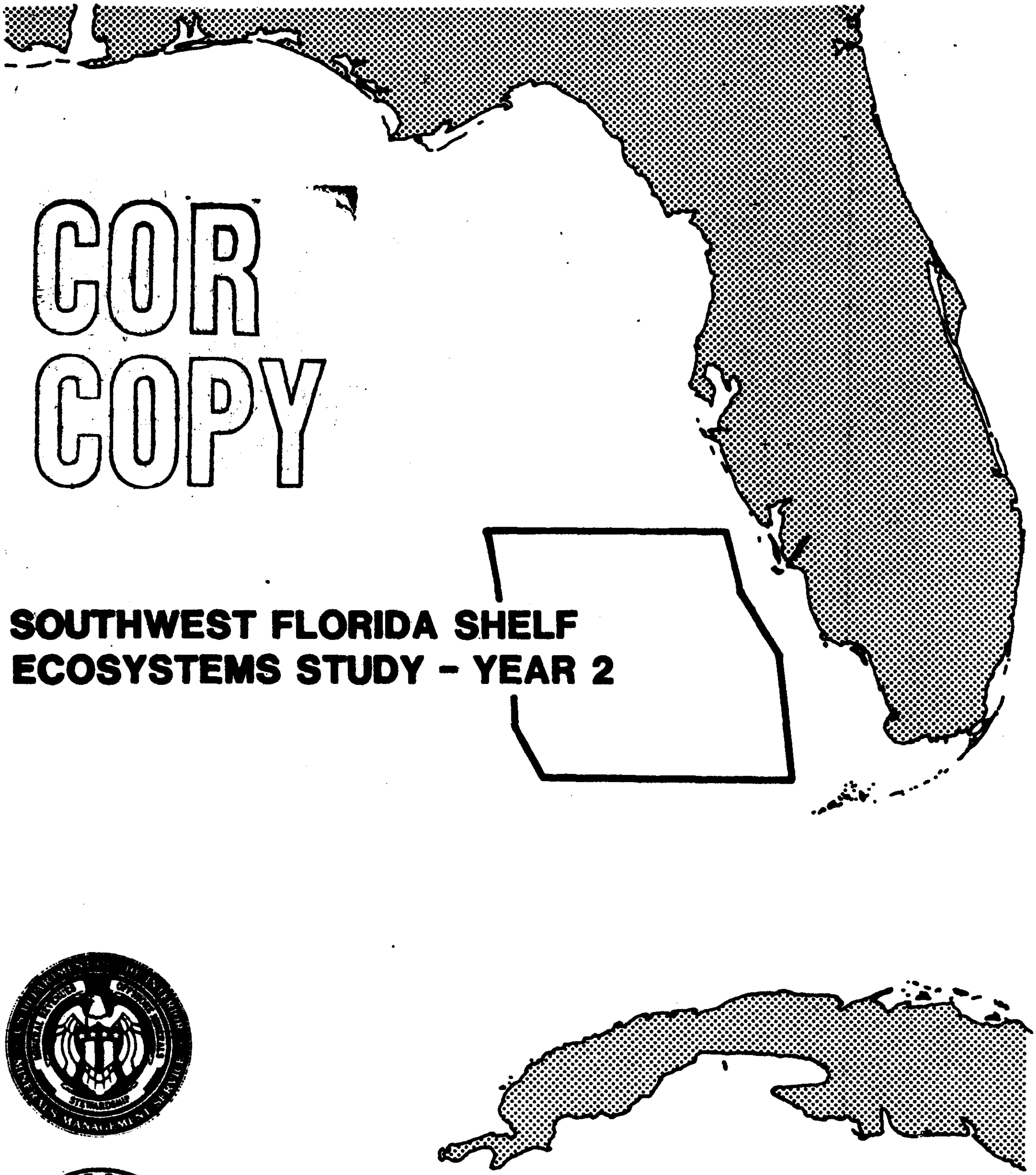
VOLUME 2 - FINAL REPORT I

OCS Study
MMS 85-0061



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SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY - YEAR 2

Prepared for:
U.S. Department of the Interior, Minerals Management Service
Gulf of Mexico OCS Region, Metairie, Louisiana
Contract 14-12-0001-29144
July 1985

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July 1985

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists

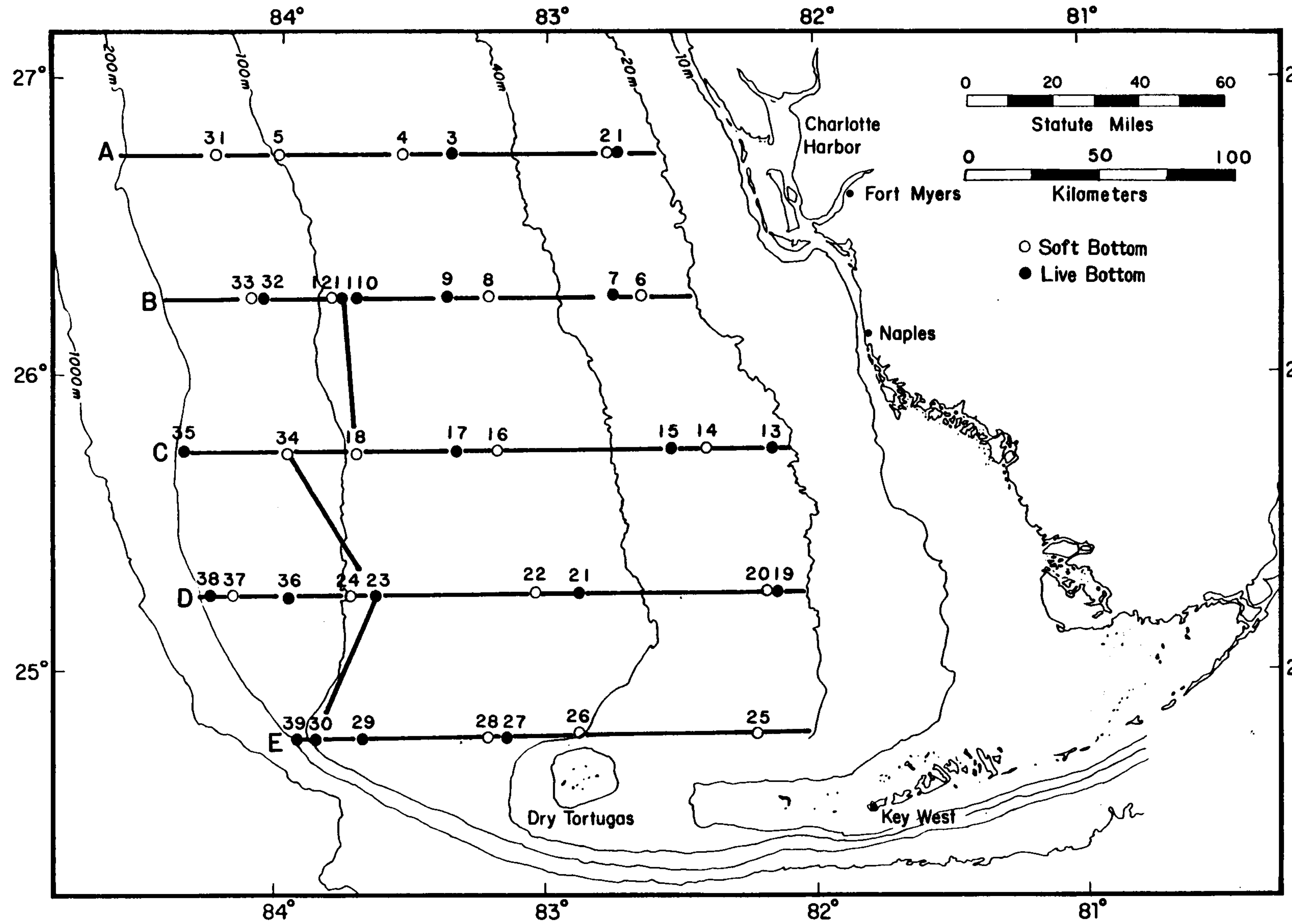
Continental Shelf Associates, Inc.
CSA
"Applied Marine Science and Technology"

PREFACE

THE SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY

To meet present and future energy requirements of the United States, the Department of the Interior has acted to expedite development of oil and gas deposits beneath the outer continental shelf (OCS). Under the Department's accelerated 5-year leasing program, the Minerals Management Service (MMS) is proposing to offer for lease certain tracts in the eastern Gulf of Mexico. The protection of marine and coastal environments is mandated by the OCS Lands Act of 1963, the National Environmental Policy Act of 1969, and the OCS Lands Act Amendments of 1978. As manager of the OCS Leasing Program, the Department of the Interior is responsible for ensuring that proposed OCS development will not irreparably damage the marine environment and its resources. To help meet this responsibility, and to provide basic environmental information for the eastern Gulf of Mexico, the Minerals Management Service initiated (1980) the multiyear, multidisciplinary, Southwest Florida Shelf Ecosystems Study Program.

During Year One of the Southwest Florida Shelf Ecosystems Study Program, bathymetric, seismic, and side scan sonar data were collected (September-October 1980), along with underwater television and still camera color photography of the sea floor. These data were augmented by analyses of a broad range of hydrographic measurements, and water column, sediment, and benthic biological samples. Sampling stations were established in water depths ranging from 20 to 90m at 30 locations distributed along five east-west shelf transects (Figure, Transects A through E). Biological and hydrographic sampling were completed in fall (October-November) 1980 and spring (April-May) 1981.



Southwest Florida shelf survey transects (A through F) and benthic sampling stations for Year One and Two programs.

During the Year Two program, additional visual and geophysical data were collected along a north-south tie-line (Figure, Transect F). Twenty-one of the 30 first year hydrographic and biological sampling stations were resampled twice more, once during summer (July-August) 1981, and again during winter (January-February) 1982. In addition, nine new sampling stations were established on Transects A through E, in water depths ranging from 100 to 159m.

A third study phase, the Year Two Modification contract, examined the importance of Loop Current frontal eddies to primary production along the outer edge of the southwest Florida shelf. This phase encompassed two seasonal hydrographic cruises, in April and September 1982, and included direct and indirect measurements of primary productivity. These hydrographic and primary productivity data have now been synthesized with previous study results into an overview of the driving energetic forces within the southwest Florida shelf regional ecosystem.

The southwest Florida continental shelf includes sandy soft bottom sea floor substrates; hard, "live bottom" habitat; and other areas which favor the development and concentration of marine biota. The distribution of these bottom types and their significance to the regional marine benthic and water column ecosystem is not well known. The interpretation and synthesis of data from this Program are directed at general characterization of broad areas of the southwest Florida shelf, characterization of individual study sites, and inter-site comparisons; assessment of OCS development impact/enhancement potential; methodology evaluation; water mass characterization; and formulation of recommendations for future studies.

The results of the Year One program have already been reported (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983), as have the results of phase three (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983). The present Year Two Final Report describes the results of the Year Two program and provides an integration and synthesis of information collected during all three phases of the study.

The Southwest Florida Shelf Ecosystems Study Program has expanded considerably beyond the work reported herein. Year Three (Continental Shelf Associates, Inc.) continued seafloor habitat mapping to fill in areas between the Year One and Two study transects. Inshore biological sampling stations were also established in 10 to 20m water depths. Years Four and Five (Environmental Science & Engineering) were concerned with dynamic processes that affect the shelf ecosystem -- bottom currents, sediment movements, and so forth. A sixth program year presently contemplates a thorough synthesis of all preceeding study results.

The Year Two Final Report includes a total of seven (7) volumes, as follows:

Volume 1 - Executive Summary, provides a brief, abstracted summary of the principal goals, methods used, and results obtained during the study program.

Volume 2 - Final Report I, includes a more complete introduction to the Year One and Two programs, a summary of geophysical results, a complete discussion of methods used, and accounts of the physical oceanography and substrates that characterize the southwest Florida shelf.

Volume 3 - Final Report II, includes detailed accounts of the live bottom and soft bottom biota of the shelf.

Volume 4 - Final Report III, presents a synthesis of the physical variables and biological assemblages, outlines the potential impacts of OCS development, and provides lists of literature cited and program acknowledgments.

Volume 5 - Appendix A, provides copies of Year One and Year Two hydrographic and biological sampling cruise logs, sample collection times, station tract plots, and hydrographic and sediment data collected during both study years.

Volume 6 - Appendix B, includes the Master Taxon Code List for all taxa recorded during the program, and computer listings of all soft bottom sample station otter trawl and box core data collected during Years One and Two.

Volume 7 - Appendix C, provides computer listings of the live bottom sample station otter trawl, triangle dredge, and quantitative slide analysis data sets for Years One and Two.

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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. Many of the Secretary's responsibilities were originally delegated to the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS). As of January 19, 1982, OCS responsibilities previously dispersed among different government programs and branches were consolidated within the Minerals Management Service (MMS). This 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 their 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 broad, shallow 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. Recognizing the possible existence of oil beneath the shelf, the demand for new domestic energy sources, and the scarcity of basic environmental information for the eastern Gulf of Mexico, the Minerals Management Service initiated in 1980 the multiyear, multidisciplinary, SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY PROGRAM.

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, the MMS is proposing to offer for lease certain tracts in the eastern Gulf of Mexico. The proposed lease offering (Lease Sale 94) is presently scheduled for November 1985 (MMS, 1984).

The southwest Florida continental shelf includes sandy "soft bottom" seafloor substrates, hard "live bottom" habitats and other areas that 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 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 study the term live bottom was defined 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 proposed study, 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 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 area covered by each type of live/reef bottom.

1.2 PROGRAM SCOPE

Since the Southwest Florida Shelf Ecosystems Study is a multiyear, multidisciplinary program, the following paragraphs are included to provide the reader with a general perspective on first, second, and third year activities within the Study.

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 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 (10-9-80 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 (71-16-81 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	Spring Cruise
Cruise II (9-12-82 to 9-19-82)	Hydrography and Primary Production	Summer Cruise

*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 Year One program, a variety of geophysical, hydrographic, and biological parameters were studied along five east-west transects (Transects A-E) across the southwest Florida shelf. Study transect locations are shown in Figure 1-1. Remote sensing geophysical data -- bathymetric, seismic, and side scan sonar surveys -- were collected along each transect from about 40m water depth out to 200m water depth. Visual "ground-truth" data -- combining black and white underwater television and 35mm, still color photography -- were collected in depths between 20 and 200m. 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 45m, 45 to 70m, and 70 to 100m water depths, respectively. 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. Final Year One sampling locations are shown in Figure 1-2. Each of these sampling stations was occupied twice during the Year One program, 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 sea floor substrate identifications into interpretations of specific community types, with emphasis on speciation, diversity, biomass, recreational, and commercial value.

