruise.

TAXA	STATION 1	3	7	9	10	11	13	15	17	19	21	23	27	29	30
Chlorophycophyta	6.8	0.1	0.6	1.7	1.4	2.7	0.6	0.0	1.1	0.0	1.1	3.4	0.7	0.9	0.3
Caulerpa spp.	0.0	0.5	0.0	0.1	0.1	0.0	2.3	0.0	3.1	3.0	0.5	0.0	0.3	0.0	0.0
Halimeda spp.	0.0	1.4	0.2	9.4	1.3	28.0	0.3	2.2	4.6	0.0	0.1	2.4	0.9	0.0	0.0
Anadyomene menziesii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	36.2	8.6
Phaeophycophyta	6.0	0.0	0.0	1.8	0.1	0.3	5.9	0.0	0.0	0.7	1.7	0.0	0.0	0.0	0.1
Rhodophycophyta	0.0	0.0	0.0	0.3	1.2	3.2	0.4	0.2	1.5	0.1	0.0	1.0	0.0	0.0	0.0
Cryptonemiales	0.0	0.1	0.0	0.8	2.1	2.0	0.0	0.7	0.0	0.0	0.1	5.7	0.8	7.0	18.2
Peyssonnelia simulans	0.0	0.0	0.0	0.0	1.6	1.8	0.0	0.0	0.0	0.0	0.0	8.0	0.0	8.8	14.2
Porifera	0.4	1.1	1.9	0.0	0.4	0.2	0.4	3.0	0.8	4.7	3.1	0.1	1.5	0.2	0.7
Calcarea	0.1	1.1	2.3	0.1	1.2	1.2	0.0	0.1	1.0	0.4	3.3	4.3	0.9	0.5	3.2
Placospongia melobesioides	0.0	1.3	2.3	0.0	0.0	0.0	0.6	2.6	0.0	0.1	1.8	0.0	0.5	0.0	0.0
Geodia spp.	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.4	0.0	7.8	0.8	0.0	0.2	0.0	0.1
Agaricia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	9.2	0.0

* Dominant taxa defined as having an average percent cover ≥0.5%, which implies it occurred, on the average, at least once on half of the slides examined.

Table 11-2. Average percent cover of dominant taxa in quantitative slide analysis on the Spring Cruise.

TAXA	STATION 1	3	7	9	10	11	13	15	17	19	21	23	27	29	30
Halimeda spp.	0.0	0.0	0.0	3.9	0.8	0.2	0.0	0.0	0.6	0.0	0.0	3.8	0.8	0.0	0.0
Anadyomene menziesii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	34.3	6.0
Phaeophycophyta	15.2	3.5	2.6	5.7	7.2	0.0	0.8	0.4	1.7	0.3	0.6	0.1	0.1	0.0	0.0
Cryptonemiales	0.4	0.5	0.0	0.9	1.3	0.0	0.0	0.0	0.2	0.0	0.6	4.8	0.5	13.5	22.6
Peyssonnelia simulans	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	13.9	15.7
Porifera	0.5	1.2	1.4	0.3	2.4	0.8	6.0	4.1	1.6	0.9	5.0	3.6	3.7	2.6	3.9
Calcarea	0.6	3.1	2.2	1.5	3.5	0.6	0.6	2.1	1.4	0.0	0.5	0.0	0.0	0.2	0.0
Hydrozoa	0.0	0.0	0.0	0.0	0.0	0.7	8.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Agaricia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	12.4	0.1
Osteichthyes*	0.0	0.1	7.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.1

* The inclusion of Osteichthyes (fish) seems somewhat spurious, since fish do not actually constitute cover as epibiota per se. However, this taxon was sufficiently abundant in the photographs taken to be considered as "coverage" in this analysis.

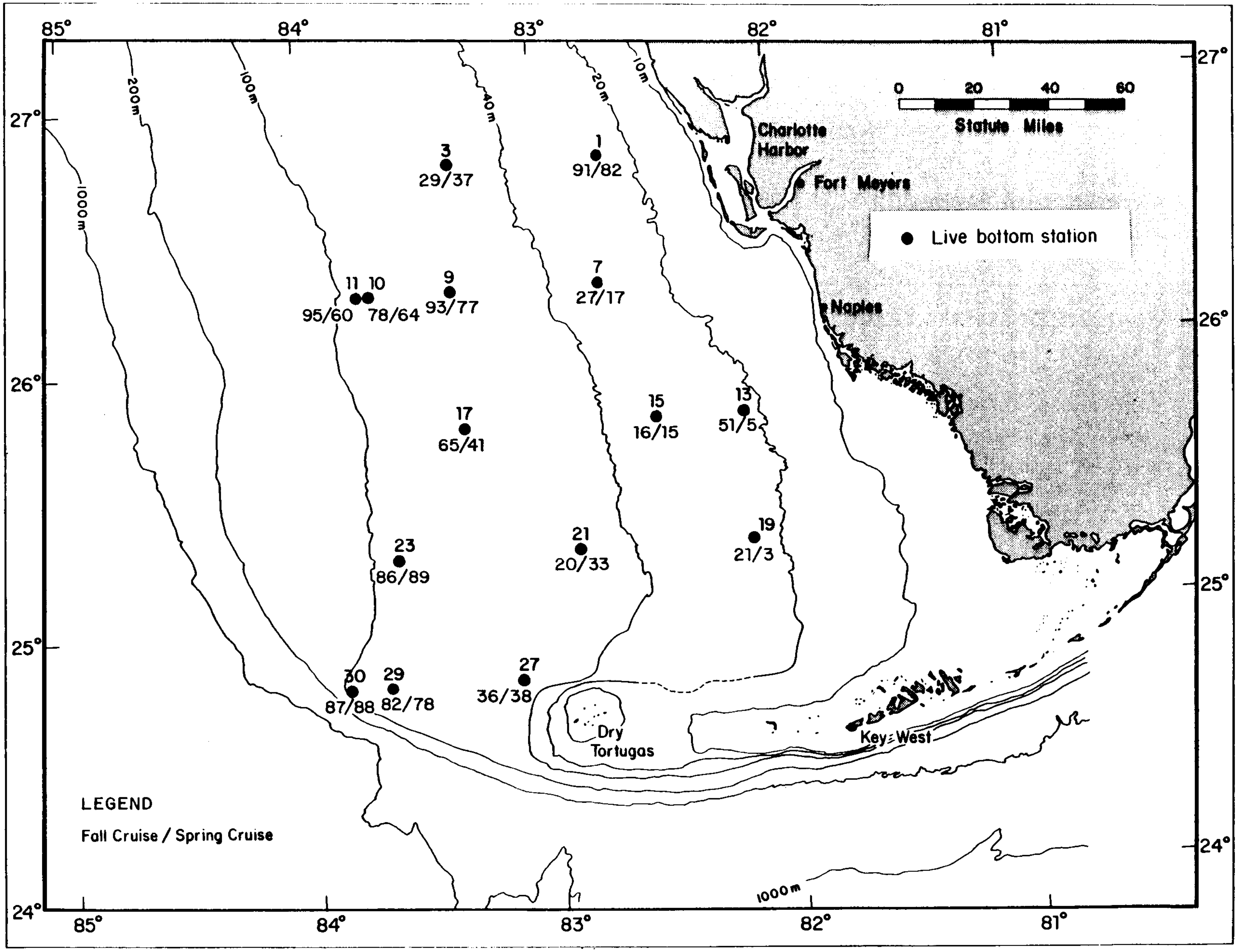


Figure 11-7. Epifloral (algae) coverage expressed as percent of total epibiotal coverage within sample station live bottom patches.

Rhodophycophyta, Cryptonemiales, Halimeda spp., Peyssonnelia simulans and Chlorophycophyta were the predominant epiflora at Station 10 during the Fall Cruise while Phaeophycophyta, Cryptonemiales, Peyssonnelia rubra (coralline alga), and Peyssonnelia simulans predominated during spring. Halimeda spp. were overwhelmingly dominant at Station 11 during the Fall Cruise but essentially absent during the Spring Cruise where Peyssonnelia spp. was the predominant taxon. Stations 10 and 11 tended to have a substantial coralline algae component on both cruises. Station 17 was found to be dominated by the epiflora coverage on the Fall Cruise. This was due to greater coverages of Caulerpa spp. and Halimeda spp. at this time and substantial reduction of coverage by these two taxa during the spring.

The three stations in the southwestern portion of the study area (23, 29, and 30) were dominated by epifloral coverage on both cruises. The epiflora at these stations was dominated by the green alga, Anadyomene menziesii, the coralline algae, Cryptonemiales, and Peyssonnelia simulans on both cruises. Peyssonnelia rubra also contributed substantially to the coverage at Station 13 during the Spring Cruise.

Although a great deal of seasonal variation was observed at several stations, such as Stations 11, 13, and 19, it was not possible to ascertain the rate of growth for the epiflora. Since the same locations were sampled during both cruises, it is unlikely that the variations were due to spatial differences; i.e., the temporal variations were not an artifact of sampling different locations; however, sampling on two cruises was inadequate for determination of growth rates.

11.3.2.3 Epifauna

In contrast to the coverage of the epiflora, the epifauna dominated at Stations 3, 7, 15, 19, 21, and 27 on both cruises and at Stations 13 and 17 on the Spring Cruise (Figure 11-8). Stations 3, 15, 21, and 27 were located in the mid-shelf portion of the study area. Sponges accounted for the greater portion of the coverage of the epibiota at these four stations, categorized primarily as Porifera. Other sponge categories which were dominant in the quantitative slide analysis of these four stations were Calcarea, Placospongia

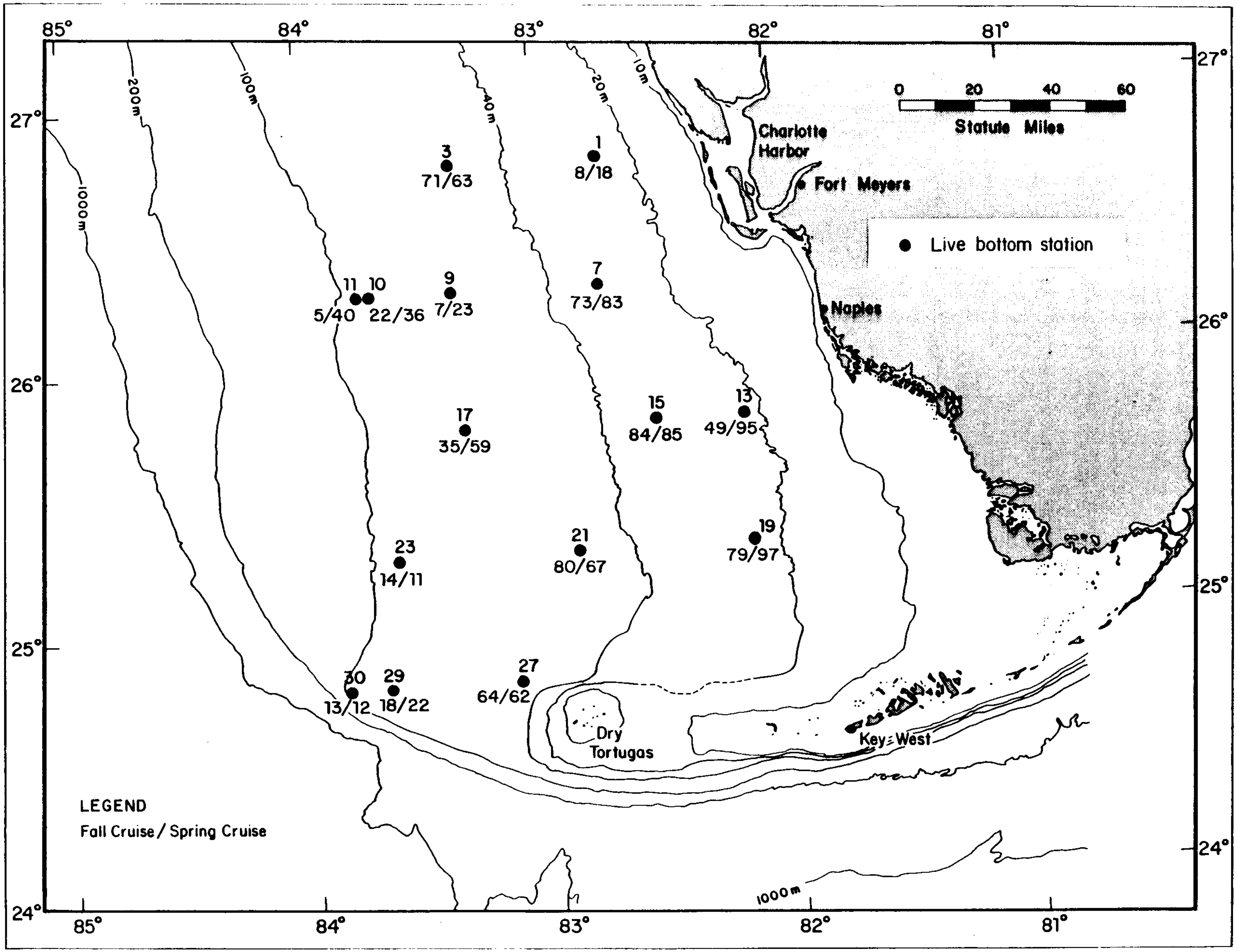


Figure 11-8. Epifaunal coverage expressed as percent of total epibiotal coverage within sample station live bottom patches.

melobesioides, and Geodia spp. Calcarea was important at Station 3 on both cruises as well as Placospongia melobesioides. At Station 15, Placospongia melobesioides and Geodia spp. were major contributors to the percent coverage during the Fall Cruise while Calcarea occurred during the Spring Cruise. Both Calcarea and Placospongia melobesioides were among the dominant taxa, based on percent coverage, at Station 21 on the Fall Cruise. These two taxa contributed less to the percent coverage of Station 27 during the Fall Cruise.

The epifauna at Stations 7 and 19, which were inner shelf stations, were also dominated by sponges. Porifera was important at both stations on both cruises. Calcarea and Placospongia melobesioides were major contributors to the percent coverage at Station 7 on the Fall Cruise while Calcarea was present at this station on the Spring Cruise.