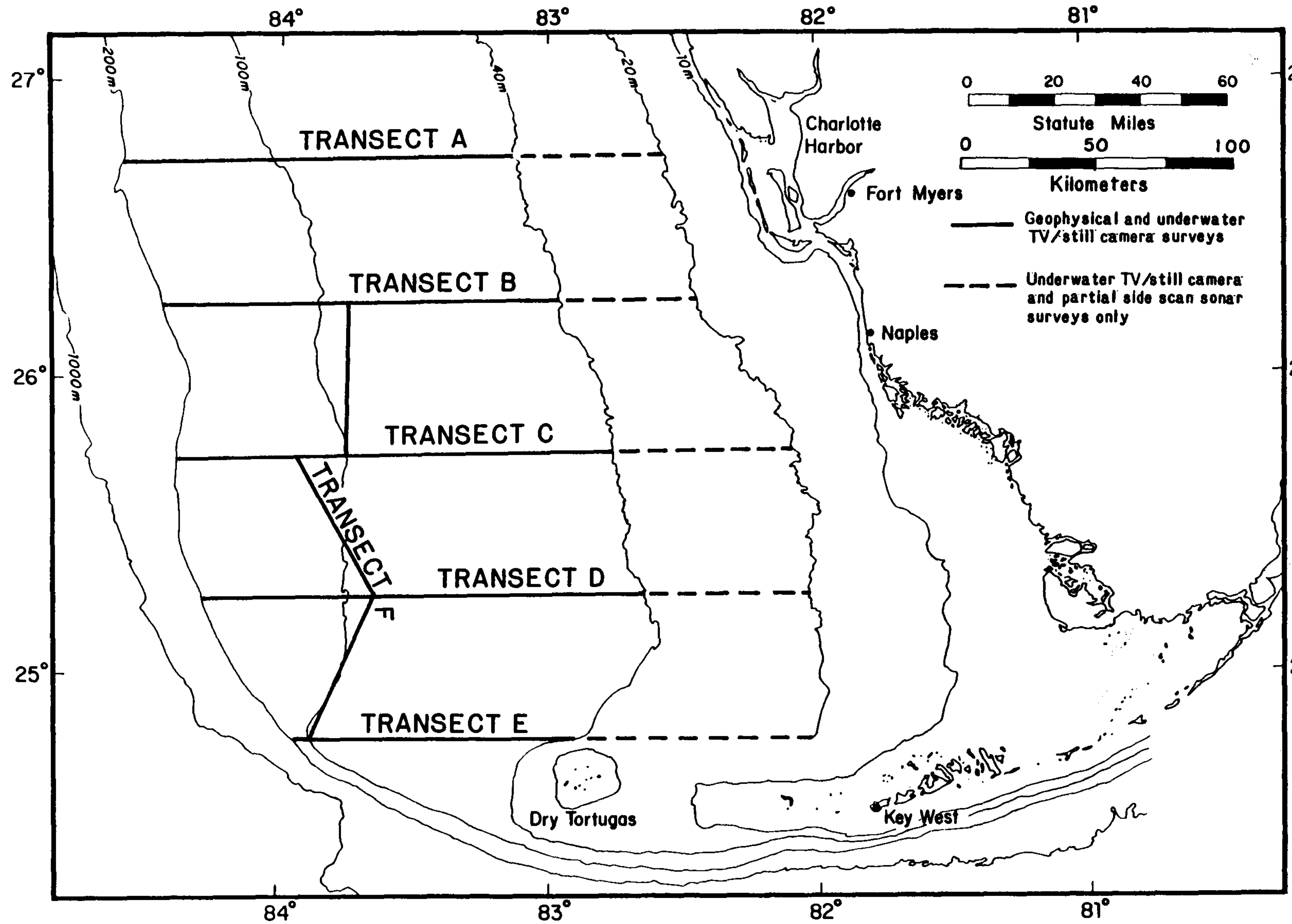

Figure 1-1. Southwest Florida survey transects.

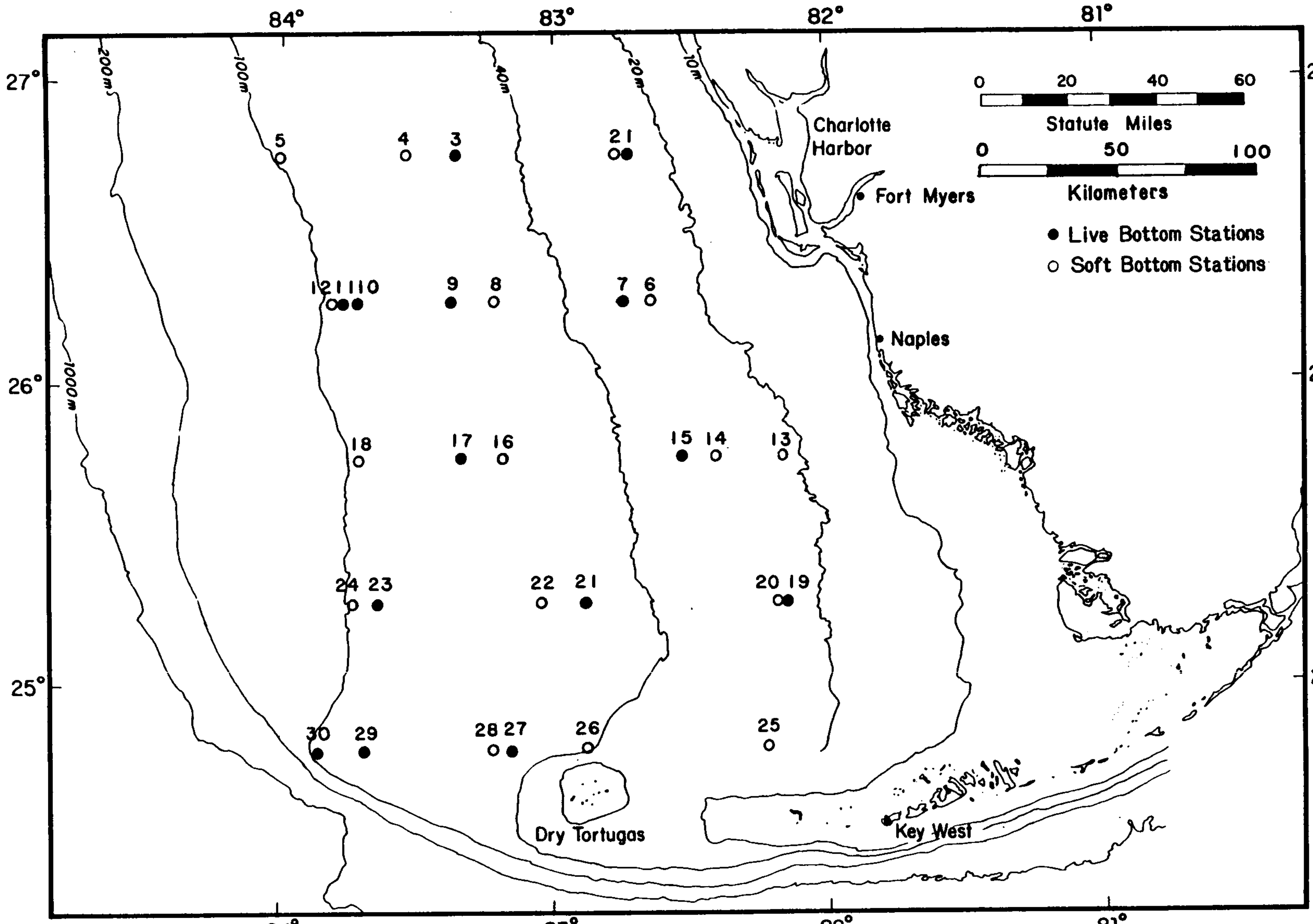

Figure 1-2. Year One sampling station locations for biological and hydrographic studies.

1.2.2 Year Two

During the Year Two program, geophysical information was collected along a new north-south transect (Transect F), at about 100m water depth, that tied together several of the previously surveyed east-west transects (Figure 1-1). Visual data, again including underwater television and still camera photography, was extended along each east-west transect from 100 to 200m 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 200m. Each of these stations was sampled during both the Summer and Winter Cruises. Year Two sampling station locations are shown in Figure 1-3.

Overall program objectives for Year Two remained the same as for Year One; however, the volume of biological data available for analysis proved to be about double that originally anticipated. A more complete understanding of possible seasonal changes resulted from combining results for all four seasonal cruises.

1.2.3 Year Two Modification

The Year Two Modification Contract, essentially a third year program, was significantly different from the Year One and Year Two studies. Two seasonal hydrographic cruises (April and September 1982; Table 1-1) provided data that were synthesized with Year One and Year 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 allowed meaningful interpretations to be placed on nutrient and other physio-chemical

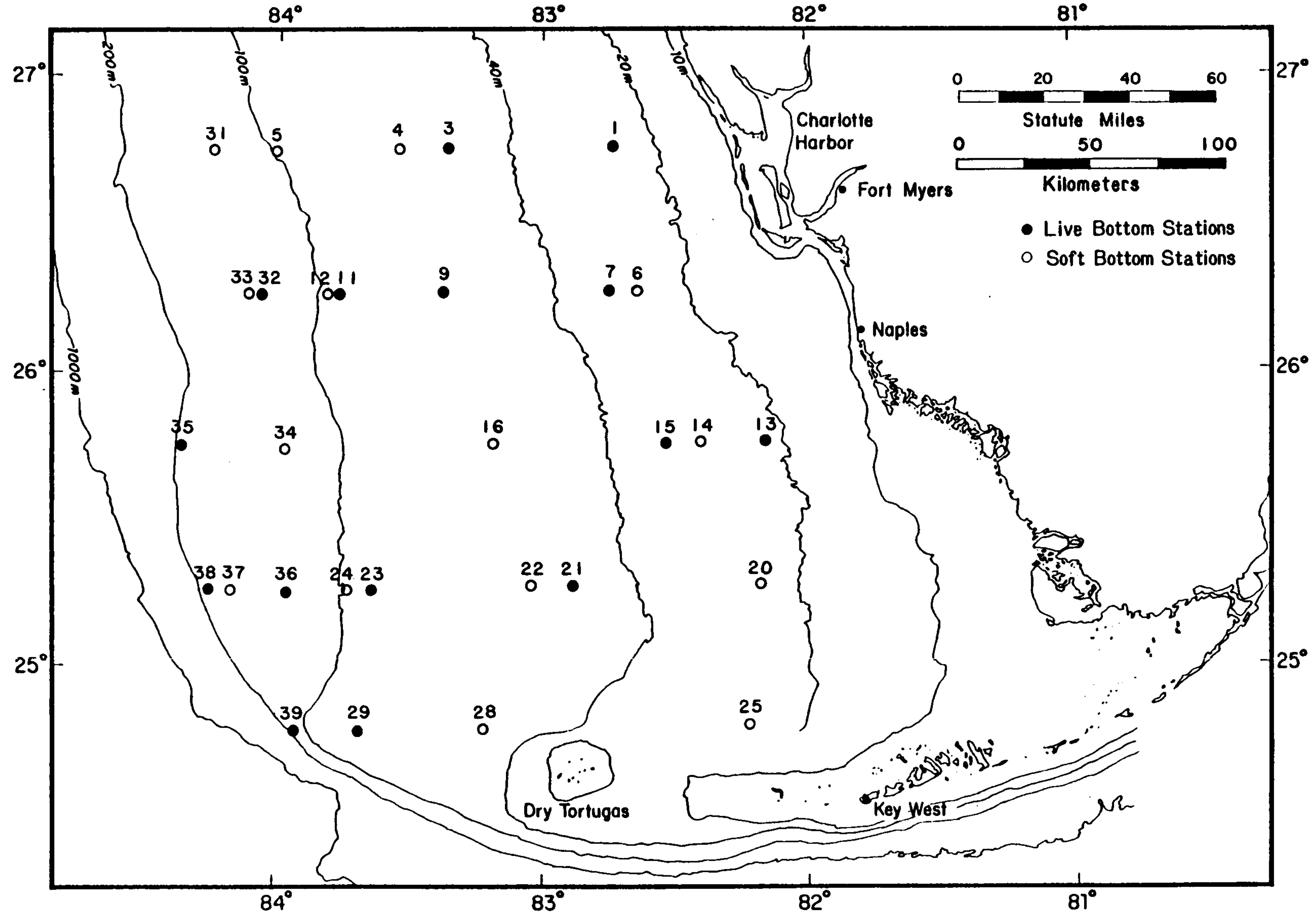

Figure 1-3. Year Two sampling station locations for biological and hydrographic studies.

data. A simultaneous overflight by the NASA Ocean Color Scanner during the April Cruise allowed 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 allowed reduction of the Color Scanner data, and yielded 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 Modification Contract was to snythesize 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 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 were 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 been completely resolved, but most are addressed in this Year Two Final Report. Interruption of the Fall Cruise (1980) by a hurricane and BLM's rescheduling of Cruise IV from January to April-May 1981 slowed Year One 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 during both Years One and Two.

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 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 as high, medium, or low relief on the seafloor, 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 MMS 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 context 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 40m water depths
Middle Shelf:	40 to 100m water depths
Outer Shelf:	100 to 200m water depths

These designations were originally established to reflect differences between the Year One and Year Two contract scope, as well as preliminary geophysical interpretations.

Year One geophysical surveys were conducted across the shelf in 40 to 200m water depths as contracted, while visual data and hydrographic and biological samples were to be collected from 20 to 100m water depths. (In fact, Woodward-Clyde was able to "bootleg" some additional geophysical data from 20 to 40m water depths concurrently with the visuals observations during the Year One Television Cruise.) The Year Two contract extended the visuals data, hydrographic and biological sampling out to 200m water depths. This difference in the timing and availability of various data sets during Year One 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 were worked up, the division of the shelf was supported by more objective criteria. The benthic biological data were found to support the threefold subdivision of the shelf in a general manner; however, exceptions to the arbitrary depth limits are evident.

1.5 BASE MAPS AND LEASE BLOCKS

To facilitate comparisons among different data sets, many of the study results have been presented visually in this report on standard lease area base maps. The base map used for the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983b) was 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. Several Year One Final Report figures reproduced here in Section 2.0 (Shelf Characterization) use this earlier base map. The remaining Year Two figures utilize a slightly enlarged base map allowing data points to be located more clearly and accurately.

The southwest Florida shelf study region is shown in Figure 1-4, superimposed with the MMS lease block grid. This grid system divided 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, 4,828m 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

The most recent annual Gulf of Mexico Summary Report summarizes the prior leasing history of the southwest Florida shelf and presents a wide range of current information on OCS oil and gas activities throughout the Gulf of Mexico Region (OCS Oil and Gas Information Program, MMS, 1984; see earlier editions in the series also).

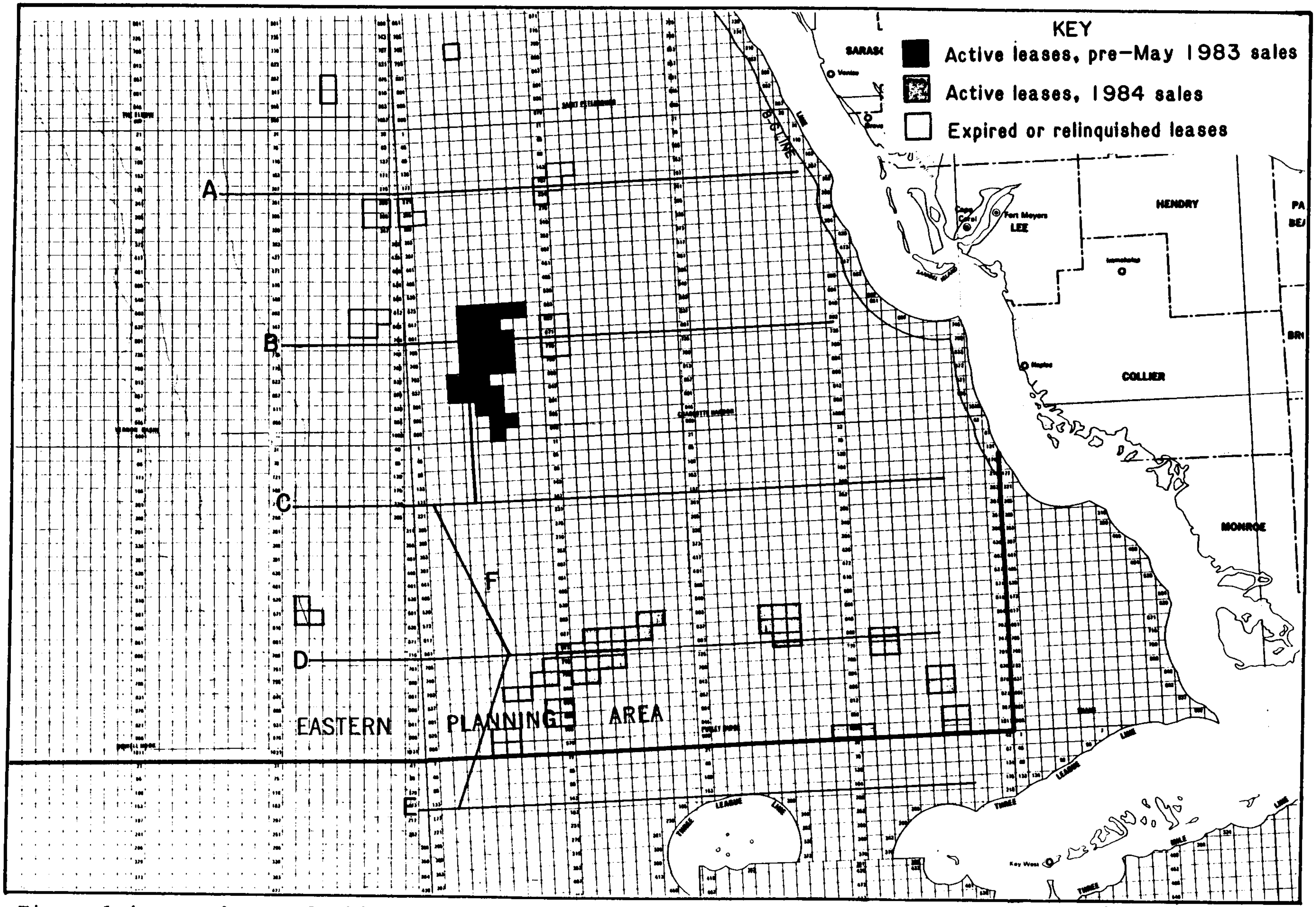

Figure 1-4. Southwest Florida shelf OCS oil and gas lease tracts and Year One and Two Study transects (A-F ; after MMS, 1984).