Sponges (Calcarea and other Porifera) contributed to the percent coverage of the epifauna at Station 17 during the spring, when the epifauna dominated the coverage of the epibiota at this station. Hydrozoa were dominant at Station 13 during the Spring Cruise.

Although the epiflora dominated the percent coverage at Station 29 on both cruises, Agaricia spp. were also important in the coverage of the epibiota during both sampling periods.

Large differences in the coverage of epifauna at Stations 1, 9, 11, 13, and 17 were observed between the Fall Cruise and Spring Cruise. These differences in epifaunal percent coverage were primarily due to the changing seasonal abundance of the epifloral component at these stations. Changes in the percent coverage of the epifauna were simply inversely proportional to changes in the percent coverage of the epiflora.

11.3.3 Composition of the Biota

Samples of the epibiota at the live bottom stations were collected using two methods: otter trawl and triangular dredge. Although there was an overlap of the composition of the biota collected by these two methods, there were also substantial differences in the collected biota.

11.3.3.1 Fall Cruise (October-November)

The otter trawl and triangular dredge data collected during the Fall Cruise were analyzed using normal and inverse clustering analyses. Replicate samples were averaged for these analyses and transformed using the square root transformation to aid in normalizing the data. The binary complement of the Bray-Curtis index, the Czekanowski measure (Smith, 1976), was used as the ecological measure of faunal affinity.

Results of normal analysis of the otter trawl data showed a distinct onshore-offshore trend. The three resultant station groupings for the otter trawl are presented in Figure 11-9. The associated dendrogram for this normal analysis is presented in Figure 11-10. Three major groups of stations were delineated in this analysis. One group was composed of four middle shelf stations (11, 23, 29, and 30). Ophioderma rubicundum (brittle star) was found solely at stations in this group. Other taxa, such as Erylus spp. (sponges), Serranus tortugarum (chalk bass), and the family of sponges Nepheliospongiidae, were not found exclusively at the stations in this group, but were collected more frequently at these stations.

Another group of stations was composed of the remaining middle shelf stations (3, 9, 10, 17, and 27) at which otter trawl samples were collected during the Fall Cruise. The stations in this group were located closer to shore than the stations in the first group. Taxa which were collected solely at the stations in this group included Manucomplanus corallinus (anomuran), Galathea rostrata (anomuran), Terpios spp. (sponges), and Madracis aspersula (hard coral).

The inner shelf stations (1, 7, 13, 15, and 19) composed a third group of stations. The species Pilumnus sayi (brachyuran) and Diplectrum formosum (sand perch) were collected only at the stations in this inner shelf group. Other taxa which were found principally at these inner shelf stations included Synodus foetens (inshore lizardfish), Mithrax pleuracanthus (brachyuran), and sponges of the family Haliclonidae.

The normal clustering analysis of the triangular dredge samples collected on the Fall Cruise also showed a distinctive onshore-offshore pattern. Resultant

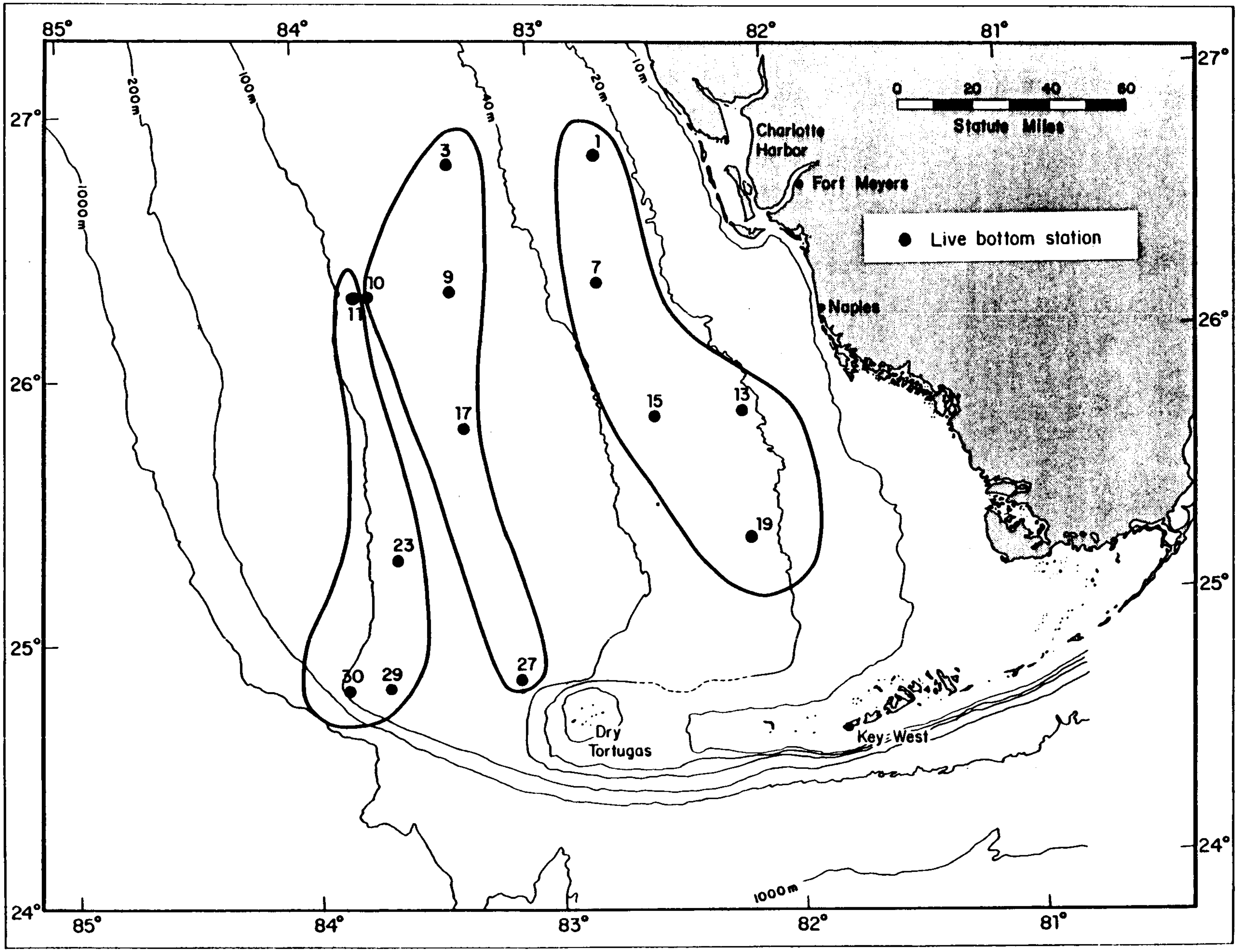


Figure 11-9. Results of normal clustering analysis of live bottom trawl data - Fall Cruise.

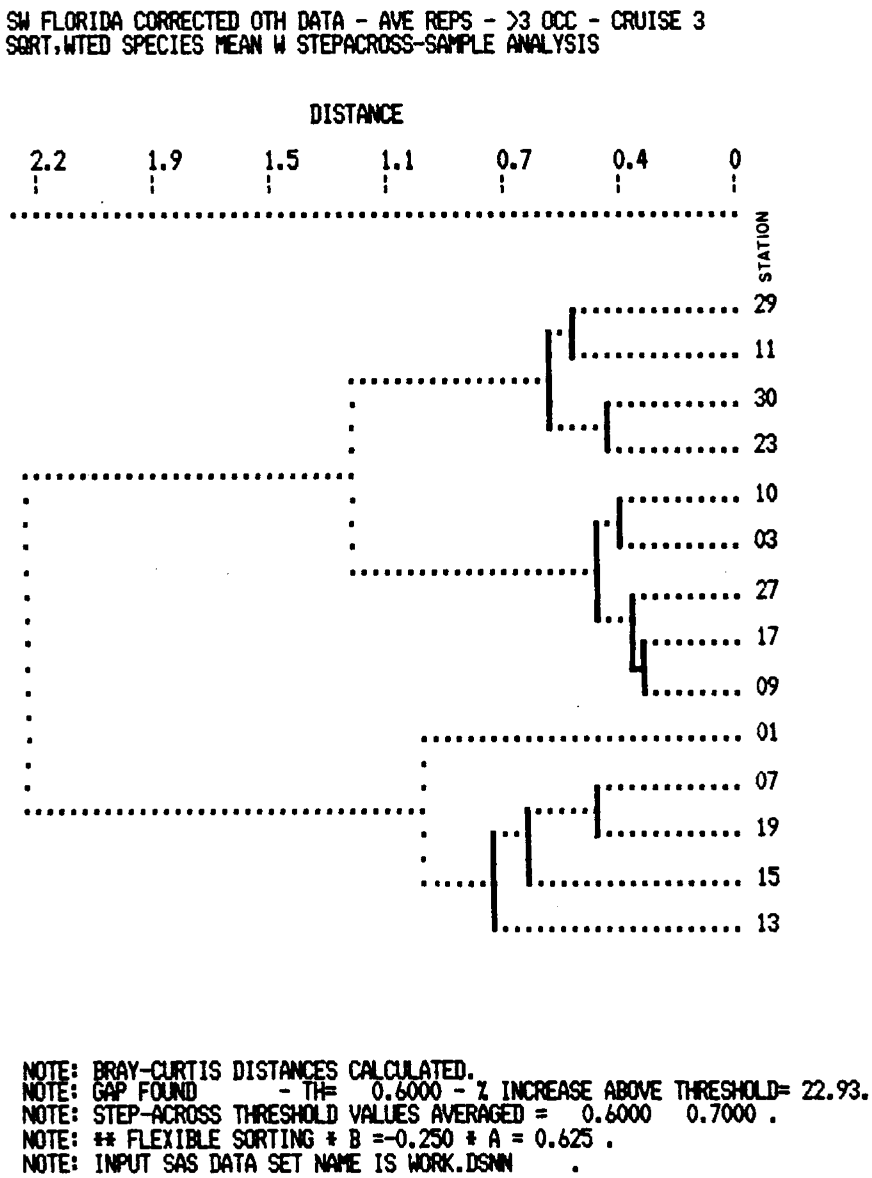


Figure 11-10. Dendrogram for normal clustering analysis of live bottom trawl data - Fall Cruise.

groups delineated by this analysis are presented in Figure 11-11, and the dendrogram is presented in Figure 11-12. One group of stations was composed of the five offshore middle shelf stations (10, 11, 23, 29, and 30). Two subgroups of stations, Stations 29 and 30 and Stations 10, 11, and 23, within this first group showed some north-south variability in taxonomic composition. None of the taxa included in the analysis were found strictly at the stations in the group, but taxa which were found predominantly at these stations included Peyssonnelia rubra (coralline alga), the sponge family Desmacellidae, Mithrax acuticornis (brachyuran), Gonodactylus torus (stomatopod), Ophiomyxa flaccida (brittle star), and Madracis aspersula (hard coral).

A second group of stations was composed of five remaining middle shelf stations (3, 9, 17, 21, and 27) and one inner shelf station (15). The delineation of two subgroups of stations showed an onshore-offshore pattern within this group. Pilunnus floridanus (brachyuran) was collected solely at stations in this group. Species which were principally collected at the stations in this group included Cinachyra alloclada (sponge), Paguristes sericeus (anomuran), Phimochirus holthuisi (anomuran), Stenocionops furcata (brachyuran), Pilumnus floridanus (brachyuran), Stylopoma spongites (bryozoan), and Didemnum candidum (tunicate).

The remaining inner shelf stations composed a third group of stations. The two subgroups (Stations 1 and 7 and Stations 13 and 19) suggested a small amount of latitudinal variation. Species which were collected principally at the stations in the third group included Paguristes tortugae (brachyuran), Macrocoeloma trispinosum (brachyuran), Mithrax pleuracanthus (brachyuran), and Lytechinus variegatus (echinoid).

11.3.3.2 Spring Cruise (April-May)

Normal and inverse analyses were performed using the otter trawl data collected on the Spring Cruise. Results of the normal analysis are presented in Figure 11-13. The dendrogram for this analysis is presented in Figure 11-14. The southwestern, middle shelf stations (23, 29, and 30) comprised one group of stations. This group of stations was dominated by a group of taxa, including

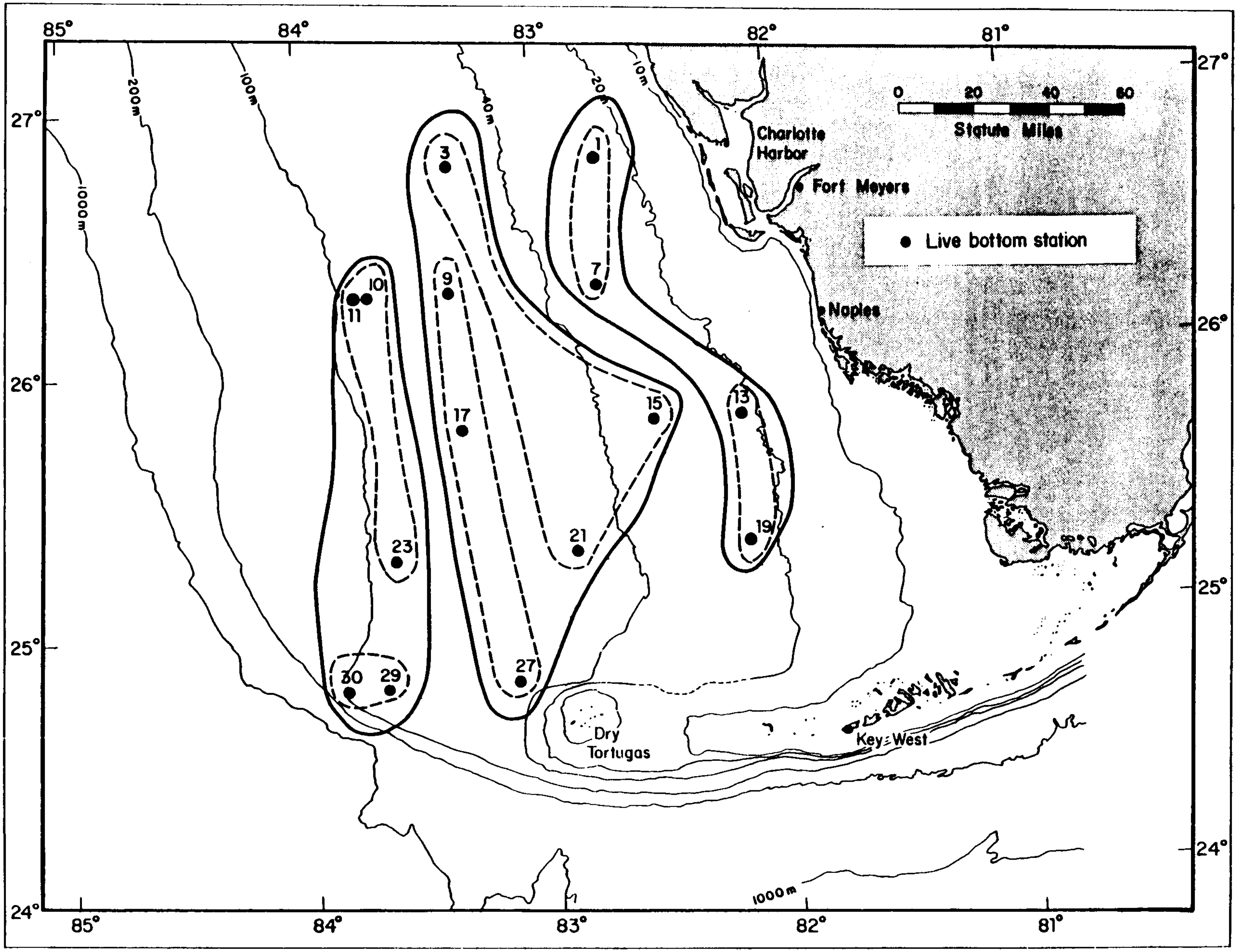
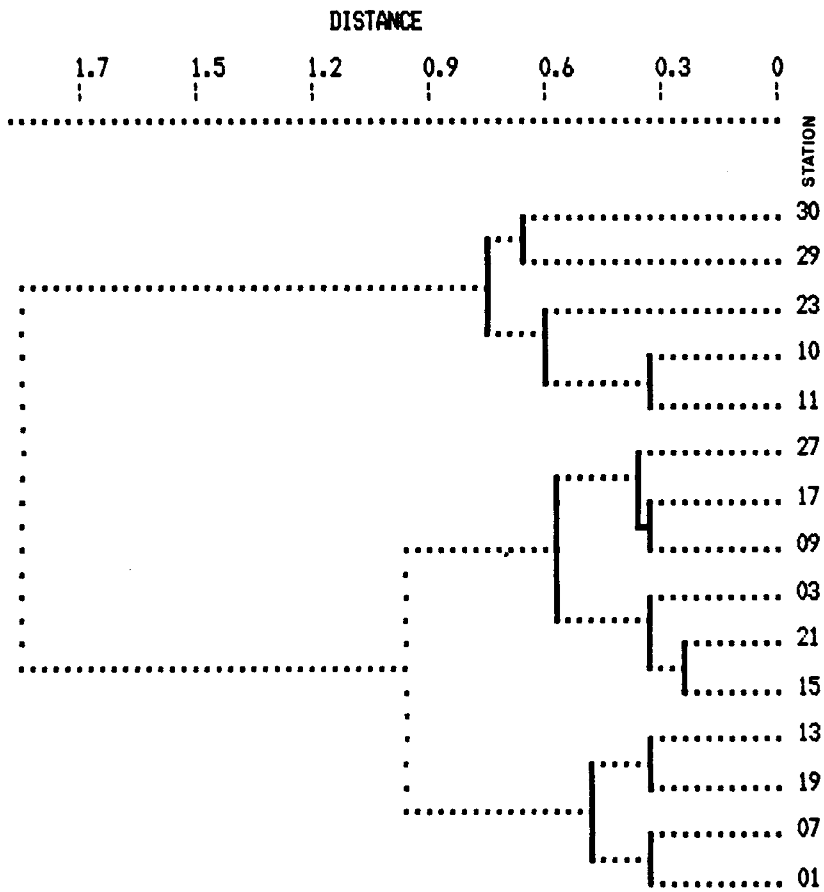


Figure 11-11. Results of normal clustering analysis of live bottom dredge data - Fall Cruise.

SW FLORIDA CORRECTED TDS DATA - AVE REPS - >5 OCC - CRUISE 3
SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.5000 - % INCREASE ABOVE THRESHOLD= 17.32.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.5000 0.6000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .

Figure 11-12. Dendrogram for normal clustering analysis of live bottom dredge data - Fall Cruise.

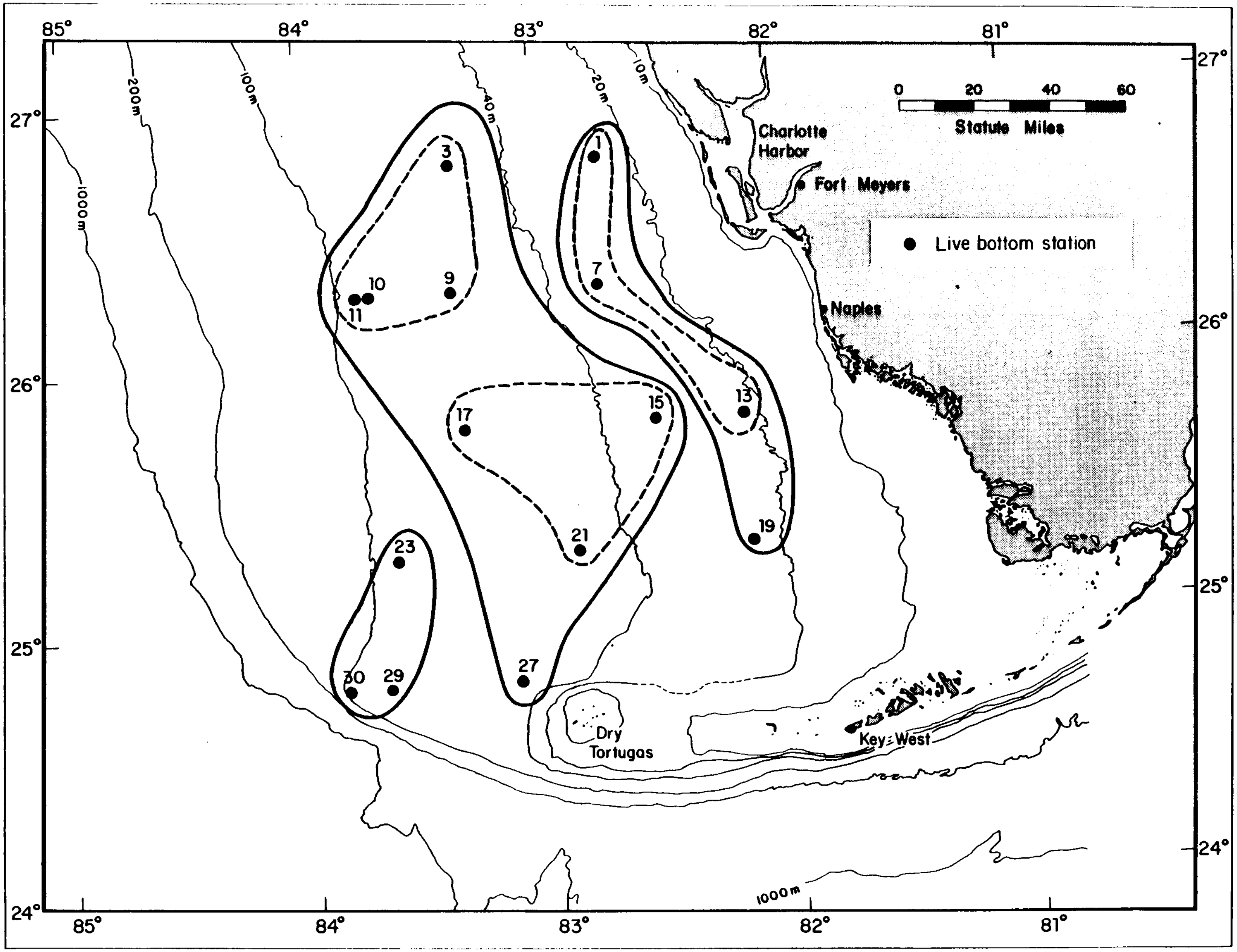
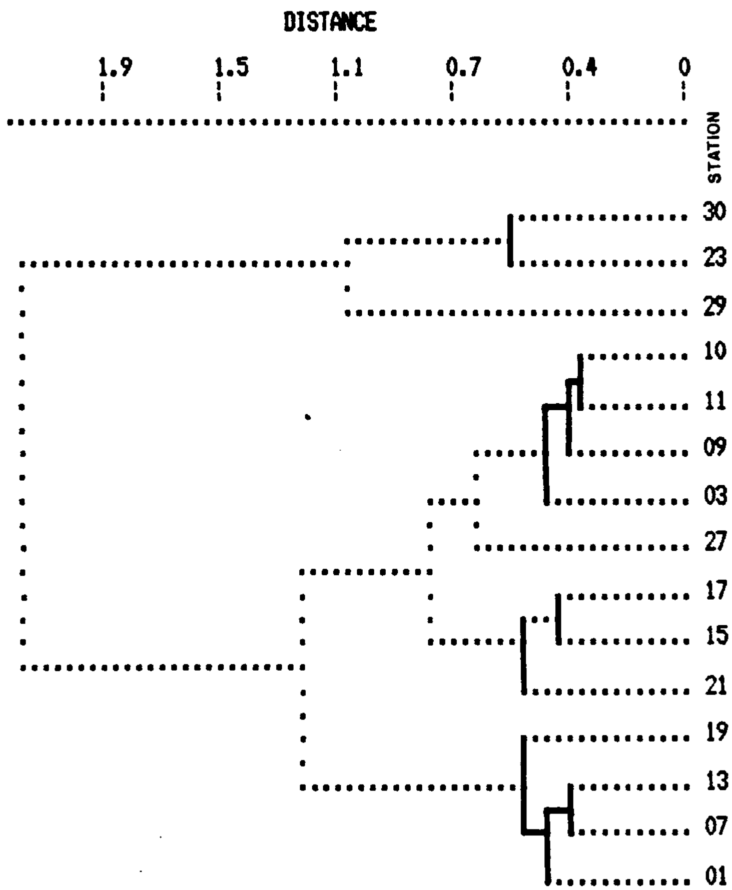


Figure 11-13. Results of normal clustering analysis of live bottom trawl data - Spring Cruise.

SW FLORIDA-OTH QUAL DATA->5 OCC - REPS AVERAGED - CRUISE 4
SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.6000 - % INCREASE ABOVE THRESHOLD= 24.25.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.6000 0.7000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .
NOTE: LABEL ON INPUT SAS DATA SET IS "S

Figure 11-14. Dendrogram for normal clustering analysis of live bottom trawl data - Spring Cruise.

Jaspis spp. (sponges) and Peyssonnelia simulans (coralline alga), which were infrequent or absent at stations in the other two major groups.

A second major group of stations included the inshore middle shelf stations (3, 9, 17, 21, and 27), an inner shelf station (15), and the northerly offshore middle shelf stations (10 and 11). Subgroups within this second group showed a north-south trend. This group of stations had a taxonomic composition intermediate between the other two major groups. This was an expected result since this group is geographically intermediate between the areas of the other two groups. Taxa which were frequently found at the stations comprising the second group of stations were Ophiothrix angulata (brittle star), Syacium papillosum (flounder), and Steganoporella magnilabris (bryozoan).

A third group of stations was composed of the inner shelf stations (1, 7, 13, and 19). The epibiota at the stations in this group overlapped in composition to a large extent with that of the second group of stations, but fewer taxa were common between this group of stations and the first group of stations. Species such as Udotea conglutinata (alga), Cladocora arbuscula (hard coral), and Haliclona compressa (sponge), were present at this inner shelf group of stations, rare at the second group of stations, and absent from the first group of stations.

The analysis of the Spring Cruise triangular dredge data showed more distinctive onshore-offshore trends than did the analysis of the otter trawl data. These results are presented in Figure 11-15, and the corresponding dendrogram is presented in Figure 11-16. One group of stations was composed of the offshore middle shelf stations (10, 11, 23, 29, and 30). Subgrouping within this first group pointed to a north-south trend in taxonomic composition. The epibiota at these stations overlapped with the other two groups of stations, but included species such as Anadyomene menziesii (green alga), Peyssonnelia simulans (coralline alga), and Peyssonnelia rubra (coralline alga), which were infrequent at the stations in the inshore middle shelf group and absent at the stations in the inner shelf group.