All of Florida's west coast submerged territory was at one point under lease. Only three leases presently remain active (East Bay - Getty/Exxon; Apalachicola to Naples, offshore - Coastal Petroleum Company) however, all other rights having reverted back to the State. A total of 19 exploratory wells have been spudded in Florida State waters, but there has been no production.

Several federal OCS oil and gas lease sales were conducted for tracts within the Eastern Gulf of Mexico Planning Area prior to the initiation of "areawide" sales in May 1983. These included Lease Sales 5 (1959), 32 (1973), 41 (1976), 65 (1978), 66 (1981), 67 (1982), and 69-Part II (1983). The first federal areawide sale for the Eastern Gulf of Mexico Planning Area, Lease Sale 79, was conducted in January 1984. Sale 79 attracted more interest than anticipated, with industry attention focused on the Pulley Ridge and Destin Dome leasing areas (MMS, 1984). The current 5-year offshore leasing schedule, extending through June 1987, calls for a second Eastern Planning Area Sale (Sale 94) in November 1985.

Figure 1-4 indicates the locations of three categories of federal OCS leases within and adjacent to the southwest Florida shelf study area: (1) active leases from pre-May 1983 lease sales; (2) active leases from 1984 lease sales; (3) expired or relinquished leases (MMS, 1984, Visual No. 1).

1.8 SOUTHWEST FLORIDA SHELF STUDY REPORTS PREVIOUSLY SUBMITTED TO BLM/MMS

This Year Two Final Report is the last publication to be formally submitted to the MMS under the terms of Woodward-Clyde Consultants' Year One, Year Two, and Year Two Modification study contracts. Some sixteen (16) publications describing various aspects of these three contract studies have been submitted previously. Each of these earlier reports is fully referenced below. They are listed in chronological sequence, according to their publication dates.

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 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.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1981. Southwest Florida shelf ecosystems study - Year 2. Summary cruise report. Cruise II - Bilogical and hydrographic sampling. Prepared for Bureau of Land Management (9-17-1981). 74 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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*Publication date.

Woodward-Clyde Consultants and Continental Shelf Associates, Inc. 1982. Southwest Florida shelf ecosystems study - Year 2 Modification. Summary cruise report. Cruise III - Biological and hydrographic sampling. Prepared for Bureau of Land Management (4-6-1982). 61 pp.

Woodward-Clyde Consultants and Skidaway Institute of Oceanography. 1982. Southwest Florida shelf ecosystems study - Year 2 Modification. Summary cruise report. Cruise I - Hydrography and primary production. Prepared for Bureau of Land Management (5-25-1982). 42 pp.

Woodward-Clyde Consultants. 1982. Gulf of Mexico studies meeting, May 12-13, 1982, Mobile, Alabama. Proceedings. Prepared for Minerals Management Service (6-25-1982). 85 pp.

Woodward-Clyde Consultants and Skidaway Institute of Oceanography. 1982. Southwest Florida shelf ecosystems study - Year 2 Modification. Summary cruise report. Cruise II - Hydrography and primary production. Prepared for Minerals Management Service (10-21-82). 33 pp.

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2.0 SHELF CHARACTERIZATION

2.1 INTRODUCTION

One of the primary objectives of the Southwest Florida Shelf Ecosystems Study Program has been to broadly classify bottom substrates and benthic biological communities across the southwest Florida shelf. This regional characterization was conducted over a two-year period. Five east-west transects (A through E) and one north-south transect (F) were surveyed, covering the shelf area from Charlotte Harbor in the north, to the Dry Tortugas in the south (Figure 2-1). Each transect was studied using high-resolution, multisystem geophysical surveys and underwater television and still camera "ground-truth" surveys. Detailed information on the field programs, equipment, procedures, and data collected has previously been reported (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a,b).

The Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983b) provides complete discussions of the Marine Geological Investigations (Section 2.0), Underwater Television and Still Camera Observations (Section 3.0), and the Integration of the Geophysical and Ground-truth Data Sets (Section 4.0). The reader is particularly directed to these earlier discussions for a review of the relative strengths and shortcomings of geophysical "remote sensing" versus underwater television and still-camera "ground-truth" benthic survey methodologies.

To provide additional background for this Year Two Final Report, some of the figures from Section 2.0 of the Year One Final Report have been reincluded here. Figure 2-2 shows the generalized distribution of side scan sonar patterns recorded along the various study transects. Figure 2-3 indicates the occurrence of major sea floor topographic features, and Figure 2-4 shows the distribution of buried geologic features such as buried channels, collapse features, and shallow faulting.

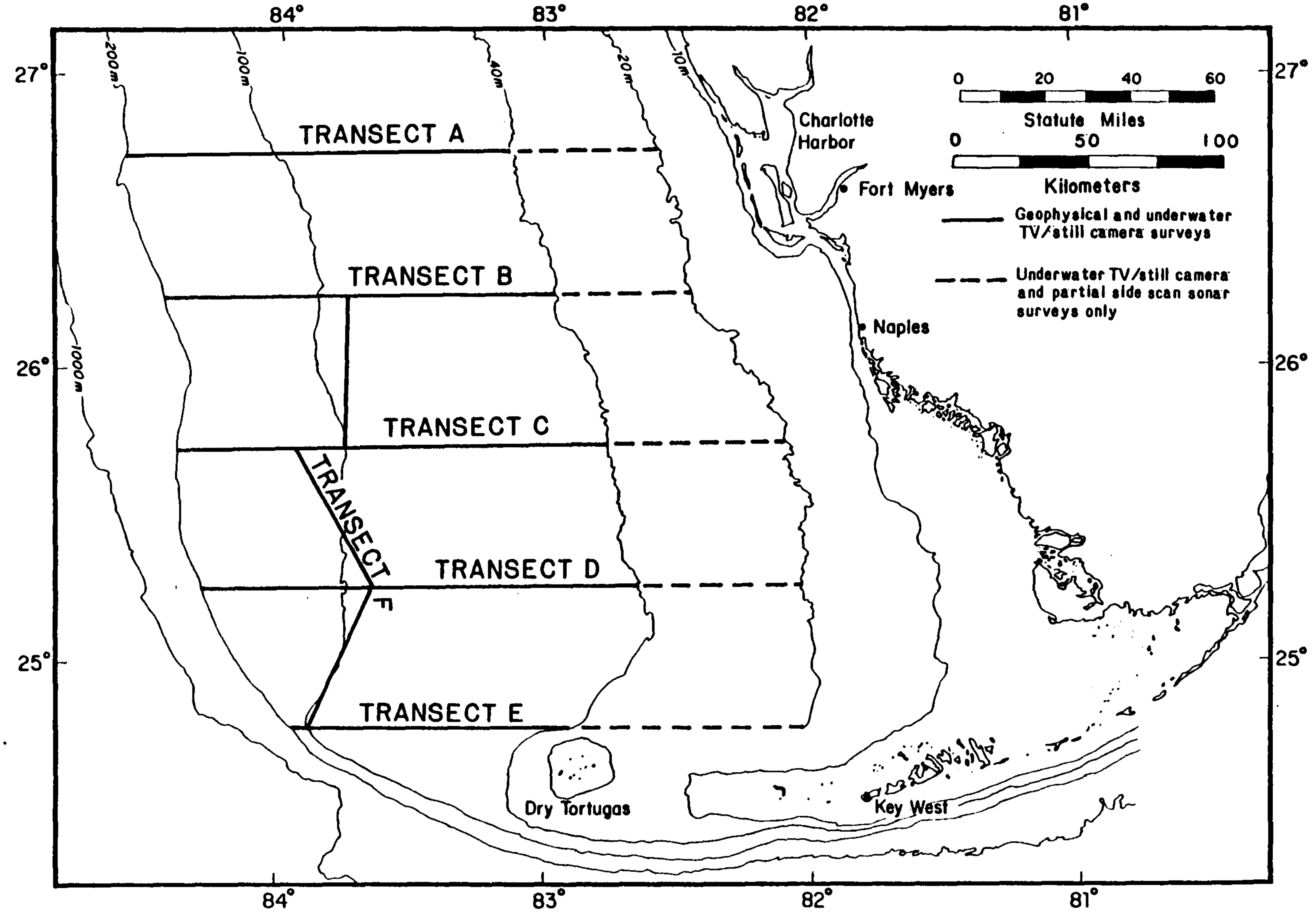

Figure 2-1. Southwest Florida survey transects.

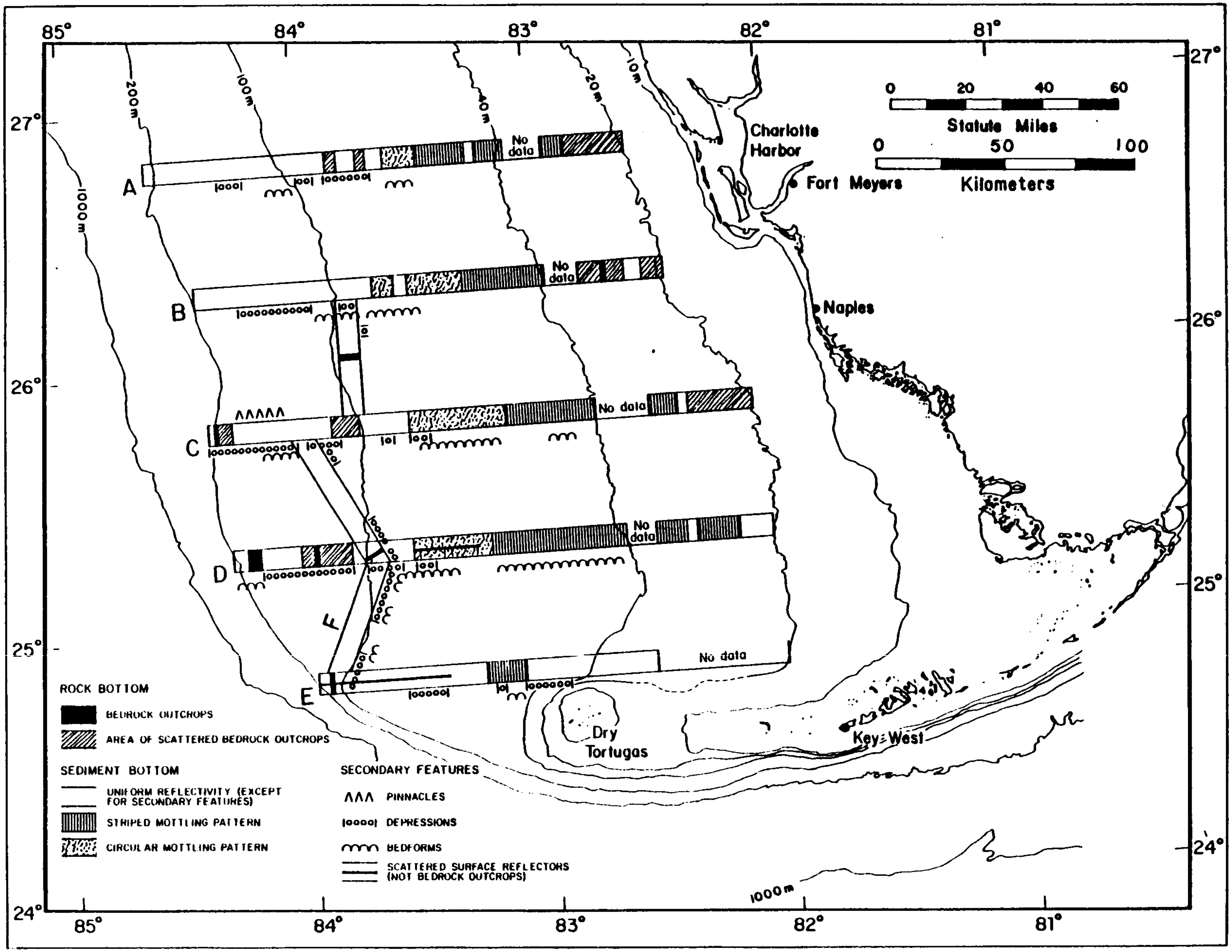

Figure 2-2. Generalized distribution of side scan sonar patterns.

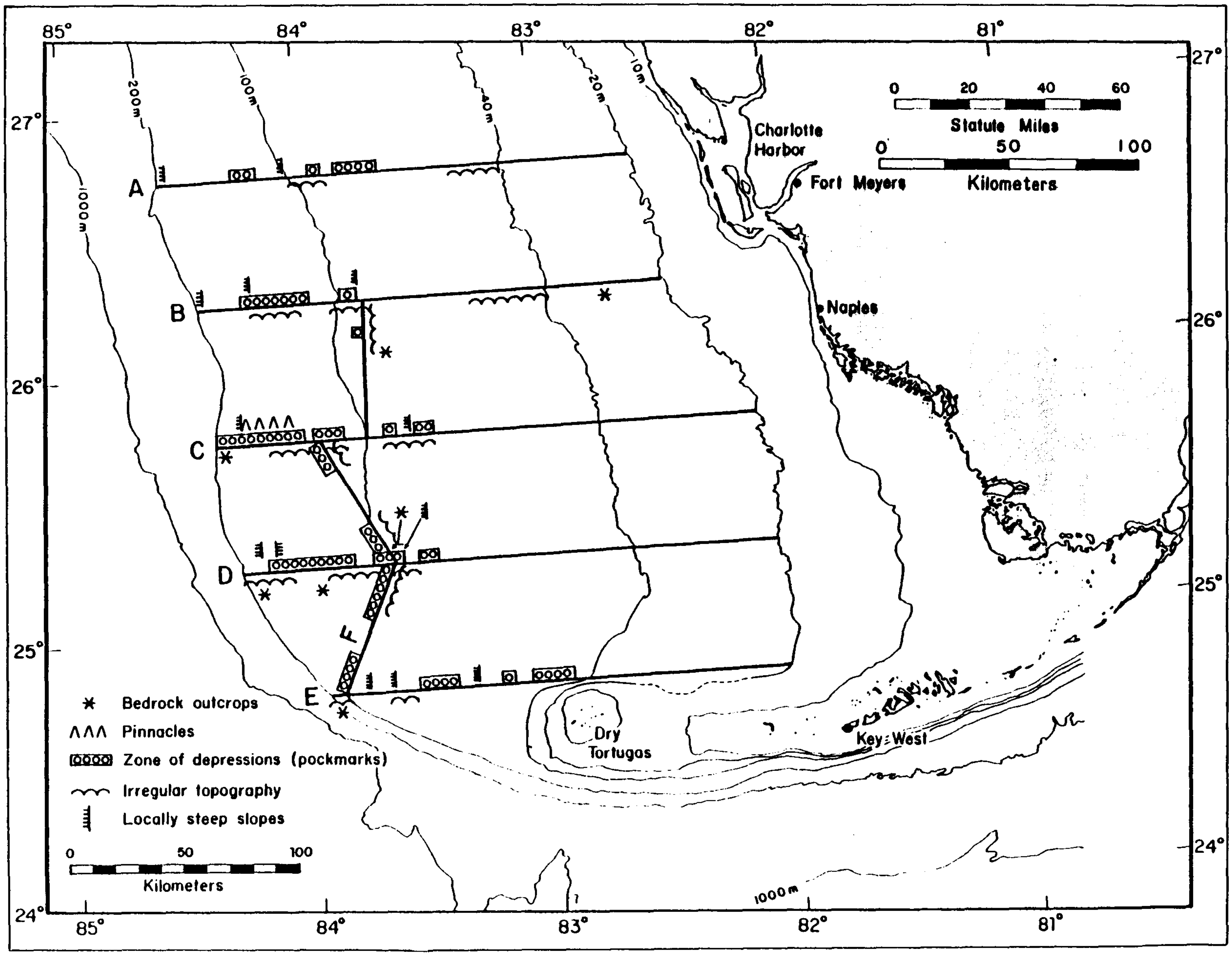

Figure 2-3. Sea floor topographic features (generalized from Marine Habitat Atlas).