A second group of stations was composed of the inshore middle shelf stations (3, 9, 17, 21, and 27). No distinctive trends were found in the subgroups of

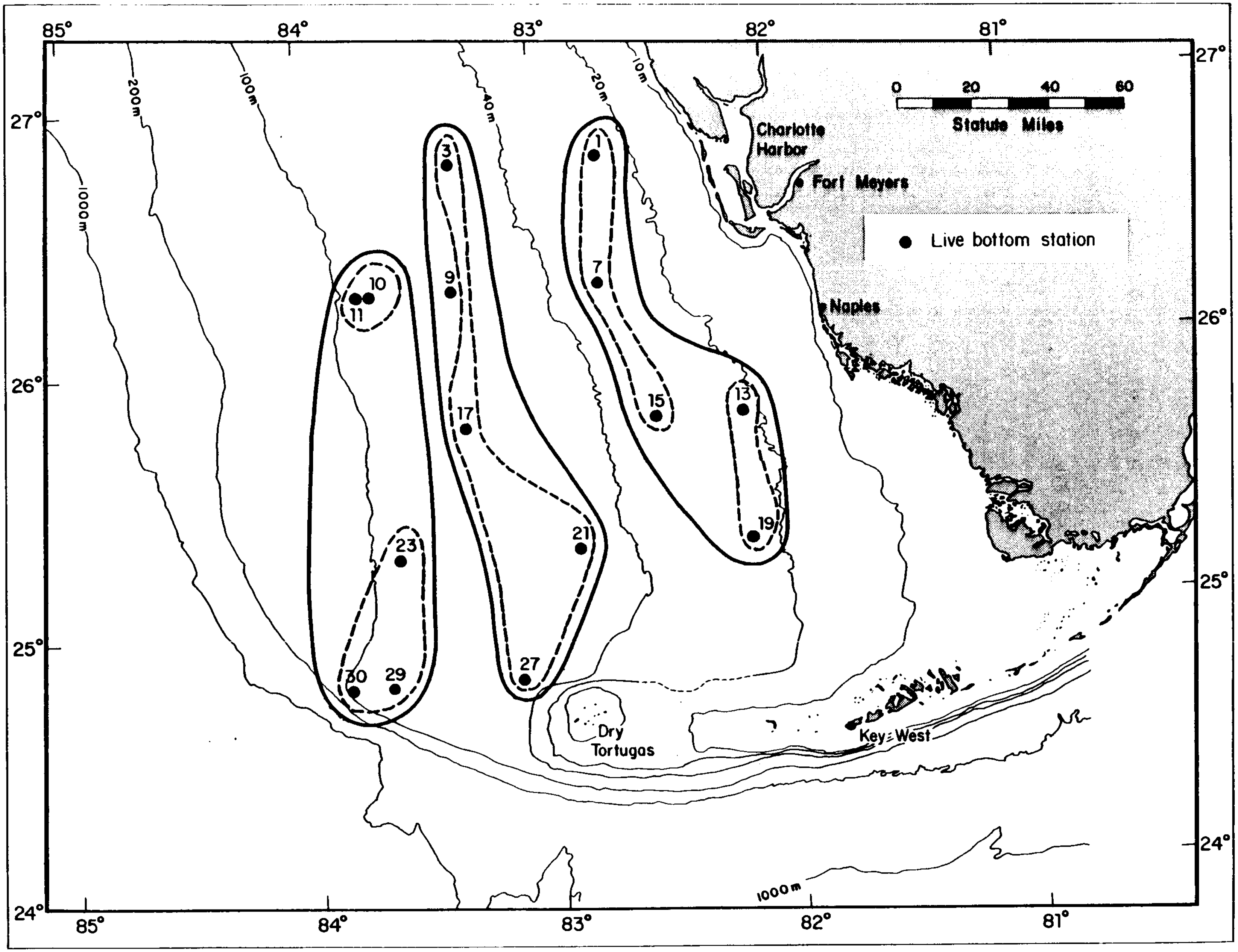
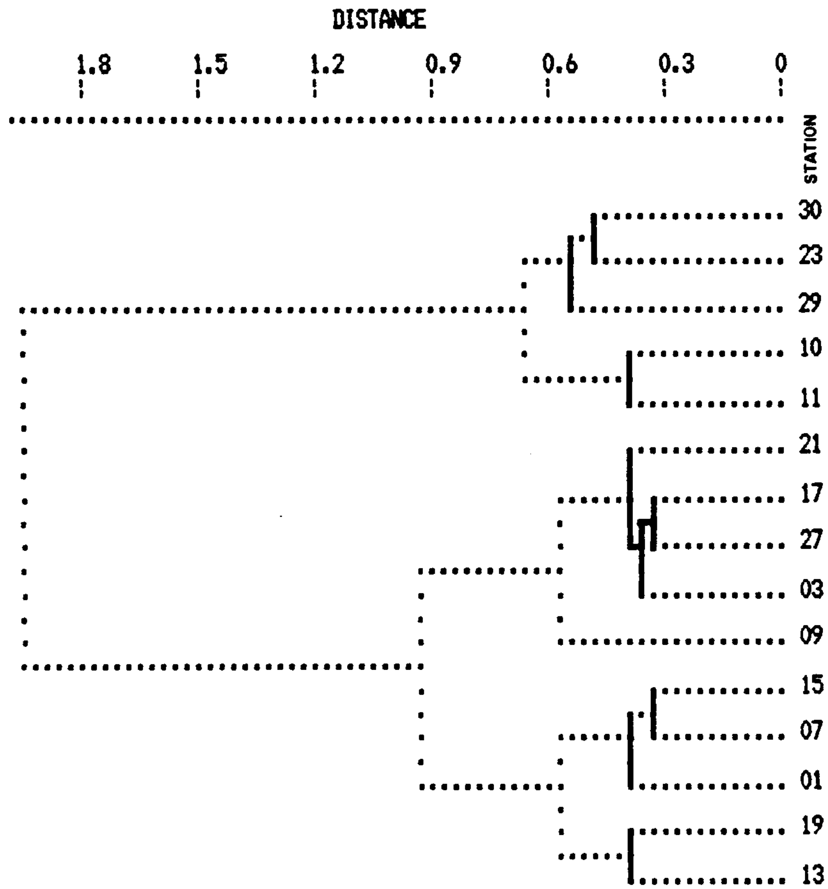


Figure 11-15. Results of normal clustering analysis of live bottom dredge data - Spring Cruise.

SW FLORIDA-TDS QUAL DATA->7 OCC - REPS AVERAGED - CRUISE 4
SQRT,WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.6000 - % INCREASE ABOVE THRESHOLD= 21.07.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.6000 0.7000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .
NOTE: LABEL ON INPUT SAS DATA SET IS "S

Figure 11-16. Dendrogram for normal clustering analysis of live bottom dredge data - Spring Cruise.

this group. None of the taxa were uniquely present at stations in the second group. Widely distributed taxa which were present at stations in the second group included Celleporaria albirostris (bryozoan), Ophiothrix angulata (brittle star), Dromidia antillensis (brachyurid crab), Paguristes sericerus (anomurid crab), and the sponges, Spheciospongia vesparium, Anthosigmella varians, Placospongia melobesioides, and Geodia neptuni.

A third group of stations was composed of the inner shelf stations (1, 7, 13, 15, and 19). Subgroups within this third group of stations showed some north-south trends. Many of the taxa which were present at the stations in the third group were also present at stations in the first and second groups; however, taxa, such as Solineastrea hyades (coral), Homaxinella waltonsmithi (sponge), and Udotea conglutinata (alga), were collected exclusively in the triangular dredge samples at the stations in the third group during the Spring Cruise.

11.3.3.3 Combined Fall and Spring Cruises

The combined otter trawl data from both cruises were analyzed during normal and inverse clustering analyses. The dendrogram for the normal analysis is presented in Figure 11-17. Three major groups of stations were delineated, and results indicated a lack of temporal variability of the assemblages at each station between the two cruises. This conclusion was supported by the incidence of each station assemblage in the same group for both cruises.

One cruise-station group was composed of Stations 29 and 30 for both cruises. These two middle shelf stations were the southwestern most stations sampled. Taxa which were collected more frequently at these stations on both cruises included the sponges Erylus spp. and the families of sponges Nepheliospongiidae and Desmacellidae.

A second cruise-station group was composed of the remaining middle shelf stations (3, 9, 10, 11, 17, 21, 23, and 27) for both the Fall and Spring Cruises. Taxa which were collected exclusively at these stations included Madracis aspersula (hard coral), Scyllarus chacei (macruran), and Munida pursilla (galatheid crab). Other species which were found solely at these

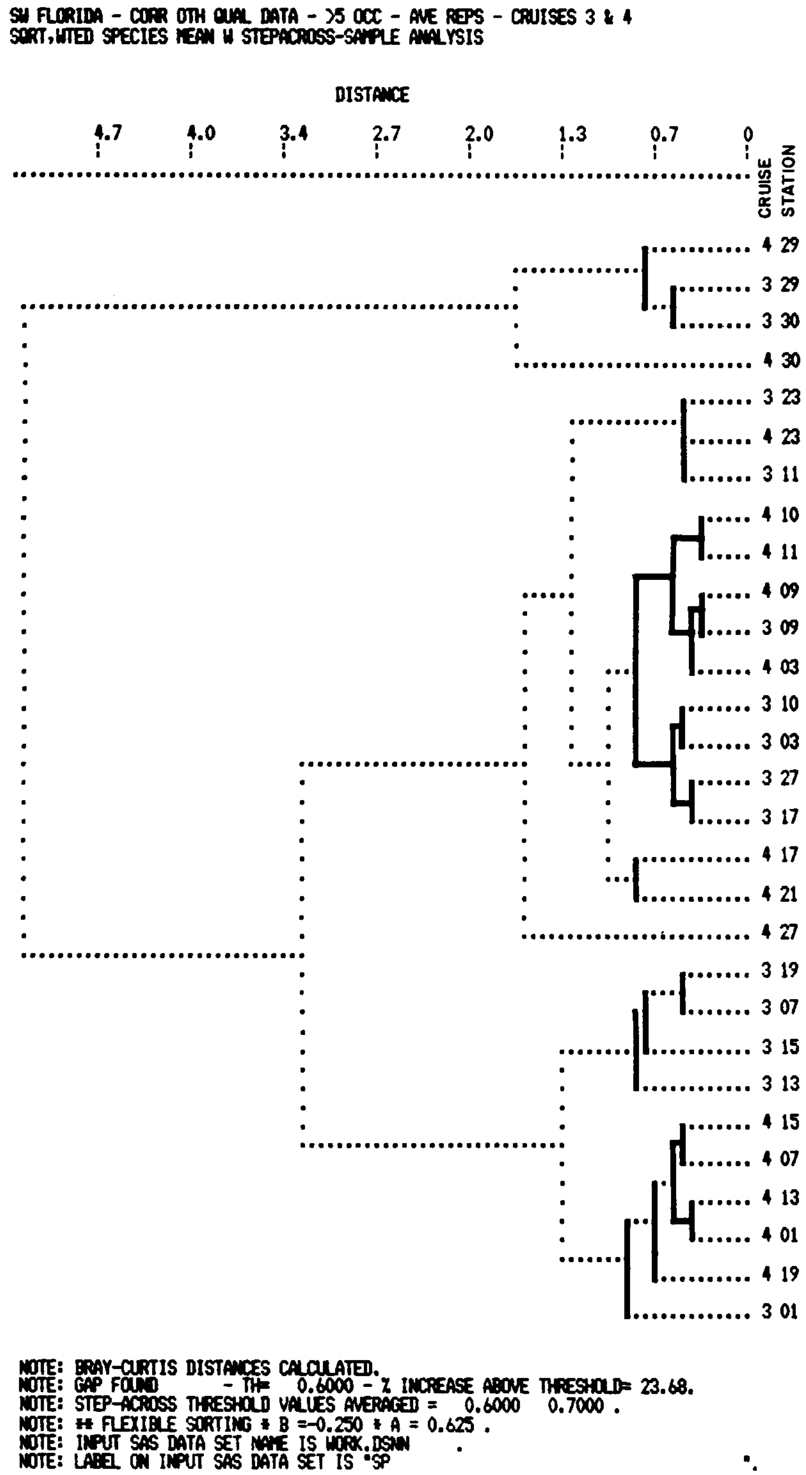


Figure 11-17. Dendrogram for normal clustering analysis of combined Fall(3) and Spring(4) Cruise trawl data.

stations on both cruises were the brachyurans *Podochela lamelligera* and *Parthenope fraterculus*, the pancake batfish *Halieutichthys aculeatus*, and the longfin scorpionfish *Scorpaena agassizi*. Species which were collected more frequently at these stations included *Portunus spinicarpus* (portunid crab), *Steganoporella magnilabris* (bryozoan), *Idmidronea atlantica* (bryozoan), *Ophiothrix angulata* (brittle star), *Synodus poeyi* (offshore lizardfish), *Serranus phoebe* (sea bass), and *Sphoeroides dorsalis* (marbled puffer).

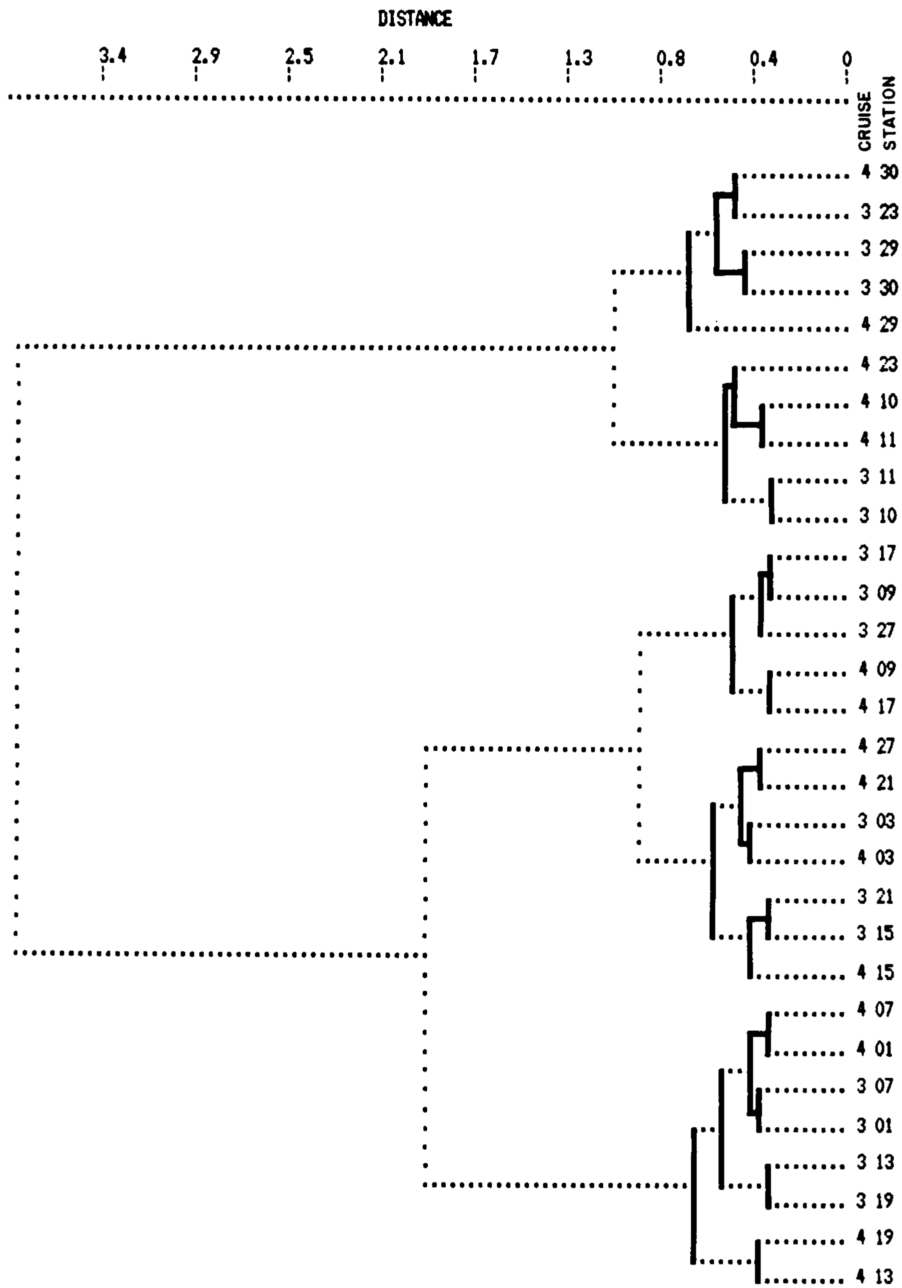
The inner shelf stations (1, 7, 13, 15, and 19) from both cruises formed a third cruise-station group. Among the species which were collected exclusively at these stations were *Udotea conglutinata* (green alga), *Homaxinella waltonsmithi* (sponge), *Macrocoeloma camptocerum* (brachyuran), and *Pilumnus sayi* (brachyuran).

The results of normal and inverse clustering analyses on the combined triangular dredge data also indicated temporal stability of the stations between the Fall and Spring Cruises (Figure 11-18). One cruise-station group was composed of the offshore middle shelf stations (10, 11, 23, 29, and 30). Taxa which were collected solely at these stations during the two cruises included the sponges *Discodermia* spp., the macruran *Scyllarus depressus*, the bryozoan *Cigclisula pertusa*, and the starfish *Poraniella regularis*. The coralline alga *Perssonnelia rubra*, the sponges *Erylus* spp. and *Erylus formosus*, the brachyurid crab *Micropanope sculptipes*, and the echinoid *Stylocidaris affinis* were collected principally at these stations on both cruises.

A second cruise-station group was composed of the more inshore middle shelf stations (3, 9, 17, 21, and 27) and one inner shelf station (15). Species which were collected principally at these stations included *Oculina tenella* (hard coral), *Turritella exoleta* (gastropod), *Chlamys benedicti* (bivalve), *Scyllarus chacei* (macruran), and *Bracebridgia subsulcata* (bryozoan).

A third cruise-station group was composed of the remaining four inner shelf stations (1, 7, 13, and 19). The red alga *Gracilaria debilis* and the bivalve *Macrocallista maculata* were collected exclusively at the stations in this group on both cruises. Species which were principally collected at these stations were *Udotea conglutinata* (green alga), *Oxeostilon burtoni* (sponge), *Cladocora*

SW FLORIDA - CORR TDS QUAL DATA - >7 OCC - AVE REPS - CRUISES 3 & 4
SORT;WTED SPECIES MEAN W STEPACROSS-SAMPLE ANALYSIS



NOTE: BRAY-CURTIS DISTANCES CALCULATED.
NOTE: GAP FOUND - TH= 0.6000 - % INCREASE ABOVE THRESHOLD= 22.94.
NOTE: STEP-ACROSS THRESHOLD VALUES AVERAGED = 0.6000 0.7000 .
NOTE: ** FLEXIBLE SORTING * B =-0.250 * A = 0.625 .
NOTE: INPUT SAS DATA SET NAME IS WORK.DSNN .
NOTE: LABEL ON INPUT SAS DATA SET IS "SP

Figure 11-18. Dendrogram for normal clustering analysis of combined Fall(3) and Spring(4) Cruise dredge data.

arbuscula (hard coral), *Mithrax forceps* (brachyuran), *Mithrax pleuracanthus* (brachyuran), *Scyllarus americanus* (macruran), *Pilumnus sayi* (brachyuran), *Lobopilumnus agassizi* (brachyuran), and *Gonodactylus brendini* (stomatopod).

11.3.4 New Species and Range Extensions

The biota of the southwest Florida shelf is very diverse, therefore, records of range extensions and new species are expected during an investigation of this relatively unknown area. A list of geographical range extensions discerned in the course of this Year 1 effort is presented in Table 11-3. A number of undescribed species was found. A minimum of 28 new species of sponges, three new fishes, one new echinoderm, and four new molluscs were distinguished by the consulting taxonomists.

11.3.5 Relict Mollusca of the Southwest Florida Shelf

The Inner and Middle Shelf Live Bottom Assemblage II (see Section 3.0), the Middle Shelf Algal Nodule Assemblage, and the *Agaricia* Coral Plate Assemblage have yielded a significant number of Pliocene and Pleistocene relict molluscs (Table 11-4 and Figure 11-19). This indicates that the algal nodule areas at the edge of the southwest Florida continental shelf may represent an upper Neogene[1] relict pocket that survived the Pleistocene glacial sea level fluctuation and lowered temperatures. A further discussion of this topic is found in Appendix B-11.

11.4 Discussion

11.4.1 Introduction

Previous work on the west Florida continental shelf has delimited zones of faunal distribution which are correlated with depth across the shelf. Lyons

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[1] Neogene is defined as the geologic time period from 2 to 22 million years ago. It is further subdivided into the Pliocene and Miocene epochs.

Table 11-3. Range extensions from Southwest Florida Shelf Ecosystems Study - Year 1.

Taxa	Previous Recorded Range
Sponges	
Dysidea ? *avara*	Pacific
Siphonodictyon coralliphagum	West Indies, Caribbean
Microciona ? *microchela*	West Indies
Neofibularia nolitangere oxeata	Western Atlantic
Halichondria ? *magniconulosa*	Western Atlantic
Oxeostilon burtoni	Western Atlantic
Axinella bookhouti	Western Atlantic
Pseudaxinella lunaecharta	Bahamas, West African Coast
Pseudaxinella rosacea	Western Atlantic
Teichaxinella morchella	Bahamas
Teichaxinella ? *corrugata*	Western North Atlantic
Hemectyon ? *pearsei*	Western North Atlantic
Anthosigmella varians forma *incrustans*	Bahamas
Cliona schmidti	Circumtropical
Cliona delitrix	Bahamas, West Indies
Geodia neptuni	Western Atlantic
Erylus formus	Western Atlantic
Hydroids	
Plumularia nigra	Cuba
Octocorals	
Lignella richardii	Western Atlantic
Lophogorgia barbadensis	Western Atlantic
Nicella schmitti	Western Gulf of Mexico, Western Caribbean
Telesto fruticulosa	Western Atlantic
Telesto operculata	West Indies, Northwestern Gulf of Mexico

Table 11-3. (Continued)

Taxa	Previous Recorded Range
Octocorals (Continued)	
Thesea parviflora	Caribbean
Caliacis nutans	Caribbean
Eunicea fusca	Bermuda, West Indies, Caribbean
Keratoisis flexibilis	West Indies, Caribbean
Leptogorgia euryale	Western Atlantic, Western Caribbean, Western Gulf of Mexico
Leptogorgia stheno	Western Atlantic
Virgularia presbytes	Western Atlantic
Crustaceans	
Pagurus carolinensis	Western Atlantic
Echinoderms	
Luidia sagamina	Eastern Atlantic, Western Pacific
Hemichordates	
Rhabdopleura compacta	Bermuda
Fish	
Neomerinthe beanorium	West Indies, Caribbean
Pseudogramma bermudensis	West Indies
Chaenopsis roseola	Western Atlantic, Northern Gulf of Mexico

Table 11-4. Abundances and distributions of relict gastropod species found during the Southwest Florida Shelf Ecosystems Study - Year 1.

Family and Species	Cruise	Station	Count
Turbinidae			
<u>Turbo crenulatus</u> Gmelin	Fall	9	7
	Fall	23	3
	Spring	1	1
	Spring	7	18
	Spring	10	1
	Spring	23	3
	Spring	30	1
<u>Turbo ayersi</u> Olsson	Fall	29	1
Muricidae			
<u>Acanthotrophon striatoides</u> E. Vokes	Fall	29	1
<u>Calotrophon ostrearum</u> (Conrad)	Spring	3	1
	Spring	15	1
<u>Chicoreus florifer</u> (Reeve)	Fall	1	1
	Fall	9	5
	Fall	13	4
	Fall	15	3
	Fall	21	1
	Fall	27	1
	Spring	7	3
	Spring	13	1
	Spring	15	4
	Spring	19	2
	Spring	27	1
<u>Favartia cellulosa</u> (Conrad)	Fall	3	2
	Fall	7	1
	Fall	13	1
	Fall	15	1
	Fall	19	1
	Spring	7	1
	Spring	13	1
	Spring	15	1
<u>Murex bellegladeensis</u> E. Vokes	Fall	3	2
	Spring	9	1
	Spring	10	1
	Spring	11	1
	Spring	19	4
	Spring	23	1
	Spring	27	4
<u>Murex rubidus</u> F. C. Baker	Fall	3	1
	Fall	9	2
	Fall	11	2
	Fall	13	1
	Fall	15	4
	Fall	19	3
	Fall	21	1

Table 11-4. (Continued)

Family and Species	Cruise	Station	Count
	Fall	23	1
	Spring	3	1
	Spring	7	6
	Spring	9	1
	Spring	13	2
	Spring	17	1
	Spring	21	2
Phyllonotus pomun (Gmelin)	Fall	1	1
	Fall	3	1
	Fall	13	1
	Fall	27	1
	Spring	19	1
Chicoreus n. sp. (Petuch, in press)	Spring	10	2
	Spring	17	1
Nassariidae			
Nassarius floridensis Olsson and Harbison	Fall	13	1
	Spring	9	1
	Spring	19	1
Buccinidae			
Cantharus multangulus (Philippi)	Fall	1	3
	Fall	7	1
	Fall	13	2
	Fall	29	1
	Spring	13	2
Olividae			
Olivia edwardsi Olsson	Fall	3	3
	Fall	7	3
	Fall	10	1
	Fall	15	2
	Fall	17	2
	Fall	19	3
	Spring	1	5
	Spring	7	1
	Spring	11	2
	Spring	13	5
	Spring	15	1
	Spring	17	10
	Spring	19	1
	Spring	27	1
Cancellariidae			
Cancellaria cf. *floridana* Olsson and Petit	Fall	19	1
Cancellaria sp. (Petuch, in press)	Spring	27	2

Table 11-4. (Continued)

Family and Species	Cruise	Station	Count
Conidae			
Conus cf. *floridanus* Gabb	Fall	7	1
	Fall	13	1
	Fall	19	3
Conus spurius Gmelin	Spring	15	1
Turridae			
Polystira albida (Perry)	Fall	21	5
	Fall	27	1
	Spring	9	1
	Spring	17	3
	Spring	21	5
	Spring	27	11
Splendrillia cf. *brunnescens* Rehder	Spring	11	1

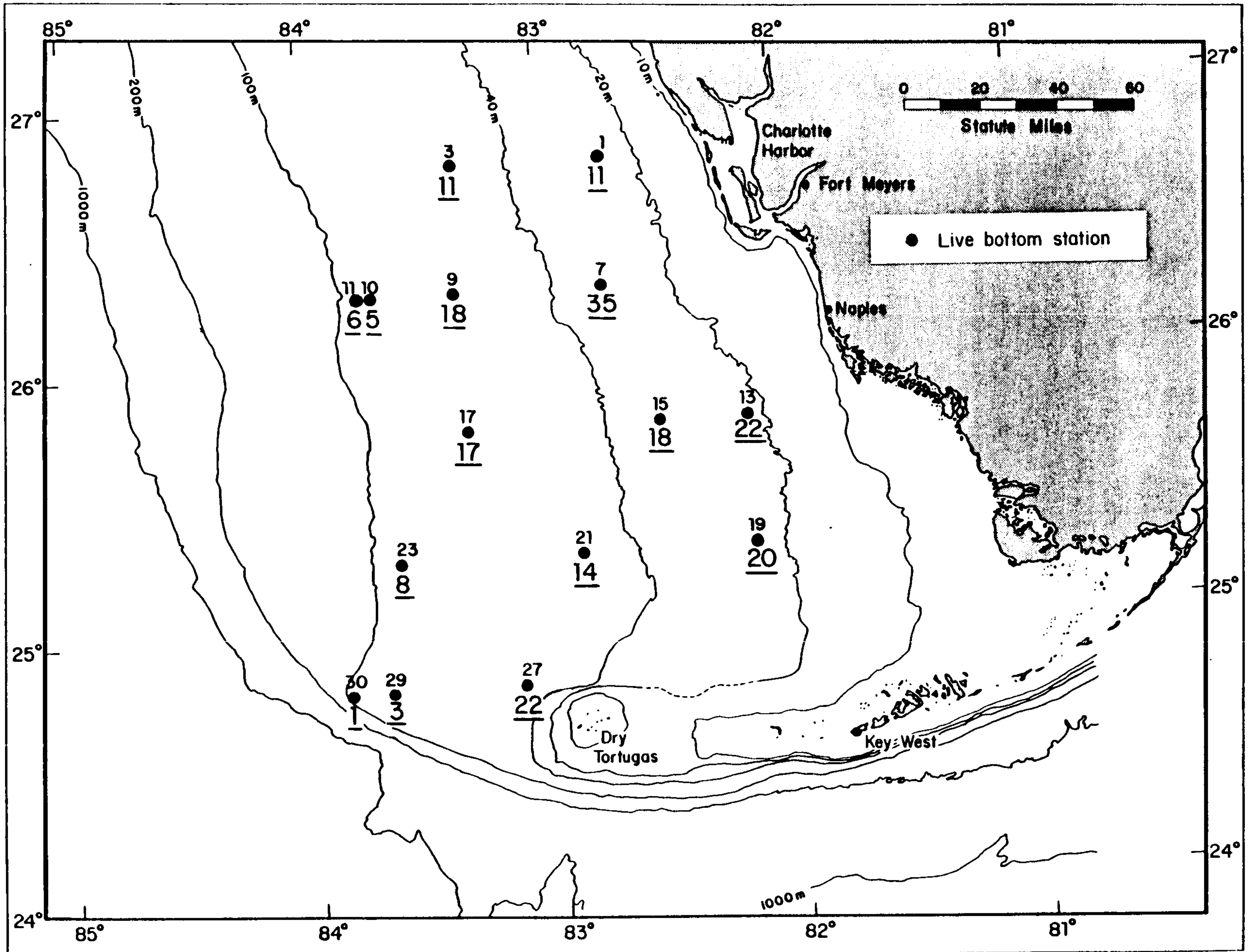

Figure 11-19. Total numbers of relict gastropods collected from each sample location, Fall and Spring Cruises combined (abundances underlined).

and Collard (1974) suggested five faunal zones on the west Florida shelf. These zones were: (1) a Shoreward Zone (0-10 m), (2) a Shallow Shelf Zone (10-30 m), (3) a Middle Shelf I Zone (30-60 m), (4) a Middle Shelf II Zone (60-140 m), and (5) a Deep Shelf Zone. Lyons (1980) discussed the molluscan communities of the west Florida shelf, basing his bathymetric zonal pattern of benthic fauna on mollusc distribution. His conclusions were based, partially, on the results of the Hourglass Cruises, which surveyed the west Florida shelf north of the study area of this project (Florida Department of Natural Resources, 1979).