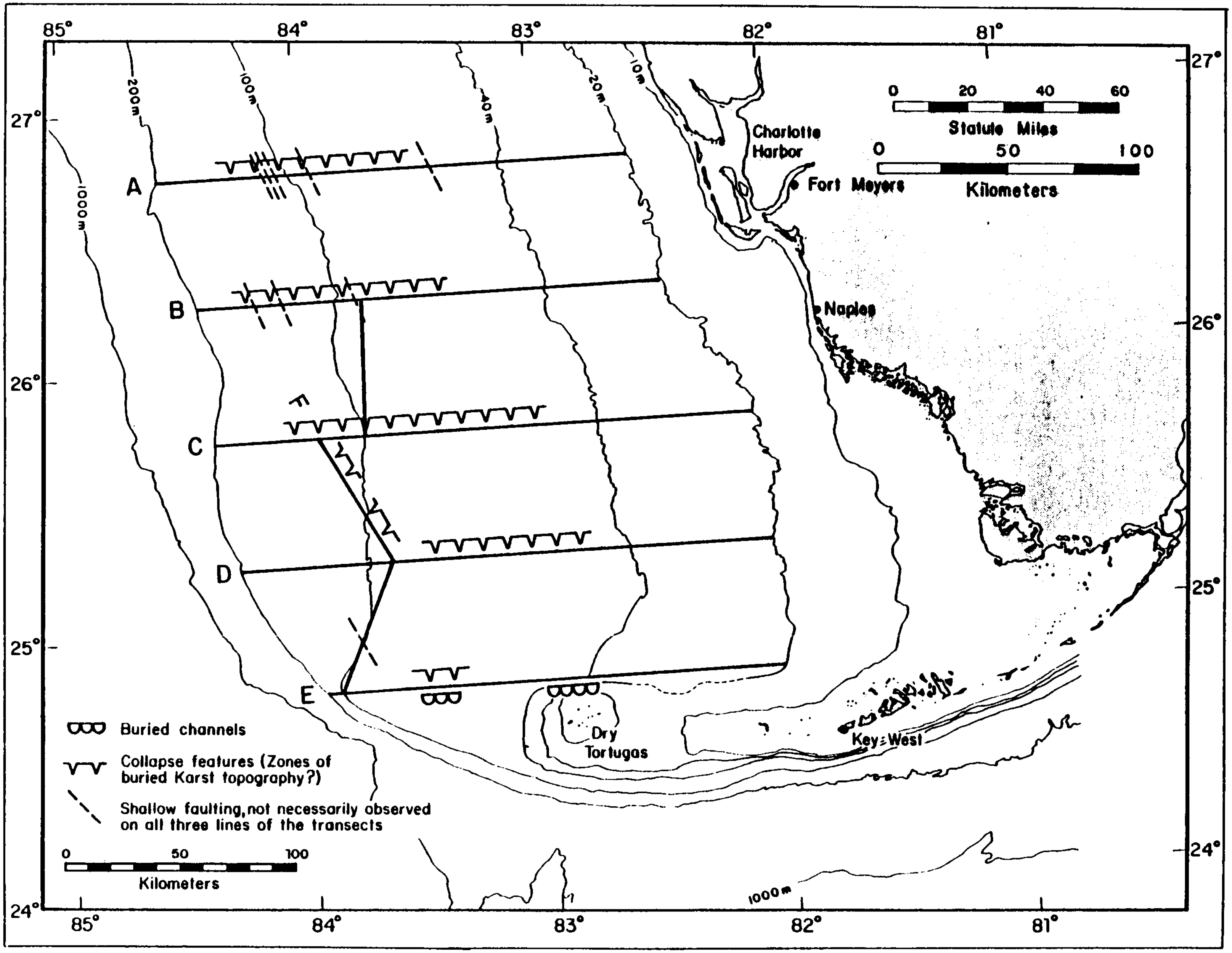

Figure 2-4. Buried geologic features (generalized from Marine Habitat Atlas).

Two geophysical cruises (Year One - Cruise I, September-October 1980, Transects A through E; and Year Two - Cruise I, July 1981, Transect F) yielded over 2,438km of side scan sonar records, subbottom profiles, and bathymetric data. Subsequent underwater television observations and still camera photographs (Year One - Cruise II, October 1980, Transects A through E; and Year Two - Cruise I, July 1981, Transect F) were used to "ground-truth" the substrate types identified by the geophysical remote sensing observations. The television and still camera were also used to collect reconnaissance level 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.

2.2 THE MARINE HABITAT ATLAS

An integrated interpretation of the geophysical and ground-truth data has already been presented in the form of a Marine Habitat Atlas (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a).

The Atlas is presented in two volumes. Volume One contains an index map and summary maps at a scale of 1:500,000, together with detailed maps and cross-sections of each survey transect at a scale of 1:48,000. Volume Two discusses the field surveys, data analyses, and mapping procedures. It also includes more complete descriptions of the bottom substrate types, biological assemblages, and shallow geologic features than could be presented in the legend for the Atlas maps.

The 1:48,000 scale maps are presented on a series of 43 sheets, as shown in Figure 2-5. 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. Figures 2-6 and 2-7, each greatly reduced from the Marine Habitat Atlas, provide examples of the 1:48,000 map series. Each Atlas 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 indicates the marine habitat including bathymetry, substrate type, biological

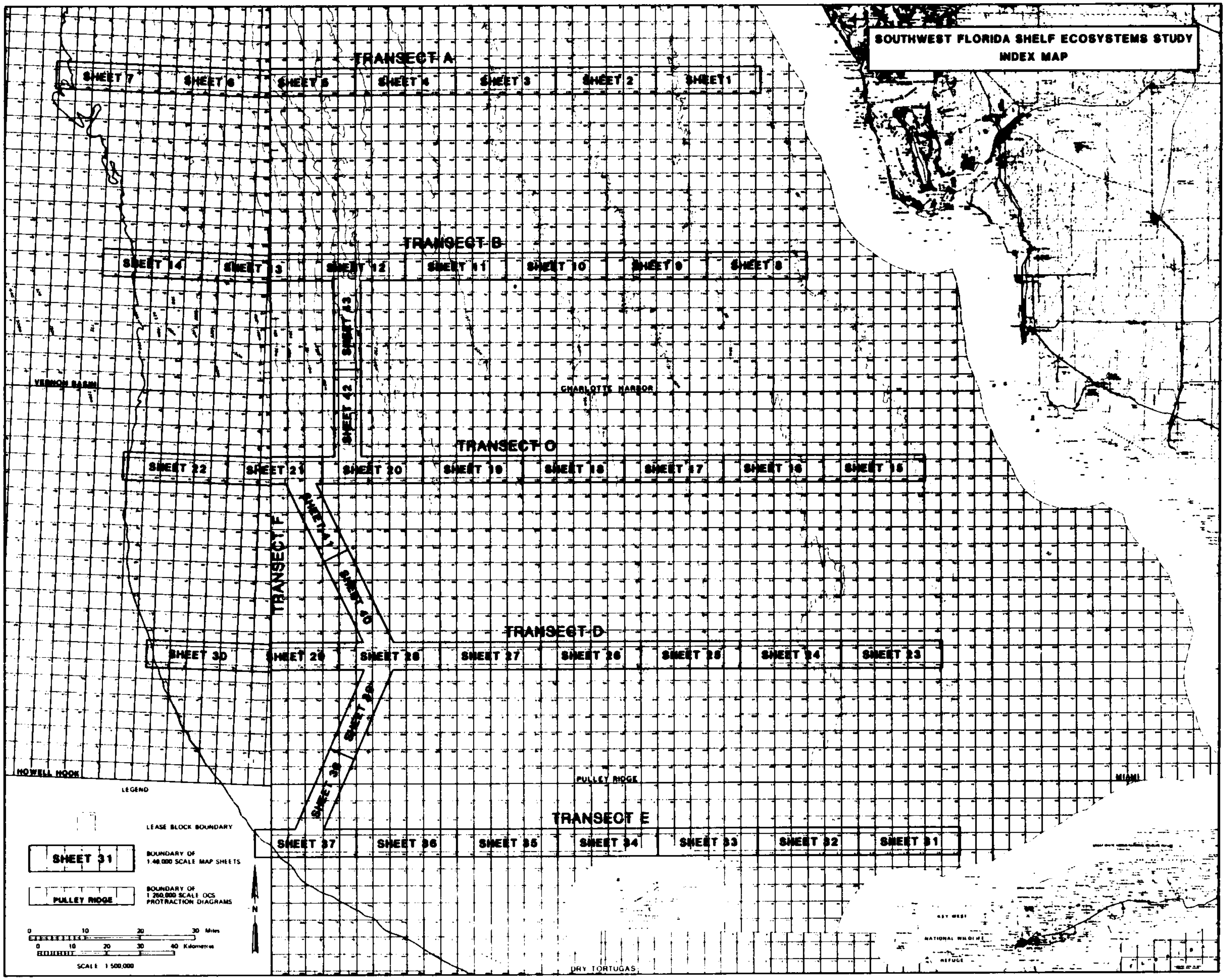

Figure 2-5. Marine Habitat Atlas, Index Map (greatly reduced).

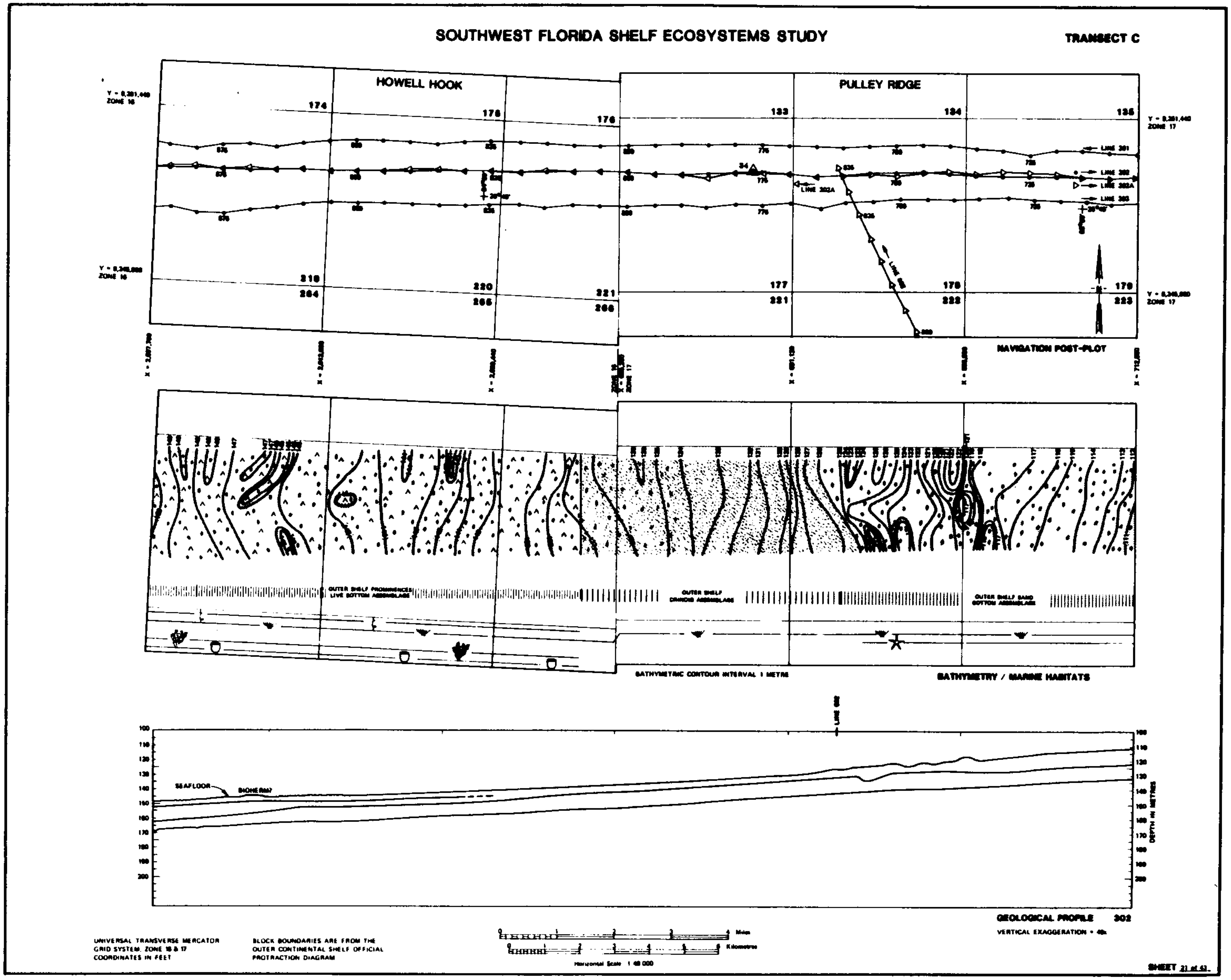

Figure 2-6. Marine Habitat Atlas, Transect C Sheet 21 (greatly reduced).

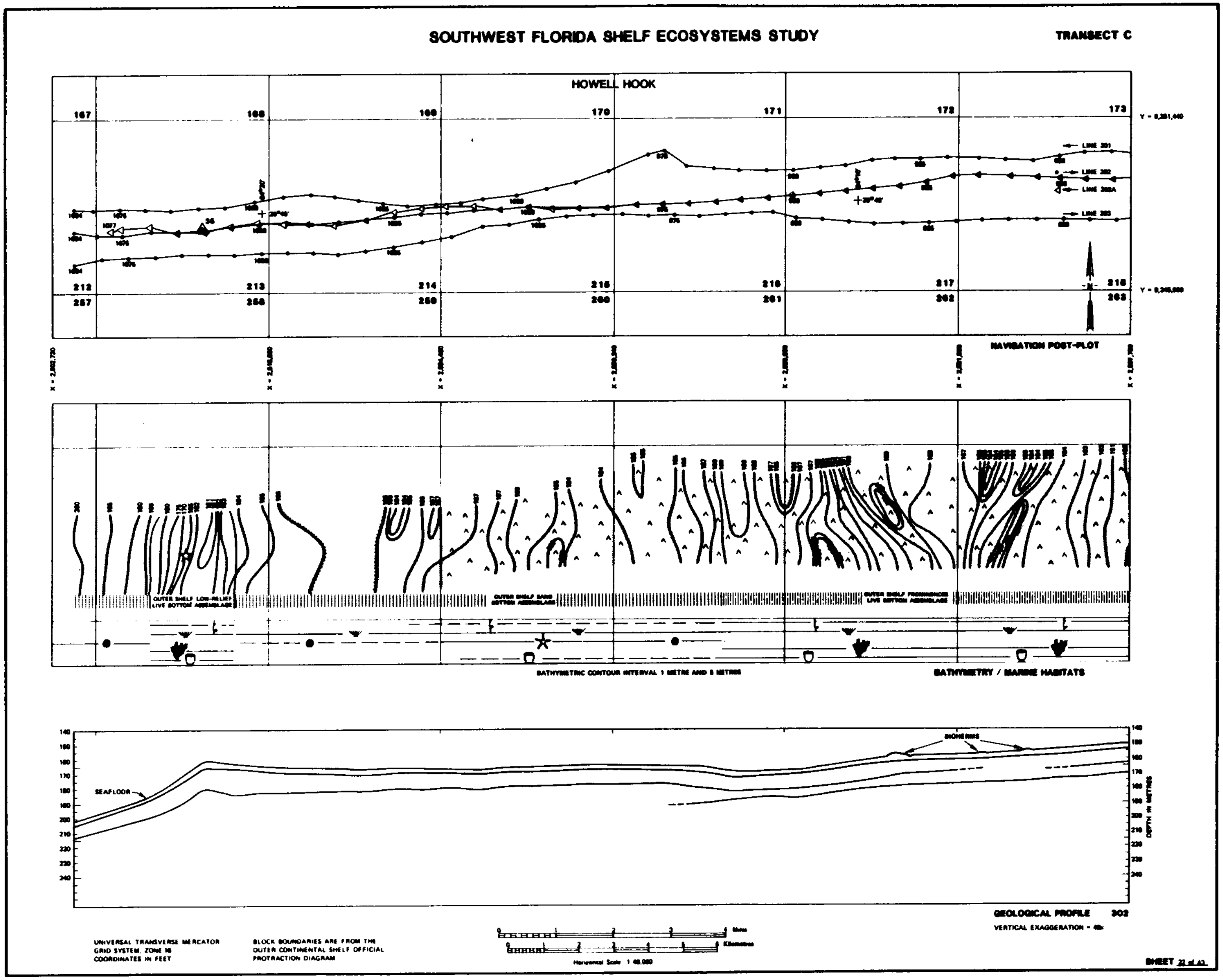

Figure 2-7. Marine Habitat Atlas, Transect C Sheet 22 (greatly reduced).