Clustering analysis of Hourglass Cruises data revealed three faunal zones which were in general agreement with the Shoreward Zone, Shallow Shelf Zone, and Middle Shelf I Zone (Lyons, 1982); however, Lyons did not ascribe causal factors which determined the distribution of the species collected on the Hourglass Cruises.

Hopkins (1979) concluded that, in the MAFLA study area (Mississippi, Alabama, and northern Florida continental shelf), the epibiotal assemblages were more related along bathymetric contours than across contours. He also concluded that assemblages at specific stations may be related to environmental parameters such as substrate and annual near-bottom temperature variation.

Biotal zonation of the southwest Florida shelf is discussed below. The delineation of the zones was based on the synthesis of the results of the Fall and Spring Cruise otter trawl and triangular dredge clustering analyses, the quantitative slide analysis, and the television observations at the specific stations. The biotal zones determined are presented in Figure 11-20. Distinct onshore-offshore patterns were revealed by analysis of the data and the assemblages within each zone were temporally stable. This temporal stability was largely due to the collection of long-lived species at each of the stations.

A number of environmental factors may contribute to the patterns of zonation and these factors may vary with respect to depth and/or distance from the coast. Some of these factors are light intensity, turbidity, temperature, salinity, and substrate availability. Lyons and Collard (1974) have suggested

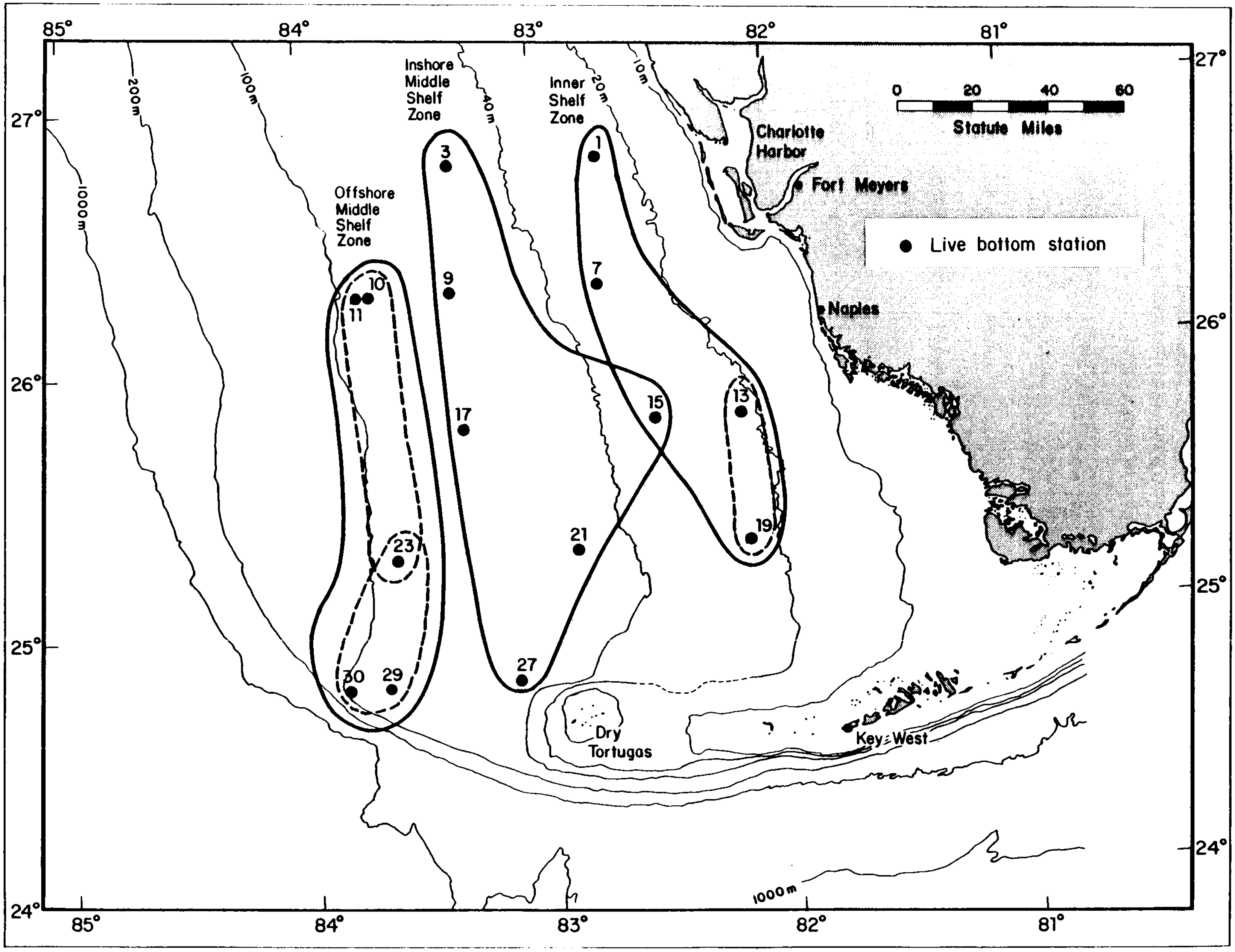

Figure 11-20. Live bottom epibiotal zones of the southwest Florida shelf, as determined by a synthesis of all live bottom data.

turbidity, temperature, and salinity as important factors controlling the distributions of benthic communities. Since only two surveys were conducted in the study area and the two surveys were during transition periods, it was not possible to determine causal factors for live bottom distributions based on the data collected during this study.

11.4.2 Inner Shelf Zone

This zone corresponded to the "Shallow Shelf Zone" suggested by Lyons and Collard (1974). It included Stations 1, 7, 13, and 19; the biota at Station 15 seemed to represent an intergradation between this zone and the more seaward Inshore Middle Shelf Zone. Station 1 was dominated by algae (Phaeophycophyta and Chlorophycophyta) in the quantitative slide analysis. Station 13 was dominated by algae (Phaeophycophyta and Caulerpa spp.) only on the Fall Cruise. Small sponges were observed to dominate the epibiota at Station 19 in the quantitative slide analysis. These three stations were grouped into the inner shelf assemblage in the clustering analyses of the Fall and the Spring Cruise otter trawl and triangular dredge data. Analysis of the combined Fall Cruise and Spring Cruise data revealed the stations were faunistically similar and that there was no temporal variability in the biotal assemblage. Television observations supported this delineation.

Station 7 could not be considered a typical inner shelf station. Although television observations and the clustering analyses categorized this station strictly with the Inner Shelf Zone, the quantitative slide analysis did not reveal the dominant coverage of epiflora at Station 7 which was observed at Station 1 on both cruises and at Station 13 during the Fall Cruise. This analysis showed sponges to be predominantly responsible for coverage at this station. Since the quantitative slide analysis was limited in scope, it probably did not adequately characterize the biota of the station.

Station 15 was transitional between the Inner Shelf Zone and Inshore Middle Shelf Zone. Analysis of otter trawl data from the Fall Cruise revealed that this station was more similar to the Stations 1, 7, 13, and 19 while analysis of the triangular dredge data suggested it to be more similar to the inshore middle shelf stations. The transitional nature of the biota was also supported by the results of the normal clustering analysis of the triangular dredge and otter trawl samples for the two cruises combined. These analyses indicated that the biotal assemblage at Station 15 did not vary temporally. It was grouped with the inner shelf stations in the analysis of the combined otter trawl data while it was grouped with the inshore middle shelf stations in the analysis of the combined triangular dredge data. Since the two methods sample different, yet overlapping, components of the biota, this inconsistency of grouping on the basis of sampling method suggests the transitional nature of the biota. Television observations suggested this station to be transitional while the quantitative slide analysis showed a predominance of the sponges *Placospongia melobesioides* and *Geodia* spp.

Analysis of videotapes from the transects of Cruise II (Television-Still Photography Cruise) support the delineation of the Inner Shelf Zone. The Inner and Middle Shelf Live Bottom Assemblage II was found at Stations 1, 7, and 15 (Figure 11-21). This assemblage consisted of algae, ascidians, bryozoans, hard corals, small gorgonians, hydrozoans, and sponges (see Section 3.3.2.3). Stations 13 and 19 were found to be dominated by the Inner Shelf Live Bottom Assemblage I (Section 3.3.2.2). This assemblage was composed of algae, ascidians, hard corals, large gorgonians, hydrozoans, and sponges.

11.4.3 Inshore Middle Shelf Zone

Substrate of this zone was predominantly carbonate sands and corresponded to the Middle Shelf I Zone of Lyons and Collard (1974). Strict Inshore Middle Shelf Zone stations were Stations 3, 9, 17, 21, and 27. Television observations indicated that the epifauna at these stations was dominated by sponges. These observations were confirmed by the quantitative slide analysis for Stations 3, 21, and 27. Sponges were major contributors to the coverage of the epibiota at Station 17 on the Spring Cruise. The results of the clustering analyses also grouped these five stations in the Inshore Middle Shelf Zone. Clustering analyses of the combined Fall Cruise and Spring Cruise data suggested that there was high temporal stability in the biotal assemblages at these stations. Since many of the species collected are long-lived, this temporal stability is not surprising.

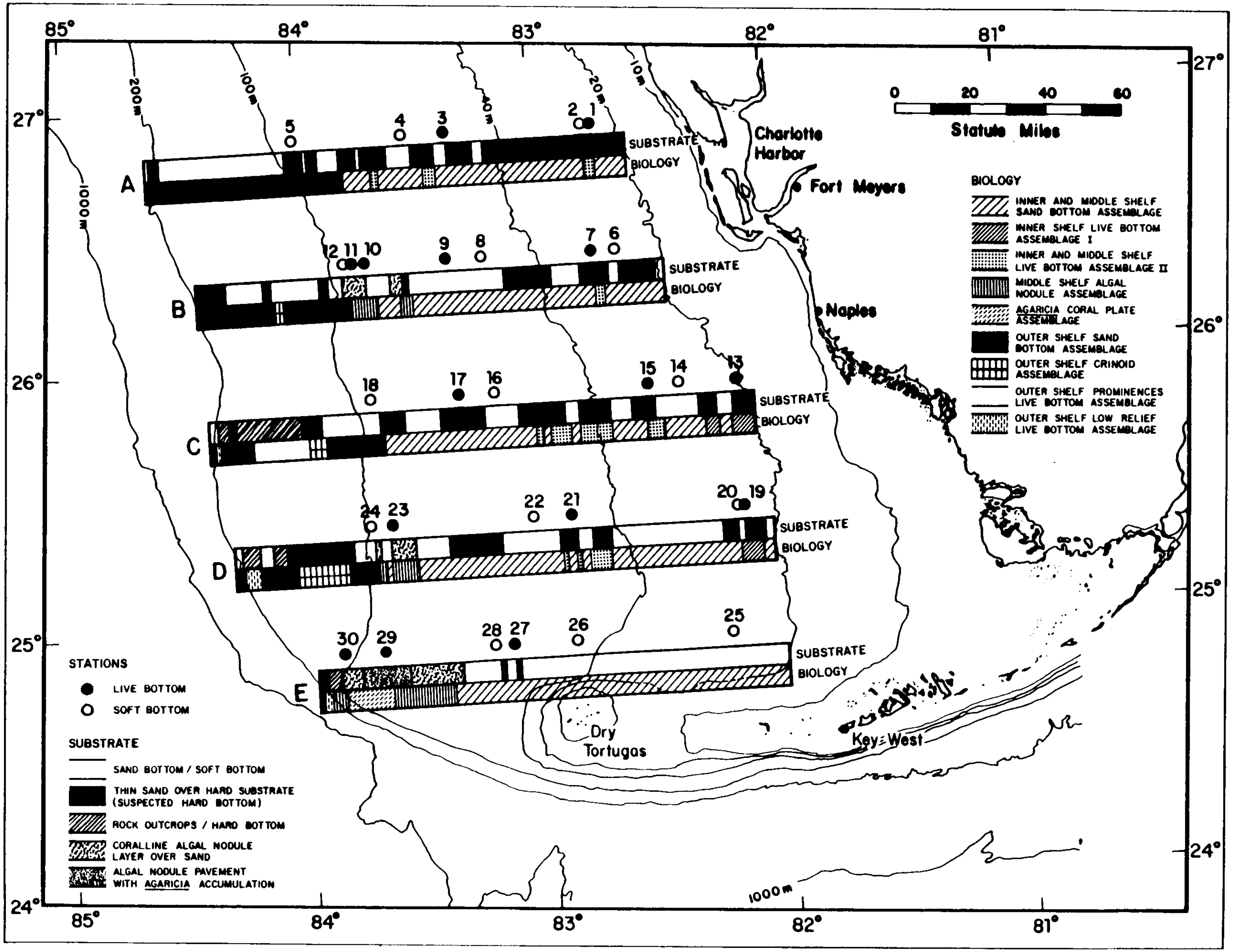

Figure 11-21. Geographic distribution of substrate types, biological assemblages, live and soft bottom sample stations.

Analysis of the television videotapes from the transects conducted on Cruise II revealed that live bottom areas at Stations 3, 9, 17, and 27 were dominated by the Inner and Middle Shelf Live Bottom Assemblage II (see Section 3.3.2.3). This assemblage was dominated by algae, ascidians, bryozoans, hard corals, small gorgonians, hydrozoans, and sponges. The presence of this assemblage at Stations 3, 21, and 27 is clearly shown in Figure 11-21. However, the live bottom patches at Stations 9 and 17 were scarce and widely dispersed and, therefore, not distinctly illustrated in Figure 11-21.

11.4.4 Offshore Middle Shelf Zone

The Offshore Middle Shelf Zone comprised Stations 10, 11, 23, 29, and 30. This zone corresponded to the Middle Shelf II Zone of Lyons and Collard (1974). Coralline algae was an important group which delineated this zone. Within this zone, two sub-zones were evident; one composed of Stations 10 and 11, and the other of Stations 23, 29, and 30.

11.4.4.1 Stations 10 and 11

Stations 10 and 11 composed a distinct sub-zone within the Offshore Middle Shelf Zone. Television observations indicated the epibiota was dominated by small coralline algae and small algal nodules. These two stations showed similarities to Station 9 in the quantitative slide analysis, which revealed a distinct epifloral component in the percent coverage (*Halimeda* spp. on the Fall Cruise and Phaeophycophyta on the Spring Cruise). Results of the Spring Cruise otter trawl clustering analysis also grouped these stations with Station 9, while they were grouped with Stations 23, 29, and 30 in the Spring Cruise triangular dredge clustering analysis. Results of the Fall Cruise triangular dredge data showed the biotal similarity of these stations.

11.4.4.2 Stations 23, 29, and 30

Station 23 was transitional in nature between the two sub-zones on the Offshore Middle Shelf Zone. Television observations showed it to be dominated by algal nodules on sand. The percent coverage of *Anadyomene menziesii*, as measured in the quantitative slide analysis, indicated the similarity of this station to Stations 29 and 30.

Stations 29 and 30 were consistently grouped in both Spring Cruise clustering analyses. Television observations indicated coverage by coralline algal plates on sand. The quantitative slide analysis indicated Agaricia spp. coral plates were important in the percent coverage at Station 29 on both cruises and important to a lesser extent at Station 30. The green alga Anadyomene menziesii was important at both stations, confirming the similarity of these two stations to Station 23.

Stations 10, 11, 23, and 30 were observed to be dominated by the Middle Shelf Algal Nodule Assemblage on the television transects made during the Fall Cruise. This assemblage was dominated by coralline algal nodules, algae, corals, and small sponges (Section 3.3.2.4). The Agaricia Coral Plate Assemblage was found to dominate at Station 29. This assemblage was dominated by algae, live hard corals, gorgonians and sponges (Section 3.3.2.5).

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12.0 POTENTIAL IMPACTS OF OIL AND GAS OPERATIONS ON SOUTHWEST FLORIDA SHELF ECOSYSTEMS

The majority of effort during the first year of the Southwest Florida Shelf Ecosystems Study was devoted to collecting and working up a broad range of geophysical, underwater television and photographic, water column and benthic sampling (biological, hydrocarbons and trace metals) data. An important longer-term goal of the study will be to assess environmental impacts likely to result from potential oil and gas development on the southwest Florida shelf. The following paragraphs present a preliminary overview of some of these potential impacts. The second year report will explore these and other potential impacts in greater depth.

12.1 Oil and Gas Activities as Agents of Change

Lease sales on the southwest Florida shelf will undoubtedly include lease blocks near or adjacent to biologically sensitive areas. The purpose of the following discussion is to identify probable biologically sensitive areas in the study area and to describe the potential impacts of the major routine oil and gas operations (not including accidental oil spills) upon the biota.

12.1.1 Exploration

Exploratory drilling within a lease block is the initial activity which could impact the biota of the southwest Florida shelf. Sources of potential impact include the placement of the drilling platform and/or anchoring of the platform; the discharge of drilling muds, drill cuttings, and cooling water; and other minor discharges including sanitary wastes and deck drainage. The latter minor discharges will not be discussed further due to the fact that their potential impacts are probably slight.

12.1.1.1 Placement of the Platform

Initial geophysical surveys are performed to determine geologic hazards, bottom stability, cultural resources, and other conditions which bear on the choice of exploratory drillsite locations. Within the present study region, the location of buried channels and karst features, minor near-surface faults, rock outcrops, and sea floor depressions, as well as live bottom distribution would need to be reviewed. Subsequently, a mobile drilling platform (jack-up, drillship, or semi-submersible) would be moved to the selected location. Depending on the type of platform utilized, it is positioned by either lowering of the legs (jack-up) or anchoring (semi-submersible and drillship).

12.1.1.2 Drilling Mud and Cuttings

Drilling muds are used in the drilling operation to cool and lubricate the drilling bit and drill pipe, to remove formation cuttings, to insure controlled and efficient drilling through maintenance and integrity of the borehole, and to minimize corrosion. Generally, the drilling muds are separated from the cuttings (which are continuously discharged during actual drilling operations) and recirculated through the borehole; however, the drilling muds must be discharged periodically to meet changing conditions in the borehole with depth. Discharges of drilling fluids without cuttings generally occur eight to ten times during the drilling of an offshore well (Offshore Operators Committee, 1976).

Cuttings are composed of small pieces of the drilled formation and range in size from microns to a few centimetres (Gettleson and Laird, 1980). Large cuttings have been found to fall directly to the bottom. Drilling muds adhering to the cuttings wash free as the cuttings descend to the bottom. Fine cuttings and muds generally form a visible plume which disperses from the discharge pipe (Ayers et al., 1980b). In areas where bottom current velocities are high, drill cuttings do not accumulate on the bottom but are either entrained into the sediments or dispersed over a large area (Ray and Meek, 1980). In contrast, cutting piles have been observed in areas of low bottom current velocities (Zingula, 1975). Piles of cuttings as large as 30 m in diameter and 1 m in height have been observed at drilling rigs where discharges were near the surface in areas of low current velocity. In similar low velocity areas, piles up to 2 to 3 m in height and 18 to 22 m in diameter have been observed at drilling rigs where discharges were shunted to within 10 m of the bottom. These accumulations of cuttings would most likely smother the existing benthic biota but provide new substrates for future colonization.

12.1.1.3 Cooling Water

Sea water is often pumped through engine jackets on the drilling rig for once-through cooling of the engines. The volume of water utilized in this manner varies depending on the type of drilling rig. This water does not come in contact with anything other than the engine jacket, therefore, temperature is the only property of the water which changes during this operation. The average temperature increase of the discharged cooling water is 6 to 8°C.

12.1.2 Development and Production Operations

12.1.2.1 Produced Water

Produced water is commonly mixed with the oil and gas which is extracted at a production platform. The ion ratios of this produced water generally differ from the ion ratios found in the sea water at the production site. Appreciable concentrations of the cations sodium, magnesium, and calcium and the anions chloride, sulfate, carbonate, and bicarbonate are generally found in the produced waters. The concentrations of the total dissolved constituents vary over a wide range, generally from a few milligrams per litre to over 300,000 milligrams per litre.

Metals generally found in produced water include calcium, magnesium, potassium, strontium, aluminum, boron, barium, iron, and lithium. Other metals such as chromium, copper, manganese, nickel, tin, titanium, and zirconium are present in low concentrations. Concentrations of the trace metals, with the exception of copper, chromium, manganese, and strontium, are not substantially different from concentrations typically found in sea water.

Oil and grease in the produced water are removed by a treatment system on the production platform. Trace residues are discharged with the production water. Rapid dilution of the produced water upon discharge decreases the concentration of these hydrocarbons around the drilling platform and it is unlikely that they would produce any significant impacts.

12.1.2.2 Drill Muds and Cuttings

In contrast to exploratory drilling operations, a large number of wells are usually drilled from a production platform. Larger quantities of drilling mud and cuttings are therefore discharged during the drilling operations for a production platform. The discharge of drilling muds and cuttings, while on a larger scale, is similar to that described in Section 12.1.1.2.

12.2 Description of the Environment

12.2.1 Water Column

12.2.1.1 Physical Oceanography

Results of the present study indicate that the study area is mesotrophic to oligotrophic (see Section 6.5). This classical subtropical-tropical situation is characterized by low nutrients and high temperatures and salinities. Seasonal variability of surface temperatures is pronounced in the Gulf of Mexico. In the northern part of the Gulf of Mexico, average annual surface temperatures are around 18°C, while during the summer, the mean surface temperature is around 29°C (United States Department of the Interior, 1978). The maximum surface temperature measured during the Fall Cruise (November 1980) was 27.5°C; during the Spring Cruise (April 1981) it was 26.8°C. A greater variation is expected when the results of the Year II Summer and Winter Cruises become available.

The Loop Current dominates circulation in the eastern Gulf of Mexico and has pronounced effects on the circulation of the southwest Florida shelf. Molinari et al. (1975) listed several processes associated with the Loop Current which significantly affect circulation on the shelf. These processes are (1) momentum and water mass transfer from the Loop Current to the shelf (i.e., warm tongues), (2) direct intrusion of the Loop Current and its associated momentum and water masses onto the shelf, (3) intrusion of Loop Current related eddies and their associated momentum and water masses onto the shelf, and (4) fluxes of mass from the shelf to the deep basin instigated by Loop Current features. The salinity data for the Fall Cruise suggest the possibility of an eddy but lack of synopticity permits no conclusion. The possibility that Subtropical Underwater, an indicator of the Loop Current, occurred on the shelf during the Spring Cruise is also suggested by the salinity data. Although turbid water was observed during both cruises, it was not attributable to a specific intrusion of the Loop Current onto the shelf. This turbidity was most likely due to plankton activity and bottom sediment resuspension. Turbidity observed on Cruise II using the towed television system was hypothesized to be due to resuspension of bottom sediment by internal waves. Increased turbidity was also related to weather fronts passing over the study area.

12.2.1.2 Biota

Based on chlorophyll a measurements, El Sayed (1972) showed higher concentrations of phytoplankton in the winter than in other seasons in the Gulf of Mexico. He concluded that the Gulf of Mexico is similar to other subtropical-tropical marine systems with respect to chlorophyll a. El Sayed (1972) also found surface and integrated primary productivity values to be higher inshore than offshore, similar to the distribution of chlorophyll a.

A relationship between the concentration of chlorophyll a and the concentration of nutrients was found during the present study. Above the pycnocline, increased concentrations of phosphate were associated with increased concentrations of chlorophyll a. Increased nutrient concentrations near the surface due to upwelling in the southern portion of the study area during the Spring Cruise were found to be associated with increased concentrations of chlorophyll a. Chlorophyll a concentrations during the Fall Cruise were low throughout the study area, ranging from 1.90 mg m^{-3} to less than 0.1 mg m^{-3}. Concentrations of chlorophyll a were also low during the Spring Cruise, with values less than 0.05 mg m^{-3} throughout much of the study area and a maximum of 0.8 mg m^{-3} on the southernmost transect.

Phytoplankton data for the eastern Gulf of Mexico have been summarized by Steidinger (1973). These data indicate that diatoms dominate inshore coastal areas while dinoflagellates often dominate open Gulf of Mexico waters, particularly in terms of species richness. Steidinger (1973) also found that phytoplankton species composition in coastal areas fluctuates throughout the year. Seasonal peaks vary geographically and from year to year. Data on succession and seasonality are difficult to interpret but maximum productivity occurred during the spring and summer.

Zooplankton constitute a major link between phytoplankton primary production and higher trophic levels in the pelagic food web. Patchy distribution of zooplankton makes abundance estimation difficult. Copepods are the most abundant zooplankters. Common neritic species in the Gulf of Mexico include the calanoids *Euchaeta marina*, *Neocalanus gracilis*, *Scolecithrix danae*, *Candacia pachydactyla*, *Undinula vulgaris*, *Eucalanus attenuatus*, and *Acartia tonsa*, and the cyclopoids *Copilia mirabilis* and *Corycaeus* spp. Euphausiids, chaetognaths, ctenophores, cnidarian medusae, salps, pteropods, and a variety of meroplanktonic larvae also contribute to the neritic zooplankton assemblage in the Gulf of Mexico (United States Department of the Interior, 1978).

Ichthyoplankton, especially larvae of commercial fish, are a component of the zooplankton which is of direct economic value. Houde et al. (1979) reported the ichthyoplankton of the eastern Gulf of Mexico to be abundant and diverse. Larval species characterizing the eastern Gulf of Mexico include *Syacium papillosum*, *Decapterus punctatus*, and *Diplectrum formosum*. Houde (1975) reported higher mean abundance of ichthyoplankton at stations greater than 50 m in depth. Similarly, Houde et al. (1979) reported significantly higher ichthyoplankton species richness at depths greater than 50 m than at shallower depths.

12.2.2 Benthic Environment

12.2.2.1 Sediments

Grain size analyses from this study permit identification of three distinct sediment types in the study area. Soft bottom areas in the northeastern portion of the study area (Station 2) are dominated by a quartz clastics facies. Fine grained carbonate mud is found in the southern portion of the study area (Stations 25 and 26) adjacent to the Florida Keys. The remaining soft bottom sites within the study area are dominated by carbonate sand.

12.2.2.2 Hydrocarbons

Surficial sediment hydrocarbon analyses from this study identified low levels of biogenic hydrocarbons at all soft bottom sample sites. Anthropogenic hydrocarbons were found at a single soft bottom station (12) and were attributable to inputs of clay particles carried south by the Loop Current from the northern Gulf of Mexico and Mississippi River areas. Overall, it was concluded that the southwest Florida shelf carbonate sediments primarily contain low levels of hydrocarbons from biogenic sources. Possible hydrocarbon contamination from offshore oil and gas development activities should be readily distinguishable against these virtually "pristine" background conditions.