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.

The bottom substrate and biological assemblage information plotted on the 1:48,000 scale maps was carefully reviewed and reduced to create two marine habitat summary maps (reproduced here as Figures 2-8 and 2-9). This scale change resulted in some details from the 1:48,000 series being omitted from the reduced summary maps. It must also be noted that the 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. Figure 2-8 and 2-9 are valuable in that they show the general relationships among bathymetry, substrate, and biological assemblages across the southwest Florida shelf study area.

2.3 SUBSTRATES

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 the 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 ecosystems.

2.3.1 Substrate Categories

Five categories of substrate were defined and mapped during the Year One and Year Two investigations (Figures 2-8 and 2-9). Figure 2-10 illustrates the classification system used and the general relationships among the five substrate categories. The principal characteristics of each substrate type are summarized below.

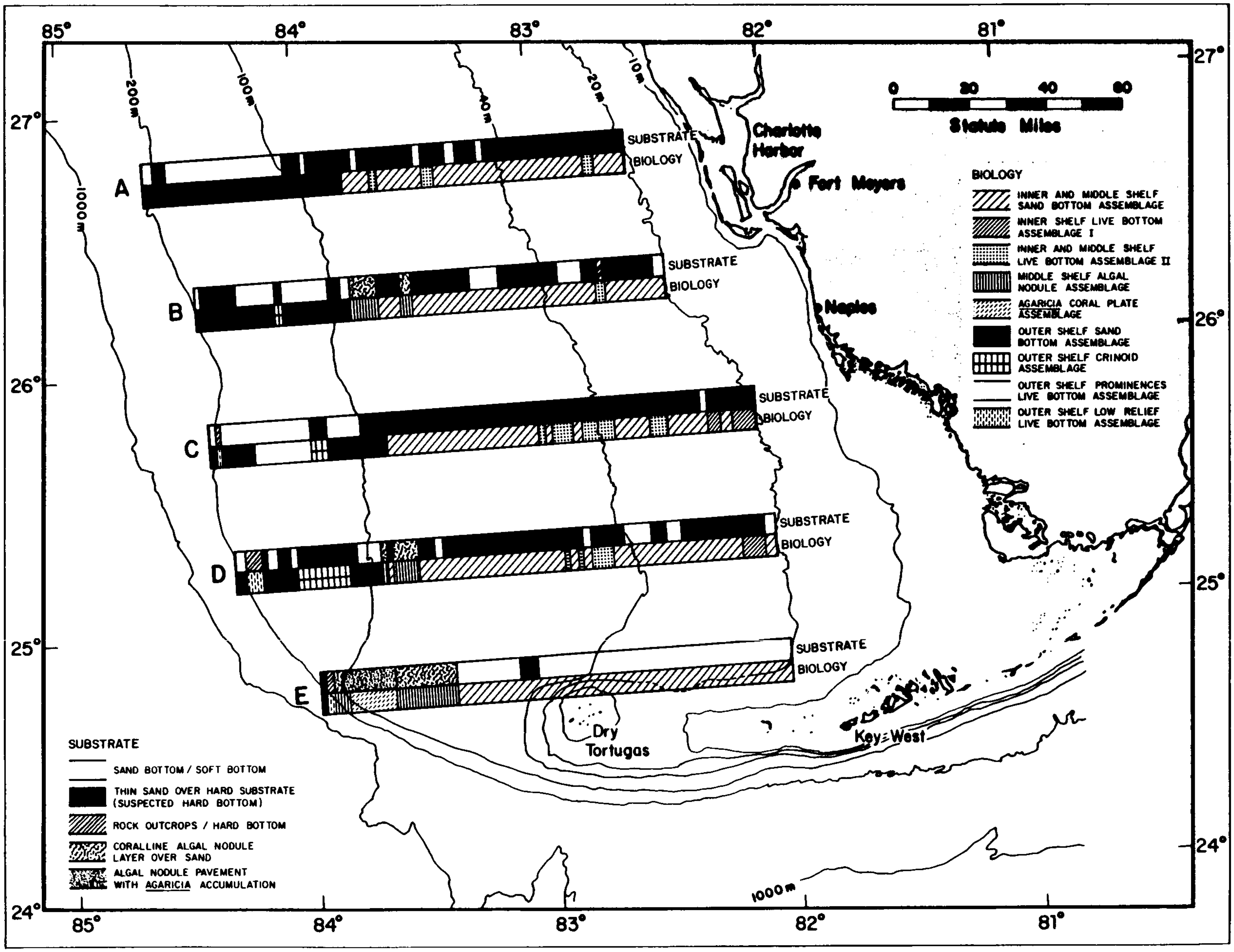

Figure 2-8. Generalized map of marine habitats along Transects A through E.

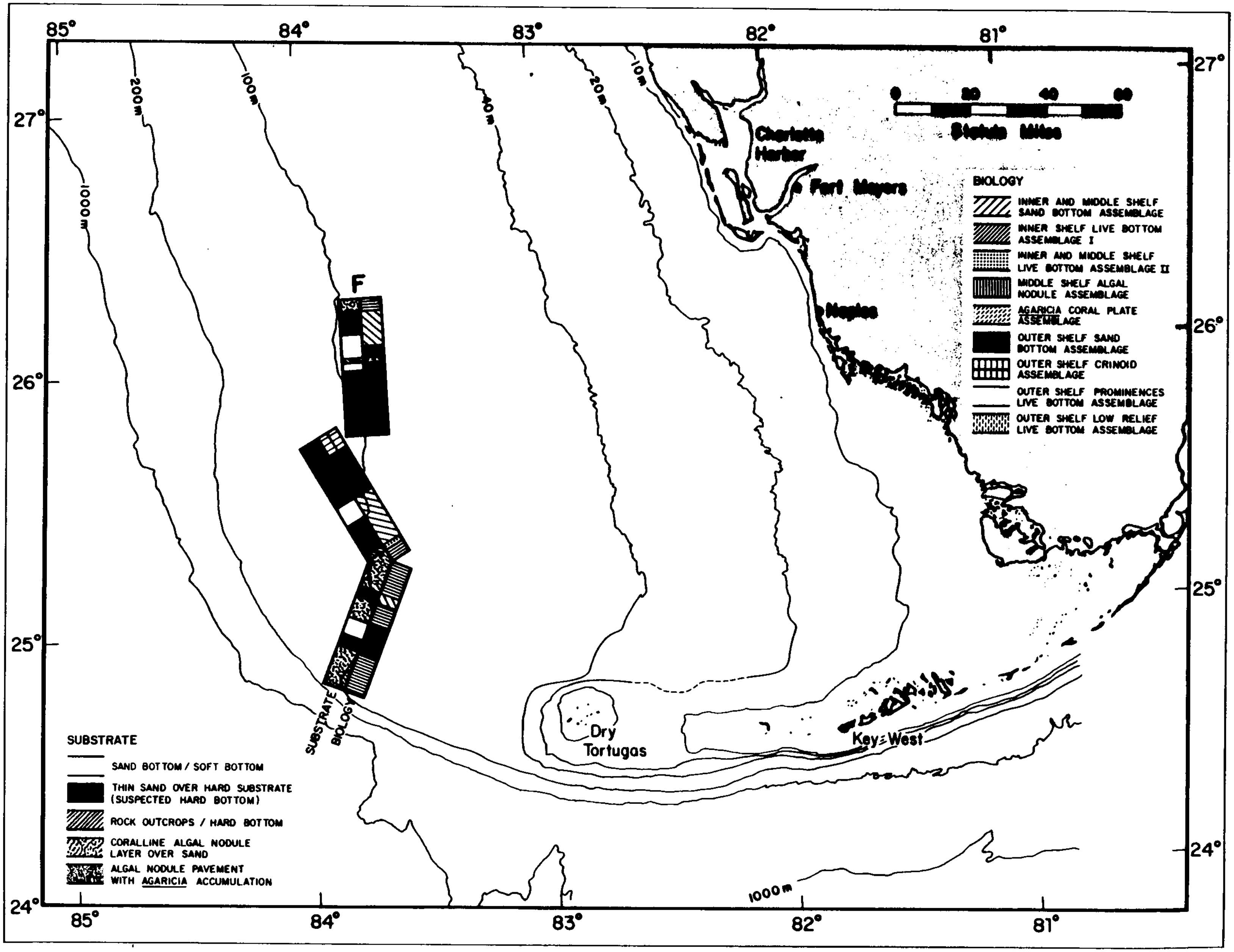

Figure 2-9. Generalized map of marine habitats along Transect F.

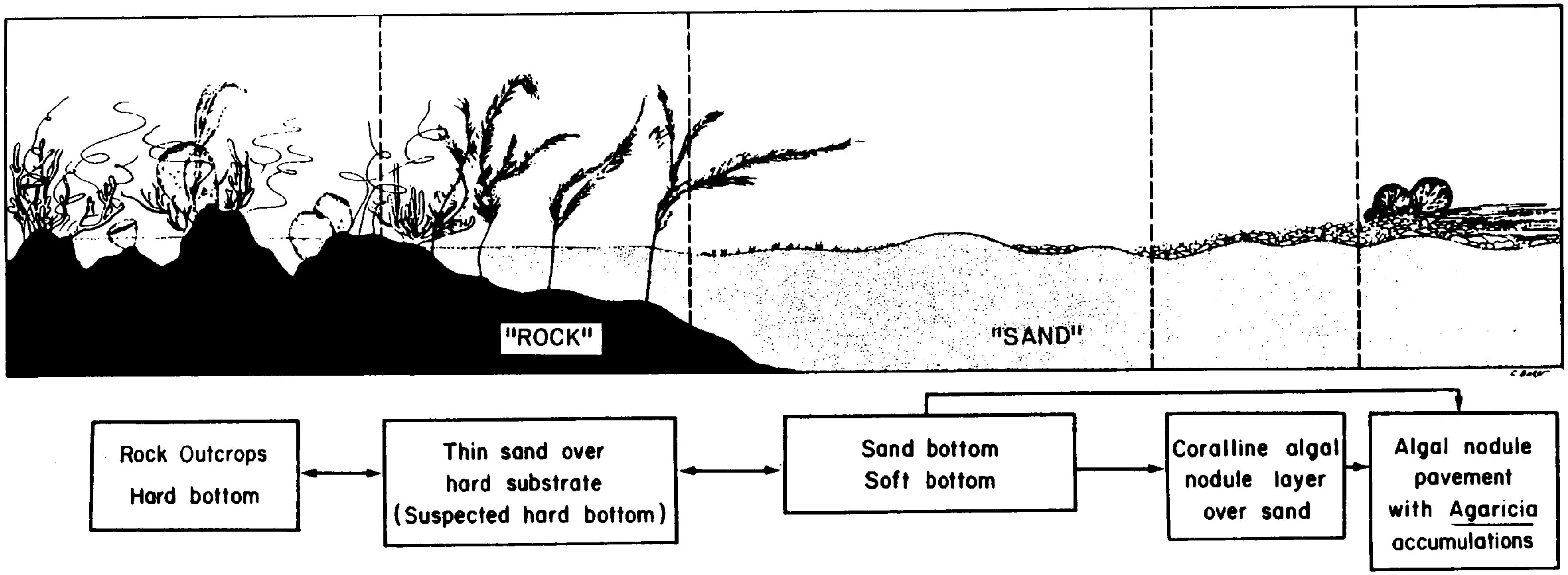

Figure 2-10. Generalized classification scheme for sea floor substrate types.

2.3.1.1 Rock Outcrops/Hard Bottom

This substrate included hard bottoms in the form of emergent rock outcrops, rocky ledges, or exposed low-relief (<1m) rock areas. Also included in this category were areas where bioherms provided the substrate for the live bottom communities. These outcrop areas were readily recognized on the underwater television and side scan sonar records and confirmed from 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 300m (two navigation fix points) or generally covered with a thin layer of sand, they were mapped as the Thin Sand over Hard Substrate category.

Typically this substrate was covered with distinctive indicator epibiotas. The following biological assemblages were found 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 Section 2.4.)

2.3.1.2 Thin Sand over Hard Substrate

This bottom type was transitional between the rock outcrops and sand bottom areas. It was very common throughout the southwest Florida shelf (Figures 2-8 and 2-9) and in most areas represents a thin veneer of sand covering a bedrock substrate. However, the term "hard substrate" is not necessarily synonyomous with bedrock and may reflect a thin calcrete layer or a calcareous rubble layer overlying softer sediment.

Side scan sonar records taken over this substrate generally indicate a mottled pattern. 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 (150m), 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.

The presence of key biological organisms was used to differentiate this substrate from the sand bottom substrate. Large gorgonians and sponges, for example, attach to and are indicative of stable hard bottoms, and can survive partial inundation by the shifting sand veneer. The Inner Shelf Live Bottom Assemblage I and the Inner and Middle Shelf Live Bottom Assemblage II were found associated with this bottom type.

2.3.1.3 Sand Bottom/Soft Bottom

The sand bottom category included thick sand, silt, or mud bottoms that primarily support soft bottom communities. Several morphological forms were 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 were variable and often transitional, ranging 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 were both associated with this bottom type.

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 0.5m, the character of the subbottom profile records.

2.3.1.4 Coralline Algal Nodule Layer over Sand

This bottom type consisted of soft bottom areas that were covered by varying thicknesses of coralline algal growths, usually in the form of loose nodules. The nodules were a few centimetres in diameter and were found over extensive areas on Transects B, D, and E. The substrate was encountered in deeper water (greater than 60m) and its presence was reflected in the occurrence of the Middle Shelf Algal Nodule Assemblage.

The typical long-range (150m) side scan sonar records obtained during Year One Cruise I were not diagnostic for this substrate and appeared similar to the records obtained over an open sand bottom. A few short-range (35m) records obtained during Year Two 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.

2.3.1.5 Algal Nodule Pavement with Agaricia Accumulations

This bottom type was 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 was covered with living coralline algae and extensive growths of the coral *Agaricia* spp. The *Agaricia* Coral Plate Assemblage was associated with this bottom type.

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 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.

2.3.2 General Distribution of Substrate Types

An analysis of the substrate data shows that approximately 50-percent of the southwest Florida shelf seafloor that was videotaped and photographed along Transects A through F was Sand Bottom/Soft Bottom substrate (Figures 2-8 and 2-9). This bottom type occurred in all water depths studied (20 to 200m) and was observed on all transects.

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 20m water depths on Transects C* and D,* at approximately 75 to 80m water depths on Transect B,* and scattered across the 100 to 185m 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 108m. Algal Nodule Pavement with *Agaricia* Accumulations was found only on Transect E in 64 to 80m water depths (Figure 2-8).

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 2-10. 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 70m depths). 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 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 suggest may be an unconsolidated sediment soft bottom.

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* Outcrop areas too small to show up in Figures 2-8 and 2-9.

Geophysical survey techniques (e.g., subbottom profiles, side scan sonar) 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. 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.

2.4 BIOLOGICAL ASSEMBLAGES

Nine major biological assemblages were distinguished during the television and still camera observations (Figures 2-8 and 2-9). It should be noted, however, that many generic and species level identifications from television footage were made possible only by knowledge obtained from dredge and trawl collections. 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 square meter; live bottom assemblages had much higher macroepifaunal densities. Live bottom algal nodule assemblages were defined for areas with greater than 10-percent 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" -- particular sets 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 for "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.

2.4.1 Descriptions of Assemblages

2.4.1.1 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 consisted 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 Lytechinus spp.), holothuroids, sea pens, and sponges (Geodia gibberosa and 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 90m. 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 2-8 and 2-9).

2.4.1.2 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 spp., Pseudoplexaura spp., and Pseudopterogorgia spp.), hydrozoans, and sponges (Geodia gibberosa, Geodia neptuni, Haliclona spp., Ircinia campana, and Spheciospongia vesparium). 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 27m.

2.4.1.3 Inner and Middle Shelf Live Bottom Assemblage II

This live bottom biological assemblage consisted of algae (Cystodictyon pavonium, Halimeda spp. and Udotea spp.), ascidians (Clavelina gigantea), bryozoans (Celleporaria spp. and Stylopoma spongites), hard corals (Cladocora arbuscula, Scolymia lacera, Siderastrea spp., and Solenastrea hyades), small gorgonians, hydrozoans, and several sponges (Cinachyra alloclada, Geodia gibberosa, Geodia neptuni, Ircinia spp., Placospongia melobesioides, and Spheciospongia vesparium). 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 75m.