12.2.2.3 Trace Metals

Previous work on central and northwest Florida shelf surficial sediments (Alexander et al., 1977; Presley et al., 1975; Trefry et al., 1978) has shown these areas to have very low trace metal concentrations. The primary factor contributing to these low concentrations is the dominance of carbonate and quartz sand sediments in these areas. Results from this study confirmed that low trace metal concentrations are also typical of the southwest Florida shelf, for the same reasons. As with hydrocarbons, possible increases in trace metal concentrations due to offshore oil and gas development activities should be readily distinguishable above present "pristine" background conditions.

12.2.2.4 Biota

Onshore-offshore zonation of biological assemblages across the west Florida shelf has been suggested by several previous workers (Collard and D'Asaro, 1973; Defenbaugh, 1976; Lyons and Collard, 1974). Collard and D'Asaro (1973) suggested two faunal provinces but found no clear-cut boundaries between them. The two provinces were shallow shelf assemblages, which had Carolinian affinities, and deep shelf assemblages, which had West Indian affinities. Defenbaugh (1976) identified three biotal zones on the west Florida shelf: an inner shelf, intermediate shelf, and outer shelf assemblage, respectively. Lyons and Collard (1974) suggested four zones in this same region: Shallow

Shelf (10 to 30 m); Middle Shelf I (30 to 60 m); Middle Shelf II (60 to 140 m); and, Deep Shelf. More recently, Lyons and Camp (1982) confirmed the designation of the Shallow Shelf (10-30 m) and Middle Shelf I (30-60 m) zones based on multivariate analysis of much of the biological data from the Hourglass Cruises .

12.2.2.4.1 Soft Bottom Biota

Results of the present study indicate that bathymetric zonation is characteristic of both the epifauna and macroinfauna from soft bottom areas of the southwest Florida shelf. Clustering analysis of the epifaunal data showed distinct bathymetric groupings, indicating onshore-offshore differences in species distributions. Analyses of the macroinfauna data also showed distribution patterns related to bathymetry. No obvious patterns of latitudinal or bathymetric dispersion were found for the epiflora, however.

Analysis of television observations revealed that offshore middle shelf stations were characterized by an Outer Shelf Sand Bottom Assemblage. This epifaunal assemblage is characterized by asteroids, crinoids, echinoids, ophiuroids, sea pens, anemones, crustaceans, and scattered hexactinellid sponges. An Inner and Middle Shelf Sand Bottom Assemblage, which is dominated by algae, asteroids, bryozoans, echinoids, holothuroids, sea pens, and scattered hard corals and sponges, characterizes the inshore middle shelf and inner shelf stations.

12.2.2.4.2 Live Bottom Biota

Results of this study indicate the presence of three live bottom biotal zones in the study area. Offshore middle shelf stations are dominated by small coralline algae, algal nodules, or *Agaricia* coral plates. A distinct inshore middle shelf zone, distinguished by the presence of sponges, is also evident from analysis of the live bottom data. Inner shelf stations are characterized by algae, ascidians, large or small gorgonians, hard corals, hydrozoans, and sponges. The depth ranges noted for these three zones confirm the bathymetric delineations presented by Lyons and Collard (1974).

12.3 Potential Impacts

The fate of drilling mud discharges from shunted and unshunted wells has been monitored on several occasions. Drilling muds are released at or near the surface of the water column at unshunted wells. Typically, two plumes have been associated with unshunted bulk discharges. The heavier fraction of the discharged drilling muds descends immediately to the bottom, leaving the less dense fraction in the water column (Ayers, et al., 1980a; Houghton et al., 1980; Ray and Meek, 1980). This upper plume has been found to spread over the thermocline (Continental Shelf Associates, Inc., 1978). Tracking studies of the water column plume have shown transmissivity to be the only hydrographic parameter altered beyond the immediate vicinity of the discharge source (Ayers, et al., 1980a). Trocine and Trefry (1981) observed a 10^6 dispersion factor for total drilling solids within 2,000 m of discharge near the Flower Garden Banks in the northwestern Gulf of Mexico.

Near biologically sensitive areas, drilling discharges are often shunted (discharged) through a downpipe that terminates within 10 m of the sea floor. Gettleson (1980) and Espey, Huston, and Associates, Inc. (1981) reviewed previous studies of shunted discharges. It was concluded by these authors that drilling discharges were not generally detected in surficial sediments beyond 1000 m from the discharge source.

Potential impacts which could occur in the water column due to toxicity of materials in the upper plume from unshunted (surface discharge) wells include reduction of primary and secondary production, changes in community structure (selective impact on key species in the pelagic community), and bioaccumulation (food web magnification). Petrazzulo (1981) reviewed previous studies on the effects of drilling muds in the Gulf of Mexico. He determined that impacts on the water column would not be substantial beyond 100 to 1,000 metres from an exploratory drilling rig, depending on the rate of dispersion of the solids in the upper plume. This conclusion was based on extrapolation of 96-h bioassay results on a variety of marine species. The most sensitive species, *Acartia tonsa*, was found to have a 96-h LC_{50} value for whole drilling mud of 100 ppm. Dispersion rates of whole muds indicate that levels below the lethal concentration are achieved at distances within 100 m of a discharge. Auble et al. (1981) attempted to synthesize all known information into a model to show the fate and effects of drilling muds discharged from an unshunted well. These investigators found that impact on benthic larvae in a 40-m water column would be a reduction of 1.7%, if 100% zooplankton mortality occurred within the plume. They also stated that the impact may be more severe at sites where multiple wells are drilled.

Primary concerns of the impact of drilling fluids on benthic systems have centered around: (1) smothering of sessile invertebrates, (2) changes in community structure due to decreased hard bottom availability, (3) burial of infauna inhabiting sand cover, and (4) decreased algal growth due to increased turbidity (Marine Resources Research Institute and Coastal Resources Division, 1981). Smothering of sessile invertebrates and coverage of emergent rock are probably the most severe potential impacts on live bottom assemblages. Petrazzulo (1981) determined that no substantial reduction in benthic macroinfaunal abundance would occur at distances greater than 1,000 m from an exploratory drilling rig. Increased turbidity in areas such as the southwest Florida shelf, which typically does not have high sedimentation and resuspension, may impact macroalgal production and filter-feeding by sessile invertebrates. An additional concern is settling of clay size particles from drilling muds over a typically carbonate sand substrate. In addition to smothering the infauna within the sediments, settlement of benthic larvae may be inhibited (Tagatz and Tobia, 1978; Tagatz et al., 1978).

Impact from oil and gas operations on the biota of the southwest Florida shelf is difficult to assess since it may be mitigated or intensified through the complex interactions of the components of the biota. For example, a decrease in the abundance of one species may result in changes of abundances of other species due to microhabitats or trophic interactions, e.g., predation. However, it is possible to speculate on potential impact which might occur as a result of drilling activities.

Discharged drilling muds, which are typically fine-grained sediments, may alter the predominant grain size of an area, if deposited. With the exceptions of Stations 25 and 26, sediments at the soft bottom stations were predominantly sand (see Section 7.0). Changes in the grain size composition of the sediments in the vicinity of a drilling operation might affect the structure of the infaunal assemblage through burial, as well as change the suitability of the sediment for recruitment. The addition of trace metals and petroleum hydrocarbons (during production activities) to the surficial sediments that have very low concentrations (see Sections 8.0 and 9.0) may also affect the biota. Deposition of discharged drilling muds on live bottom areas would decrease the availability of hard substrate. This decrease could alter the structure of the live bottom community in the immediate vicinity of the drilling operation.

Turbidity will be increased in the vicinity of drilling operations. Since turbidity is often higher inshore, the impact of decreased light penetration will probably be less nearer to the coast; however, the proximity of the bottom to the discharge source may increase this impact since dilution and dispersion will be less in shallower water. The inner and middle shelf live bottom assemblages are probably more adapted to greater fluctuation of abiotic factors (temperature, salinity, turbidity, sedimentation) than outer shelf live bottom assemblages; however, this fact does not insure that the assemblages would be able to withstand the turbidity and sedimentation added by drilling discharges. Increased turbidity would most likely impact algae and corals by reducing primary productivity (production by symbiotic zooxanthellae in the case of corals). In offshore areas (Agaricia Coral Plate Assemblage and Outer Shelf Crinoid Assemblage), the potential for dilution and dispersion of discharged drilling muds is greater, but the biota will be more sensitive to decreased light penetration since they are adapted to a clear water environment. This impact can, potentially, be alleviated to some extent by locating drilling operations away from live bottom areas. Detrimental changes due to drilling mud discharges are generally localized near the drilling operation (Ecomar, 1980).

Agaricia corals are extremely susceptible to sedimentation; hence discharges of drilling muds near the Agaricia Coral Plate Assemblage (see Section 3.0) would be detrimental. Hubbard and Pocock (1972) examined the capabilities of various scleractinian corals with respect to sediment rejection and found Agaricia to be capable of rejecting only fine-grained sediments. Since this coral is only found in clear water environments, where sedimentation is generally low, increased sedimentation in the vicinity of this assemblage could jeopardize the health of this community.

Suspension feeders may also be susceptible to increased loads of sediment in the vicinities of drilling operations. Particles of discharged drilling muds will not be of nutritive value to suspension feeders, but will increase the load for filtering. Although this may not affect organisms which routinely ingest large quantities of sediments, e.g., bivalves, other organisms may expend large quantities of energy handling particles which provide no nutrition.

The presence of drilling platforms has been found to serve as a hard substrate supporting a rich and diverse biofouling community and a complex assemblage of platform-associated biota (Galloway et al., 1981; Continental Shelf Associates, Inc., 1982; Putt, 1982). These artificial structures are important for high relief hard bottom assemblages.

12.4 An Issue Bearing on Stipulations on Drilling Activities

One of the present biological lease stipulations for live bottom areas requires the interpretation of shallow hazard (geophysical) data for the identification of potential live bottom areas (United States Department of the Interior, 1981). As noted in Section 4.0, standard geophysical techniques are not suitable for identifying the Middle Shelf Algal Nodule Assemblage and the *Agaricia* Coral Plate Assemblage. Other assemblages which will not be sufficiently identified from hazards data alone are the Outer Shelf Crinoid Assemblage and the Outer Shelf Low-Relief Live Bottom Assemblage. In many areas of the southwest Florida shelf, correct interpretation of standard geophysical data records will be difficult without visual "ground truthing."

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13.0 ACKNOWLEDGEMENTS

This study was supported by the U.S. Department of the Interior, through the New Orleans Outer Continental Shelf Regional Office of the Minerals Management Service, formerly a part of the Bureau of Land Management. Support for the first year of this multiyear, multidisciplinary program was provided under BLM Contract No. AA851-CTO-50.

Successful completion of this Final Report, describing the results of the first year of the program, reflects the enthusiastic interaction and support received by the Woodward-Clyde Consultants' Study Team from a broad cross-section of the Florida OCS community. We are particularly pleased to acknowledge critical contributions to the program's success provided by the Management and Staff of Continental Shelf Associates, Inc. (Tequesta, Florida) our Prime Subcontractor. Special thanks are also extended to the Director and Staff of the Mote Marine Laboratory (Sarasota, Florida), the Florida Institute of Technology, the University of South Florida, Texas A&M University, Science Applications, Inc. (La Jolla, California), and the numerous individual taxonomic consultants so vital to a study such as this.

On behalf of Woodward-Clyde, Continental Shelf Associates, Inc., and Mote Marine Laboratory, we gratefully acknowledge the support services provided by Captain Jack Kluever and the crew of the M/V VENTURE, chartered from Ocean Operators, Inc. (Miami Beach, Florida). Assistance from Decca Survey Systems, Inc. (Houston, Texas) during early stages of the first year work is also appreciated.

The first year of the program moved more slowly than expected. One cruise was interrupted by a hurricane, a second was deferred from January 1981 to April 1981 by BLM; the biological sampling program yielded double the volume of material and almost twice the number of species projected from previous studies. Woodward-Clyde Consultants thus particularly appreciates the continuing support, advice and encouragement received from Minerals Management Service staff: Contract Officers, Frances Sullivan and Carroll Day; New

Orlean's COAR Officers, Robert Avent and Murray Brown; and Washington, D.C. Technical Officers, Mark Grussendorf and Tom Ahlfeld.

This Final Report was prepared by Woodward-Clyde Consultants working closely with staff inputs, and draft report sections, provided by the various subcontractors cited above. Contract terms require, that for public information purposes, all principal contributors to both the study and the Final Report be clearly identified, their educational backgrounds be noted, and their roles within the program specified. This information is set out below. Woodward-Clyde Consultants gratefully acknowledges the unique personal contribution of each of these individuals to the overall success of the study.

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In addition, Continental Shelf Associates, Inc., provided a large group of laboratory technicians who assisted in sorting and identification of the live bottom macroepifauna samples: Tracey Beyer, Patricia S. Causey, Rebecca Elliott, Katharine End, Diane Geldert, Maryjon Large, Mary Ellen Lombardi, Lisa E. Martin, Craig D. McKee, Robert Mulcahy, Ky B. Ostergaard, and Alfred P. Sweeney. Electronics technicians and/or navigators included: Louis F. Blaisdell, J. Michael Costin, David Delater, James P. Lamar and Greg Kennedy.

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In addition, Mote Marine Laboratory provided a large group of laboratory technicians who assisted in sorting and identification of macroinfaunal samples: David A. Bruzek, Mark L. Gallo, Elaine Kinney, Brian L. Lewis, Nora V. Maddox, Jenny L. Mapes, Gladys McCallum, Linda D. McCann, Linda Mytinger, Geoffrey W. Patton (archive samples), Kevin C. Sorenson, Jay M. Sprinkel, Stephen G. Swingle, Steve T. Szedlmayer, Cindy B. Vernale, and Donna H. Wooding. Suzanne Hofmann assisted with sediment analysis.

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The following individuals, working as independent consultants unless otherwise indicated, provided taxonomic identifications and/or confirmations for the faunal groups indicated. Such individuals are indispensable to studies such as this one, and their professional contributions deserve broader public and institutional support than is generally provided.

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Last, but not least, important behind the scenes contributions have been made by numerous typists, illustrators and contracts personnel. While too numerous to list by name, all of their roles have been much appreciated.

The Department of the Interior Mission

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. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; 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 ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.