2.4.1.4 Middle Shelf Algal Nodule Assemblage

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

2.4.1.5 Agaricia Coral Plate Assemblage

This biotal assemblage consisted of a 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 81m (Figure 2-8, Transect E).

2.4.1.6 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 200m (Figures 2-8 and 2-9).

2.4.1.7 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 168m.

2.4.1.8 Outer Shelf Low-Relief Live Bottom Assemblage

This live bottom biological assemblage consisted of various octocorals (including *Nicella guadalupensis*), the antipatharian corals *Antipathes* spp., *Aphanipathes abietina*, *A. filix*, and *A. humilis*, occasional hard corals (including *Madrepora carolina*), crinoids, the hydrozoan *Stylaster* sp., and small sponges in the order Dictyonina. It was identified from low-relief rock surfaces with a thin sand veneer. Characteristically, this type of assemblage was identified in water depths of 125 to 185m on Transects C and D and from 108 to 198m water depths on Transect E (Figure 2-8).

2.4.1.9 Outer Shelf Prominences Live Bottom Assemblage

This biological assemblage consisted of the gorgonian *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 emerged from a sand-covered bottom and had a vertical relief of up to two metres. Geophysical and photographic evidence subsequently indicated that these prominences are dead coral pinnacles -- remnants of old, shallow, buried reefs (cf. Ludwick and Walton, 1957). The Outer Shelf Prominences assemblage extended from water depths of 136 to 169m on Transect C (Figure 2-8).

2.4.2 General Distribution of Biological Assemblages

2.4.2.1 Distribution by Depth Across the Southwest Florida Shelf

An across-shelf analysis of the biological assemblages described above 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 sediment grain size, availability of suitable substrate, and hydrographic regime, are probably more important; however, data on these parameters could not be 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 epibenthic 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 Project Hourglass (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.

Three major biological depth zones were readily distinguishable from a summary of the television/still camera survey data (Table 2-1): a 20 to 60m zone, a 60 to 90m zone, and a 90 to 200m zone.

Table 2-1. Percent coverage of biological assemblages along combined transects (A through F) in 10-metre depth increments.

Biological Assemblages	1 Metre Depth Intervals Along Transects																	
	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	8.8	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

The 20 to 60m 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 90m 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 200m water depth zone. The 60 to 90m 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 110m water depth on Transect E.

The 90 to 200m 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.

2.4.2.2 Comparison of Biological Assemblage Distributions Among 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 to be expected. These latitudinal differences are augmented by the various geological and substrate differences observed between transects. Table 2-2 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 Shelf Live Bottom Assemblage II occurred scattered along the transect from 25m to approximately 65m water depths, with no significant live bottom assemblages found deeper than 65m.

Table 2-2. 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

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 60m water depths. The Outer Shelf Prominences Live Bottom Assemblage was restricted to Transect C, located in the 135 to 165m 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 81m 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 200m. 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 2-9).

3.0 SAMPLING, METHODS, AND DATA ANALYSIS

3.1 INTRODUCTION

The purpose of the field sampling and data collection phase of the program was to characterize both the water column and benthic environments at specific locations along the six previously surveyed study transects (Figure 2-1). 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, methods, and statistical analyses used in these assessments at selected live and soft bottom stations.

3.2 SAMPLING DESIGN

3.2.1 Sampling Stations

Fifteen live bottom and 15 soft bottom stations were sampled during the Fall (1980) and Spring (1981) Cruises of the Year One Contract and during the Summer (1981) and Winter (1982) Cruises of the Year Two Contract. The Year One and Year Two stations differed, with only 21 common sites being sampled during both programs (Table 3-1). Station size remained identical both years, with each station consisting of a 1000m square block located around a selected station center point. All samples were collected from within these square blocks. Station selection rationale is discussed below.

3.2.1.1 Year One Stations

Following a review of the television videotapes from the October 1980 Year One underwater television and still camera photography cruise, 30 stations (15 soft bottom and 15 live bottom) were selected for water column and biological sampling (Figure 3-1).

Table 3-1. List of stations sampled during the Year One and Year Two programs.

			Year One		Year Two	
Transect-Station	Bottom	Depth Type	Fall (m) (1980)	Spring Cruise (1981)	Summer Cruise (1981)	Winter Cruise (1982)
A-1	Live	24	X	X	X	X
A-2	Soft	25	X	X		
A-3	Live	50	X	X	X	X
A-4	Soft	56	X	X	X	X
A-5	Soft	90	X	X	X	X
B-6	Soft	26	X	X	X	X
B-7	Live	30	X	X	X	X
B-8	Soft	48	X	X		
B-9	Live	56	X	X	X	X
B-10	Live	71	X	X		
B-11	Live	77	X	X	X	X
B-12	Soft	90	X	X	X	X
C-13	Live	20	X	X	X	X
C-14	Soft	26	X	X	X	X
C-15	Live	31	X	X	X	X
C-16	Soft	54	X	X	X	X
C-17	Live	59	X	X		
C-18	Soft	87	X	X		
D-19	Live	23	X	X		
D-20	Soft	22	X	X	X	X
D-21	Live	45	X	X	X	X
D-22	Soft	52	X	X	X	X
D-23	Live	70	X	X	X	X
D-24	Soft	88	X	X	X	X
E-25	Soft	24	X	X	X	X
E-26	Soft	38	X	X		
E-27	Live	54	X	X		
E-28	Soft	58	X	X	X	X
E-29	Live	60	X	X	X	X
E-30	Live	76	X	X		
A-31	Soft	142			X	X
B-32	Live	137			X	X
B-33	Soft	146			X	X
C-34	Soft	135			X	X
C-35	Live	159			X	X
D-36	Live	127			X	X
D-37	Soft	148			X	X
D-38	Live	159			X	X
E-39	Live	152			X	X

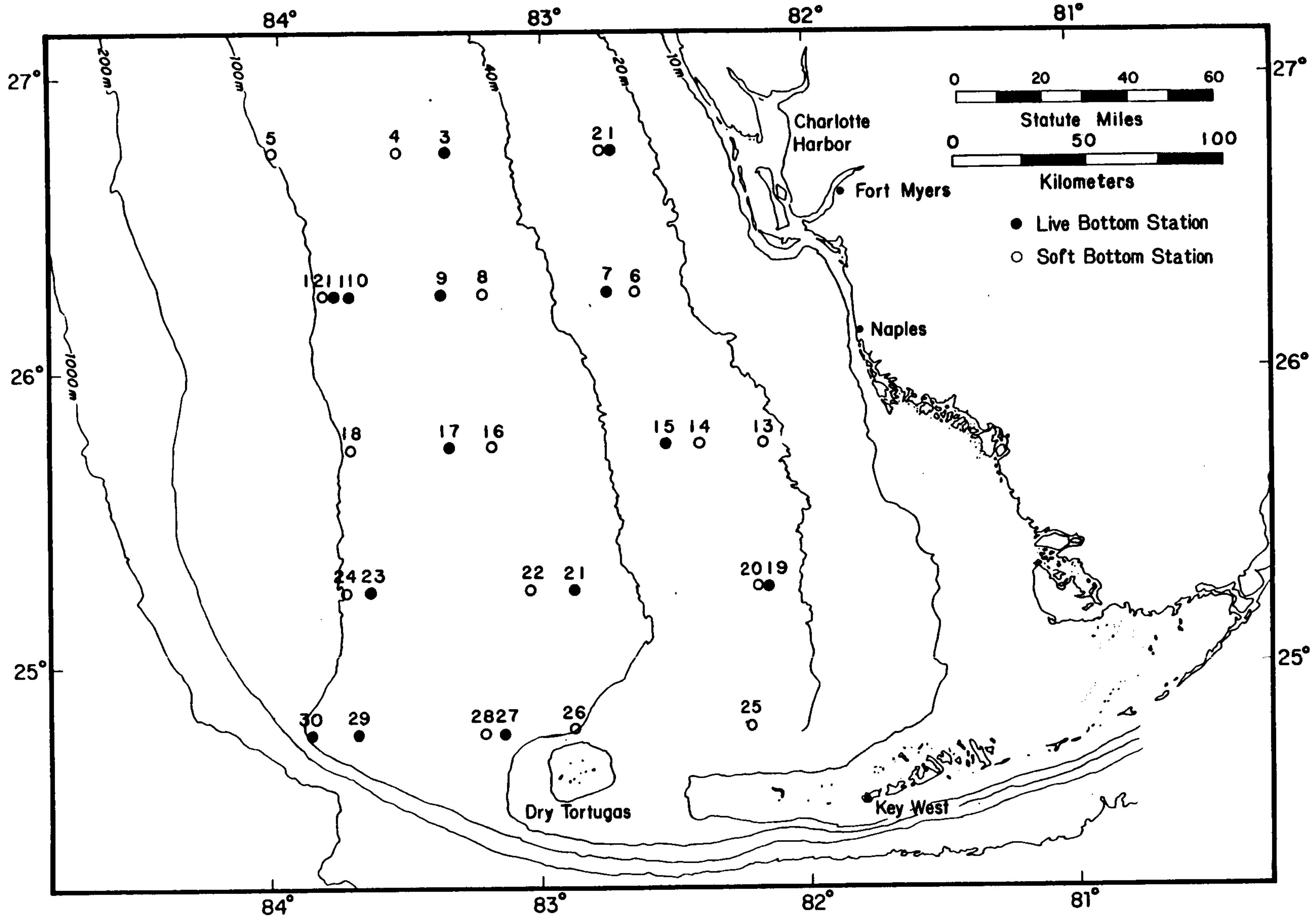

Figure 3-1. Year One sampling station locations.

Rationale for station selection was based on locations that appeared to typify broad areas of characteristic substrate types 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 100m) on each transect, a stipulation of the Minerals Management Service studies contract. This was possible on each transect except E, where no soft bottom area could be found within the 70 to 100m depth zone. A station was selected at 38m 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 70m water depths. An additional live bottom station was therefore added to Transect B in the 70 to 100m bathymetric zone. Also, on Transect E, no live bottom assemblage was observed shoreward of the 50m bathymetric contour; thus a station was selected within a live bottom area at a water depth of 62.5m.

3.2.1.2 Year Two Stations

Year Two sampling stations were selected immediately following the July 1981 combined geophysics and visual observations cruise (Year II, Cruise I). The Year Two stations included some previously sampled Year One stations and new deeper-water stations, selected in water depths of 100 to 200m (Table 3-1 and Figure 3-2).

The general criterion for selection of additional Year Two live bottom stations involved choosing sites that represented visually different and biologically significant live bottom assemblages. Five "new" live bottom areas on Transects B, C, D, and E met this criterion (i.e., Stations 32, 35, 36, 38, and 39). Ten previously sampled Year One live bottom stations were also selected for continued sampling (Table 3-1).

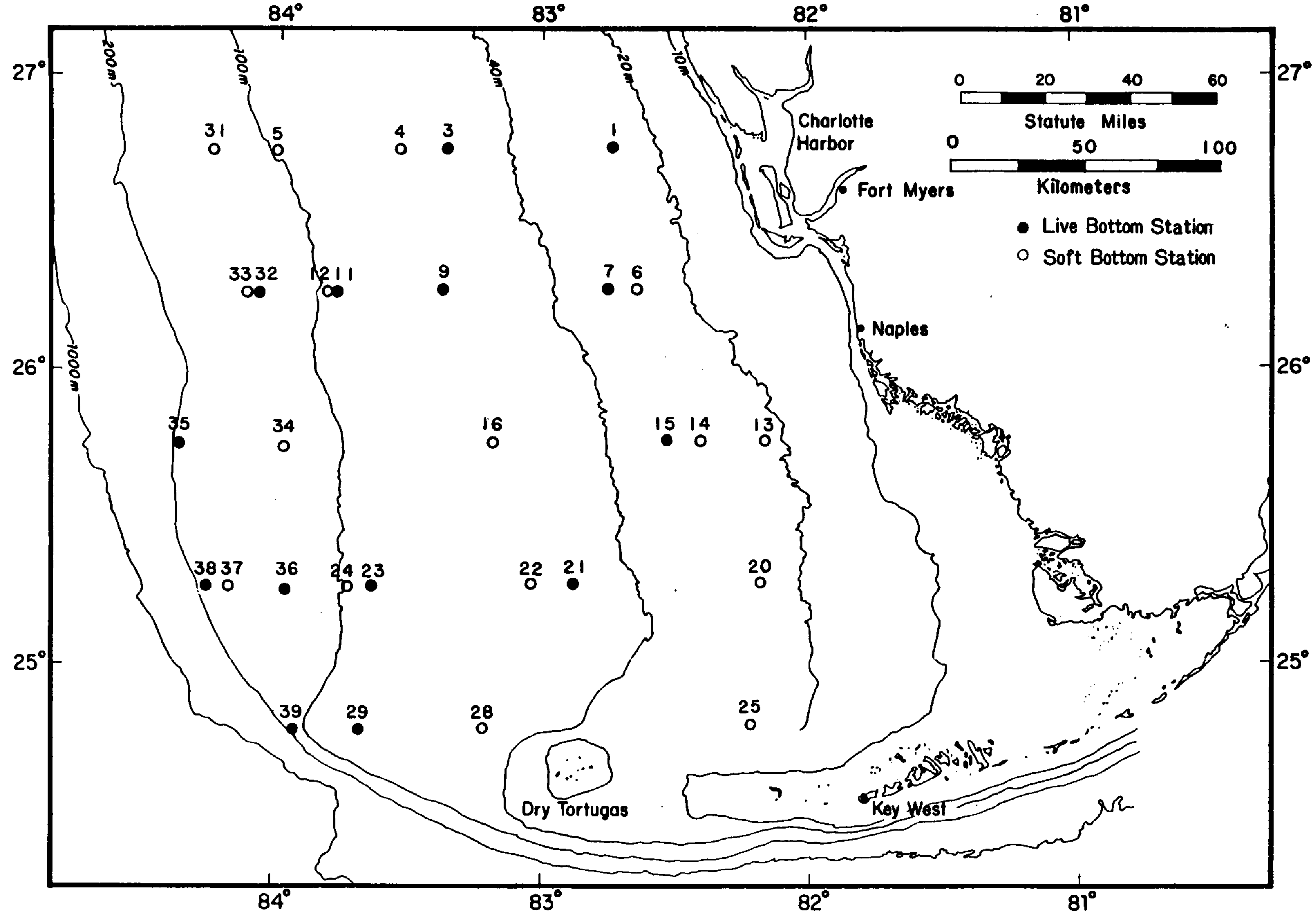

Figure 3-2. Year Two sampling station locations.

The criterion for selection of additional Year Two soft bottom stations was to provide adequate coverage of the study area in terms of water depth and latitude. It was intended that one "new" station would be selected on each east-west transect at a depth of approximately 150m. It was believed that this would best characterize the 100 to 200m depth zone. Unfortunately, insufficient soft bottom area on Transect E prevented selection of any stations between 100 and 200m, and only four new soft bottom sites (Stations 31, 33, 34, and 37) were chosen (Figure 3-2). Eleven stations providing the best geographic coverage were also selected from the previously sampled Year One stations (Table 3-1).

3.2.2 Types of Data and Samples Collected

In all, 39 different stations were sampled during the Year One and Year Two programs. Table 3-2 lists these stations and their locations in terms of latitude, longitude, and Loran C coordinates. Listings of individual stations sampled during each cruise of the two programs, their bottom types, and depths are presented in Table 3-1. Table 3-3 summarizes the various types of samples and data which were collected at live and soft bottom stations, by year and cruise. Specific sampling times (day vs. night) for a given sampling technique were generally arbitrary and depended solely upon when the ship was "on station." For detailed accounts of individual sample collection times, problems encountered, etc., the reader is referred to the respective Chief Scientist's Cruise Logs, provided in Volume 5 - Appendix A.1. Station sample collection times are listed in Volume 5 - Appendix A.2.

Table 3-2. Sampling station position data.

Transect-Station	Latitude (North)	Longitude (West)	Loran C Coordinates	
A-1	26°45.77'	82°43.11'	14075.2	44314.0
A-2	26°45.84'	82°45.18'	14070.6	44330.7
A-3	26°45.86'	83°21.44'	13979.3	44609.3
A-4	26°45.81'	83°32.12'	13949.2	44687.4
A-5	26°45.70'	84°00.13'	13863.1	44883.5
B-6	26°16.79'	82°38.35'	14020.2	44156.1
B-7	26°16.82'	82°44.02'	14007.0	44199.1
B-8	26°16.72'	83°12.81'	13934.3	44411.1
B-9	26°16.83'	83°23.81'	13904.5	44490.2
B-10	26°16.73'	83°42.81'	13849.1	44621.8
B-11	26°16.72'	83°46.82'	13836.9	44649.0
B-12	26°16.72'	83°47.67'	13834.3	44654.8
C-13	25°45.93'	82°09.35'	14019.4	43856.6
C-14	25°46.01'	82°23.82'	13988.2	43958.7
C-15	25°45.89'	82°31.62'	13970.3	44013.2
C-16	25°45.70'	83°11.07'	13872.1	44285.4
C-17	25°45.58'	83°20.24'	13847.0	44346.8
C-18	25°45.37'	83°42.22'	13783.6	44490.8
D-19	25°17.36'	82°09.00'	13964.6	43807.4
D-20	25°17.34'	82°09.73'	13963.0	43812.0
D-21	25°17.26'	82°52.16'	13864.4	44083.4
D-22	25°17.18'	83°02.07'	13839.1	44146.4
D-23	25°16.89'	83°37.79'	13740.9	44369.1
D-24	25°16.90'	83°43.18'	13725.2	44402.1
E-25	24°47.95'	82°13.26'	13901.6	43799.4
E-26	24°47.82'	82°52.07'	13810.5	44025.3
E-27	24°47.76'	83°08.01'	13769.8	44118.5
E-28	24°47.11'	83°13.08'	13756.4	44148.0
E-29	24°47.51'	83°41.19'	13678.6	44310.0
E-30	24°47.41'	83°51.15'	13649.5	44366.4
A-31	26°45.61'	84°14.81'	13813.6	44980.8
B-32	26°16.67'	84°04.08'	13781.8	44763.4
B-33	26°16.53'	84°05.97'	13775.7	44775.0
C-34	25°45.31'	83°57.63'	13736.4	44589.0
C-35	25°44.84'	84°21.03'	13659.3	44731.1
D-36	25°16.83'	83°57.35'	13682.5	44487.4
D-37	25°16.64'	84°09.39'	13644.5	44558.0
D-38	25°16.50'	84°14.77'	13627.1	44588.9
E-39	24°47.16'	83°55.36'	13636.6	44389.5

Table 3-3. Types of samples and data collected during the Year One and Year Two programs. An "X" indicates that samples/data were obtained at all respective Year One or Year Two program stations (See Table 3-1 for station listing).

	Year One		Year Two	
Sample Type	Fall Cruise	Spring Cruise	Summer Cruise	Winter Cruise
WATER COLUMN (all stations)				
STD/DO Profile	X	X	X[1]	X[1]
Salinity Samples (near-surface and near-bottom)	X	X	X[1]	X[1]
Dissolved Oxygen Samples (near-surface and near-bottom)	X	X	X[1]	X[1]
Temperature (reversing thermometer)	X	X	X[1]	X[1]
Transmissivity Profile	X	X	X[1]	X[1]
Photometer Profile (daylight only)	X[2]		X[3]	X[3]
Nutrients (inorganic nitrogen, phosphate and silicate)	X	X	X[1]	X[1]
Chlorophyll a	X	X	X[1]	X[1]
Yellow Substance	X	X		
BENTHIC				
Television Videotapes (black and white; all stations)	X	X	X	X
Still Camera Photographs (35-mm color; all stations)	X	X	X	X
Box Cores (soft bottom stations)	X	X	X	X
Macroinfauna (soft bottom stations)	X	X	X	X
Sediment Grain Size (soft bottom stations)	X	X	X	X
Sediment Total Carbonate (soft bottom stations)	X	X	X[4]	X[4]
Sediment Hydrocarbons (soft bottom stations)	X		X[4]	
Sediment Trace Metals (Ba, Cd, Cr, Cu, Fe, Pb, Ni, Va, Zn) (soft bottom stations)	X			
Triangle Dredge Epifauna and Macroalgae (live bottom stations)	X	X	X	X
Otter Trawl Epifauna and Macroalgae (all stations)	X	X	X	X

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[1] Samples/data only obtained from 15 selected stations.

[2] Equipment failure, data obtained at only 12 stations.

[3] Equipment failure, data obtained at only 7 stations.

[4] Samples collected only at the 4 "new" deep-water soft bottom stations (Stations 31, 33, 34, and 37).

3.3 FIELD AND LABORATORY METHODS

Detailed discussions of all Year One sampling and analysis methodologies were previously included in the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983). Table 3-4 lists the specific locations of the various methodology descriptions in that document. Unless otherwise indicated below, identical methods and equipment were utilized in the Year Two program and will not be described here. Specific changes in Year Two methods include the following:

- During the Year Two Winter Cruise (January-February 1982), a larger survey vessel (R/V G.W. PIERCE II) was used in anticipation of rougher seas.
- Hydrographic data were not collected at all 30 stations. Only 15 sites were selected -- one representative of each of three depth zones on each of the five east-west shelf transects.
- No yellow substance determinations were made during the Year Two program (only negligible amounts were detected during the Year One program).
- No trace metal determinations were performed on surficial sediment samples ("pristine" conditions were indicated during the Year One program).
- Surficial sediment hydrocarbons were determined only at the four "new" deep water soft bottom stations, during the Year Two Summer Cruise (again predominately "pristine" conditions noted during Year One precluded the need for further sampling).
- The triangle dredge could not be used at Station 39 due to extreme changes in bottom relief at that location. A Benthos Type 149 Rock Dredge was used instead. In addition, bottom topography prevented the use of otter trawls on Station 39.
- A different photometer, supplied by MMS, was used during the Year Two program.

Table 3-4. Location of discussions of all sampling methodologies presented in the Southwest Florida Shelf Year One Final Report.

Method	Location of Discussion
GEOPHYSICAL SURVEY	
Navigation	Methods described in Section 2.0; equipment specifications presented in Appendix A-1.
Depth Soundings	" " "
Side Scan Sonar	" " "
Subbottom Profiles	" " "
UNDERWATER TELEVISION AND STILL CAMERA SURVEY	
Data Collection	Methods described in Section 3.0; equipment specifications presented in Appendix A-1.
Analysis	Methods described in Section 3.0.
BIOLOGICAL/HYDROGRAPHIC SURVEYS	
Navigation	Methods described in Section 5.0; equipment specifications presented in Appendix A-1.
Television/Still Camera Visual Information	" " "
Bathymetry	" " "
Hydrography	Methods (field and laboratory) described in Section 6.0; equipment specifications presented in Appendix A-1.
-Weather & Wave Observations	" " "
-Salinity, Temperature, Dissolved Oxygen, & Depth	" " "
-Transmissivity	" " "
-Light Penetration	" " "
-Yellow Substance	" " "
-Nutrients	" " "

Table 3-4. (Continued)

Method	Location of Discussion
BIOLOGICAL/HYDROGRAPHIC SURVEYS (Continued)	
Hydrography (cont'd)	
-Cholophyll a	" " "
Live (Hard) Bottom Biological Samples	Field methods described in Section 5.0; processing and laboratory methods presented in Sections 5.0 and 11.0.
-Triangle Dredge	" " "
-Otter Trawl	" " "
Soft Bottom Biological Samples	Field and laboratory methods described in Sections 5.0 and 10.0
-Box Core	" " "
-Otter Trawl	" " "
Soft Bottom Sediment Samples	
-Grain Size and Percent Carbonate	Methods described in Sections 5.0, and 7.0, and Appendix A-2.
-Hydrocarbons	Field and laboratory methods described in Section 8.0 and Appendices A-3 and A-6.
-Trace Metals	Field and laboratory methods described in Section 8.0 and Appendices A-5 and A-6.

3.4 DATA MANAGEMENT AND ANALYSIS

Data management and analysis tasks were conducted under the direction of the Woodward-Clyde Consultants (WCC) Data Manager. The Data Manager was responsible for organizing and conducting all data processing, analyses, dissemination, and reporting.

Raw data chosen for computerized summarization or analysis were recorded on appropriate keypunch forms by the respective investigation teams. Completed forms were checked for accuracy and completeness, and forwarded for database entry. Once entered into the database, the data were checked and corrected using quality control procedures (Section 3.4.1.2). Upon final verification of the data, appropriate computer summaries and analyses were performed on the different data sets, as requested by the respective Principal Investigators. Specific data management and analysis procedures used during Year Two are discribed below.

3.4.1 Database Management Procedures

3.4.1.1 Hardware and Software

The quality control (Q/C) phase of data management was performed on a Digital Equipment Corporation (DEC) PDP-11/23 (RSX-11M) minicomputer; Q/C procedures were written in FORTRAN IV. Once clean, all data were transferred to an IBM 3081 (MVS/TSO) mainframe computer, where database management was performed using the RAMIS II database management system (Rapid Access Management Information System; Mathematica Products Group, Inc., 1981). Cluster analysis, principal components analysis, discriminant analysis, missing data estimation, and other multivariate statistical applications were performed using EAP (Ecological Analysis Package; Smith, 1981a) and SAS (Statistical Analysis System; SAS Institute, 1982). Data for species saturation curves and rarefaction curves were generated on the PDP-11 using FORTRAN IV programs. Ancillary data management, statistical analysis, and communications were completed on an IBM PC (DOS 2.0) microcomputer.

3.4.1.2 Quality Control

As data were received by the Data Manager, each unique "batch" of data sheets was logged in and assigned a number. Once keypunched, a log was kept of all corrections to each data file. All intermediate versions of each data file were saved on disk, then backed up on magnetic tape. Consequently, a data file could be traced back through all revisions and, if necessary, to the batch of data sheets from which it originated.

During the Q/C phase, two principal types of error checking were employed. First, the computer was used to check each data file for valid entries in each field, cross-checking data files containing valid values (e.g., taxon codes) for each field. Checks were also made for duplicate entries in each data file. Second, formatted listings of the data were generated by the computer and used in visual checks against original laboratory bench data sheets by the appropriate investigation team.

Most corrections to the database were submitted to the Data Manager on data sheets. As with the raw data mentioned above, each set of corrections was also assigned a batch number, explicitly referred to in the data file revision log. Several corrections were communicated by telephone. In these cases, a written record of the telephone call and corrections was made and listed in the data file revision log. Thus, all corrections were traceable to hard copy.

The size of the database (and consequent voluminous revisions) necessitated the adoption of a special system for making corrections to data files. Many corrections were encoded onto special data sheets as either "Additions," "Deletions," or "Global Changes." Special computer programs applied such corrections to the database automatically. Other corrections were made to the database using a text editor.

3.4.1.3 National Oceanographic Data Center Coding Procedures

Taxonomic names are often long and prove cumbersome when used directly in computer databases. For that reason numerical coding systems are generally used to represent the various organisms in a given set of data. In the present investigations, the taxonomic codes used were based upon the system established by the National Oceanographic Data Center (NODC). At the inception of the Year One program, the most recent version of the NODC taxon list available was the May 1978 edition. For consistency, that same version was used as the base list for the duration of the entire study.

The 2- to 12-digit NODC code is hierarchical, the first five sets of double digits representing five taxonomic levels and the sixth representing a subspecies or variety in some taxonomic groups. The "standard" five taxonomic levels are either (a) phylum, class, family, genus, and species or (b) class, order, family, genus, and species. For example:

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

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

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

The system enables taxa to be coded to the level to which they have been identified. For example, if a large cetacean is sighted but cannot be identified further, the code 9217 is used. However, if it is identified as a common dolphin, *Delphinus delphis*, it can be coded to species level 9218020601.

For taxa which contain more than 99 subtaxa, NODC has assigned multiple codes (e.g., protozoans [34 and 35] and insects [62 through 65]).

The May 1978 NODC taxon code list contained only a small subset of the taxa collected over the course of this project. Therefore, it was necessary for Woodward-Clyde to invent temporary codes consistent with NODC code format. The complete master taxon code list of invented temporary codes used on this project can be found in Volume 6-Appendix B.

At the time of writing (July 1984), NODC staff are working on the conversion of Woodward-Clyde's temporary species codes into permanent additions to the NODC taxon code list. Copies of Woodward-Clyde's data files, to be submitted with this Year Two Final Report, will also be converted over to the new, permanent NODC species codes.

3.4.1.4 Changes to the Year One Database

The corrected Year One data have been completely re-analyzed in this report. Significant changes were made to the Year One database as presented in the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983). These changes included refinement of the taxonomy of several groups, particularly Polychaeta, as well as the correction of errors in the database. Complete listings of the corrected data can be found in Volumes 5, 6, and 7 -- Appendices A, B, and C, respectively.

3.4.1.5 NODC Data Submission

Over the course of the project, the Woodward-Clyde Data Manager and NODC staff negotiated a series of agreements for the submission of all biological and physical data collected during Years One and Two. File types and formats were selected from the published list of acceptable formats (NODC, 1983) and conversions are to be made using the RAMIS database management system and several computer-based text editors. All data are to be submitted to NODC concurrent to submission of this Year Two Final Report.

3.4.2 Biological Data Analysis

During the Year One and Year Two investigations, five types of data were used to describe the benthic biological communities at study sites across the southwest Florida shelf. They were as follows:

- Soft Bottom Box Core Data (BCI)
- Soft Bottom Otter Trawl Data (OTS)
- Live Bottom Triangle Dredge Data (TDS)
- Live Bottom Otter Trawl Data (OTH)
- Live Bottom Quantitative Slide Analysis Data (QSA).

Table 3-5 summarizes the basic analyses which were performed on each of these five different data sets. Descriptions of the major analyses utilized are provided below.

Late in the analysis, four minor taxonomic errors (involving two red algae, one sponge, and one coral species) were detected in the live bottom biological database. All affected Report and Appendix tables were corrected and rerun, with the exception of the multivariate analyses -- e.g., cluster analyses and weighted discriminant analyses for live bottom otter trawl and triangle dredge data sets. Since the errors were minor and the resulting changes in abundance small, it was determined by the live bottom investigators that the revisions would not change any of the results of the multivariate analyses.

3.4.2.1 Indices of Diversity

The number of taxa per sample, or taxonomic richness (S), was calculated for all sampling methods. Equitability (J') and species diversity (H') were calculated for the quantitative samples (BCI and QSA data) as follows:

$$\text{Species diversity, } H' = -\Sigma\, P_i \log P_i$$

$$\text{Equitability, } J' = \frac{H'}{\log S}$$

Table 3-5. Listing of basic analyses performed on biological data sets.

	Live Bottom Data Set			Soft Bottom Data Set	
Analysis Performed	TDS	OTH	QSA	BCI	OTS
Formatted Listing of Raw Data	X	X	X	X	X
Rank Order and Relative Abundance Tables	X	X	X	X	X
No. of Taxa Captured, by Major Taxonomic Group	X	X	X		
Mean Percent Cover, by Major Taxonomic Group			X		
Mean Percent Total Biotic Cover			X		
Mean Percent Cover for Dominant Taxa			X		
Sampling Methods Comparison, by Major Taxonomic Group	X	X	X	X	X
Total Number of Taxa Captured	X	X	X	X	X
Total Faunal Density				X	
Species Richness, Equitability, Diversity				X	
Cluster Analysis	X	X	X	X	X
Weighted Discriminant Analysis	X	X	X	X	X
Rarefaction Analysis			X	X	
Species Saturation Analysis	X		X	X	

TDS = Triangle Dredge

OTH = Otter Trawl (Hard Bottom)

QSA = Quantitative Slide Analysis

BCI = Box Cores

Otter Trawl (Soft Bottom)

where: $P_i = \dfrac{\text{Number of individuals of class i in sample}}{\text{total number of individuals in sample}}$

S = taxonomic richness, and

H' = Shannon-Weiner diversity index (Pielou, 1975).

Computation of richness, equitability, and diversity were based upon the subset of taxa identified to genus or species level (NODC code of 8 to 12 digits length) in order to meet the diversity index assumption calling for "comparable taxonomic units." For example, an abundance of ten individuals identifiable only as "Crustacea" could represent as few as one or as many as ten different species. Clearly one species is not comparable with an uncertainty range of one to ten species, a fact which violates the index assumption.

3.4.2.2 Measures of Sampling Adequacy

Species Saturation Curves

The species saturation curve, also referred to as the species-area curve, examines the adequacy of sampling by plotting changes in the cumulative number of species captured over successive replicates (Figure 3-3; Gleason, 1922; Holme, 1953). Little or no increase in the cumulative number of species found indicates that adequate sampling or "saturation" has been reached (Curve A in Figure 3-3), while a continuing increase in additional species implies inadequate sampling (Curve B). Since there is no definitive quantitative measure on a species saturation curve of what constitutes adequate vs. inadequate sampling, the measure remains a subjective one.

The order of sample replication itself can affect the overall shape of the saturation curve; thus, a randomization technique was employed to minimize this influence. All possible order combinations of the sample replicates (n! possibilities, where n = the number of replicates) were run, and the mean cumulative number of taxa for each replicate was then used in the saturation curve plot.

For reasons discussed in Section 3.4.2.1, only taxa identified to genus or species level (NODC code of 8 to 12 digits) were used in the calculation of species saturation curves.

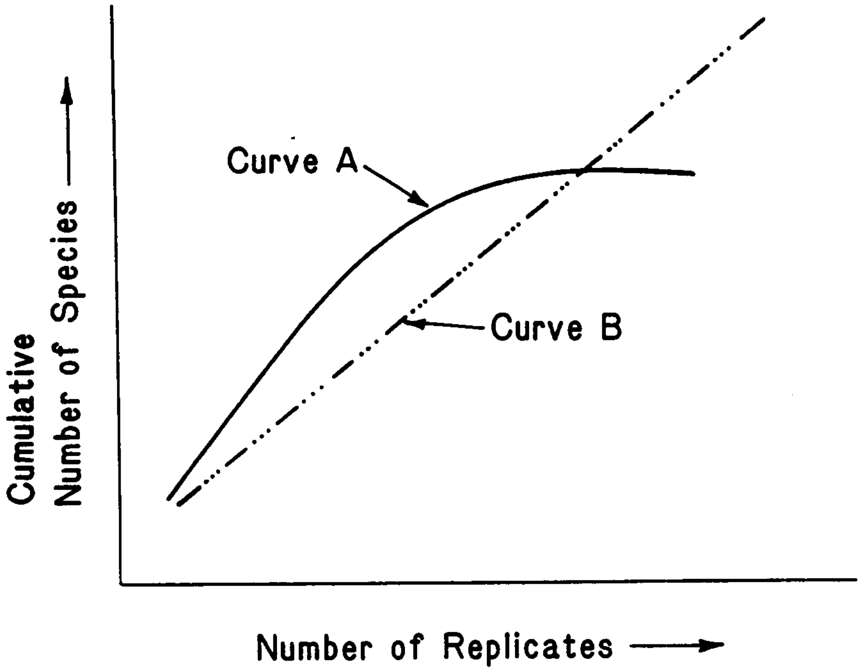

Figure 3-3. Species saturation curves: Curve A implies saturation while Curve B implies inadequate sampling.

Rarefaction Analysis

The use of rarefaction curves has been suggested as a means of examining species diversity and patchiness of biological communities (Sanders, 1968; Hurlbert, 1971; Bernstein et al., 1978). Since community patchiness affects the adequacy of sampling, rarefaction analysis can also be used as an aid to evaluate the sampling process. A typical rarefaction curve (Figure 3-4) plots the number of species versus the number of individuals collected. The actual location of samples in relation to the theoretical curve can be used to indicate relative community patchiness at those sample collection sites (Bernstein et al., 1978). Comparison of the shapes of rarefaction curves from different sampling sites can also indicate relative species diversity (Sanders, 1968).

In order to lessen the effects of sample order on the shape of the resulting rarefaction curve, Simberloff (1972) suggested a Monte-Carlo method for sampling the raw species data. Following the resampling procedure, the resultant means are plotted as the final rarefaction curves. In the present investigation the Monte-Carlo method was utilized to produce rarefaction curves for all box core station replicate sample collections. Each data base (separate for each station-cruise sampling) was resampled 100 times and the resultant means were plotted as a rarefaction curve. For reasons discussed previously, only taxa identified to genus or species level were used in the rarefaction analysis.

3.4.2.3 Cluster Analysis and Agglomerative Hierarchical Classification

Background

Cluster analysis is one of several numerical methods which can be 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. Agglomerative hierarchical classification is the form of cluster analysis which was used in the present investigation. This analysis is a multivariate numerical method aimed at calculation of a relative "distance" reflecting similarity among the entities (i.e., sampling sites or taxa) being considered.

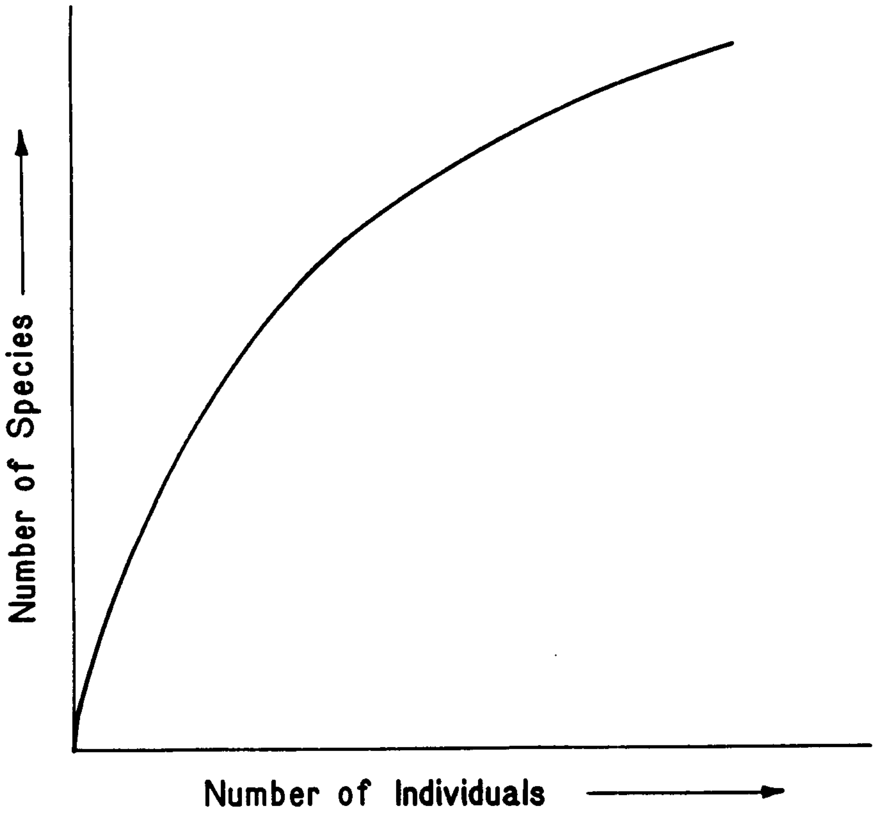

Figure 3-4. Rarefaction curve.

As a multivariate technique, agglomerative hierarchical classification considers many variables assigned to each entity -- for example, the many species present at each sampling station. Thus, the determination of "ecological distance" is based upon the species composition at each sampling site, not a univariate generalization such as species diversity (which might show two sites identical in diversity when the species comprising each might be completely different).

In ecological applications such as this one, a theoretical "ecological distance" is calculated by means of a particular mathematical distance index. A distance matrix is then produced which contains all distance values among all of the entities being considered. The relationships indicated can be graphically displayed in two dimensions by a hierarchical dendrogram. Figures 3-5 and 3-6 show examples of the two types of dendrograms usually produced from a given biological data set. The first is a hypothetical sample site dendrogram which depicts the similarities of species composition and abundance at different sampling locations. The second shows a hypothetical species dendrogram which clusters different species according to similarities in their abundance and distribution among different sample sites. In such presentations, the most "distant" (i.e., least similar) entities are separated by the greatest graphic distance on the diagrams. Finally, a two-way coincidence table is created to display the standardized raw biological data in symbol form. As used here, this table (Figure 3-7) is a matrix of species occurrences versus sampling sites, sorted in the order of their appearance on the respective dendrograms. Based on the patterns of relative distances observed in these three representations of the data, a biologist can propose hypotheses concerning the ecological similarities of sample site or species groupings. The hierarchy of dendrogram relationships also allows a multi-level approach to their ecological interpretation.

Application and Presentation

In this report, site dendrograms, taxon dendrograms, and two-way coincidence tables are presented for most cluster analyses. Due to the large number of taxa and the fact that their names are easily confused, the label for each taxon in the dendrograms and two-way tables consists of the first 32 characters of the taxon name. In those instances where the name has been

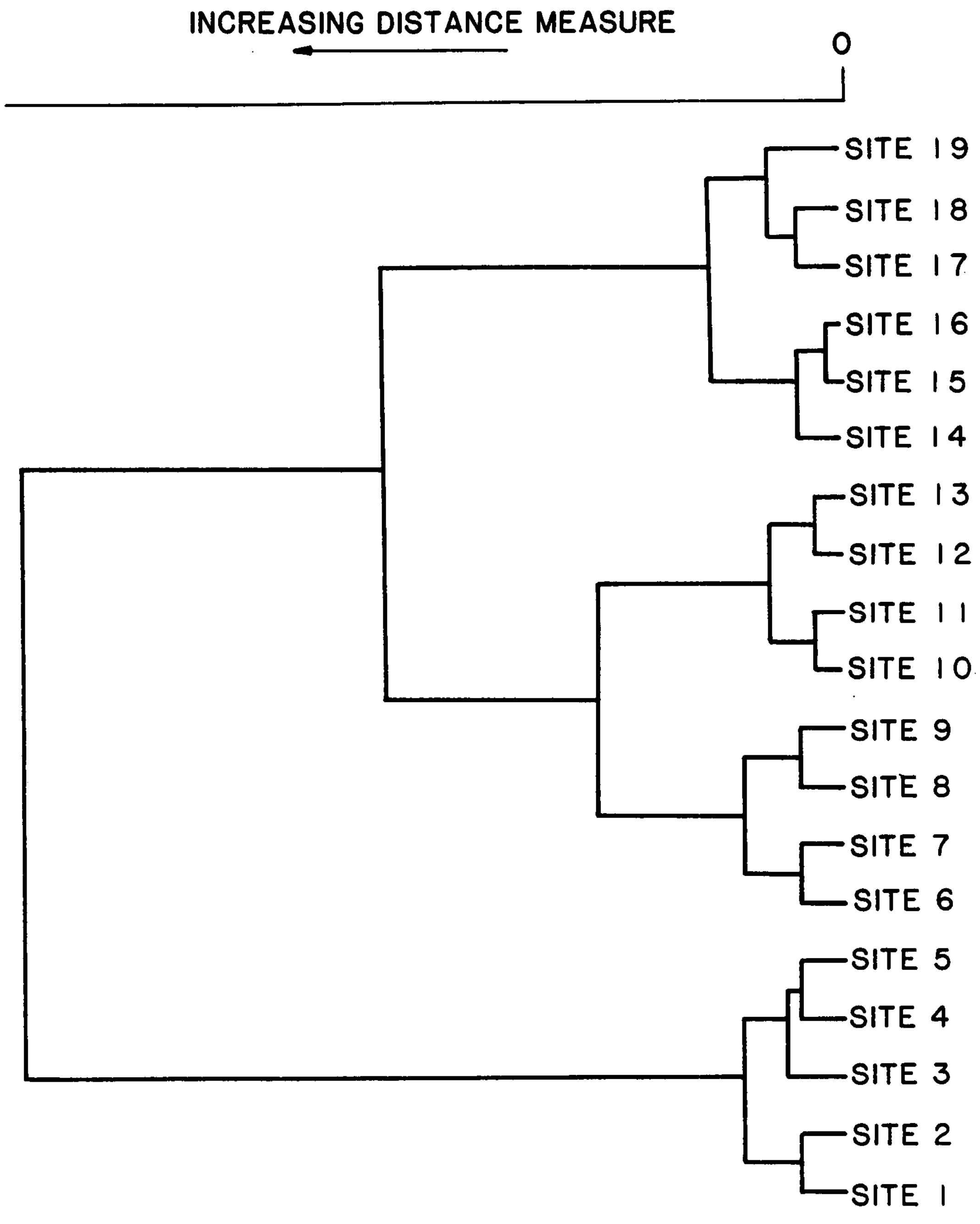

Figure 3-5. Hypothetical site dendrogram with 19 sample sites.

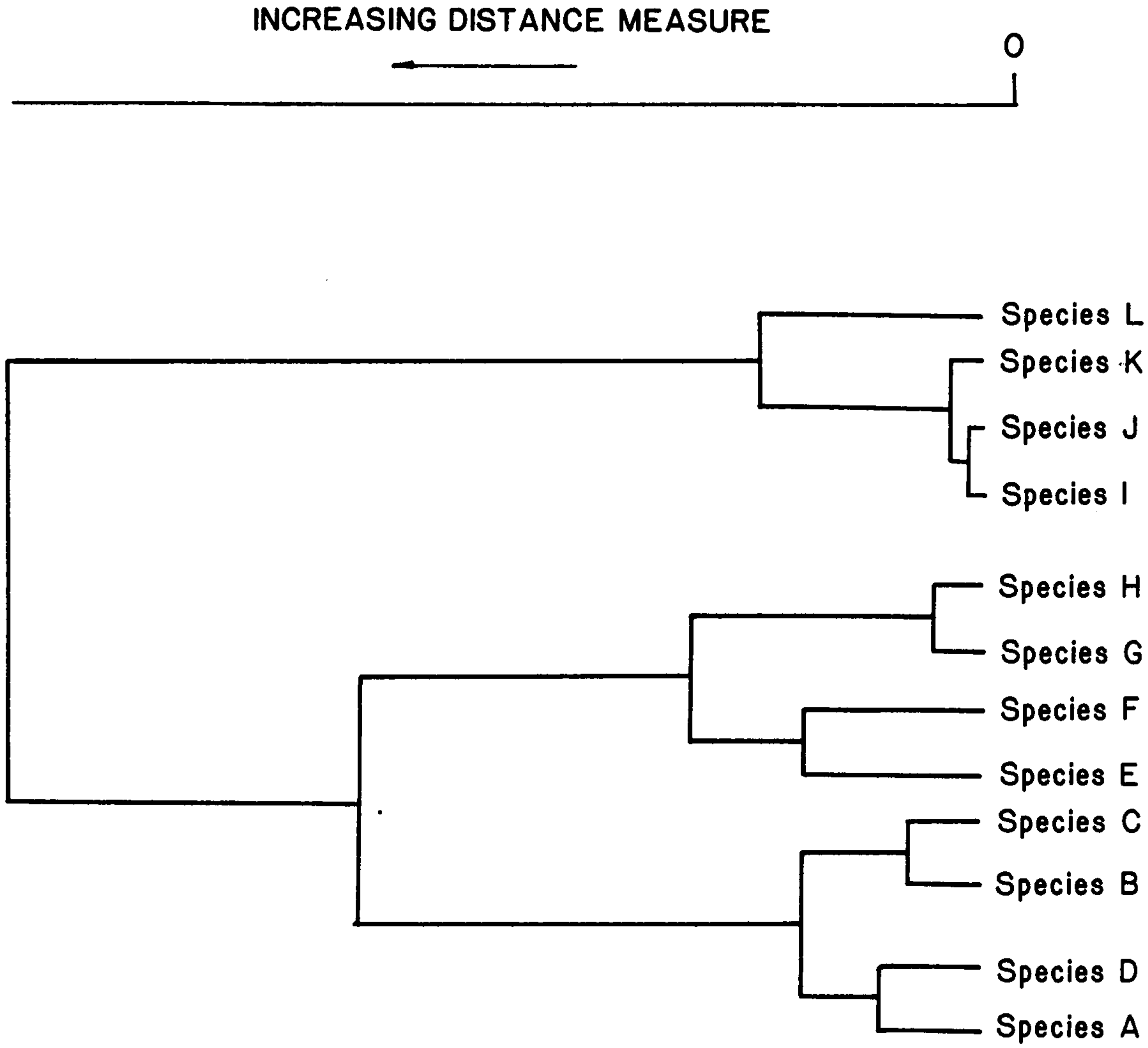

Figure 3-6. Hypothetical species dendrogram.

	SITE 19	SITE 18	SITE 17	SITE 16	SITE 15	SITE 14	SITE 13	SITE 12	SITE 11	SITE 10	SITE 9	SITE 8	SITE 7	SITE 6	SITE 5	SITE 4	SITE 3	SITE 2	SITE 1
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
SPECIES L	*	*	+	–	–	•													
SPECIES K	–	+	*	*	*	*	+	–	•										
SPECIES J	+	*	*	*	*	*	*	+	–	–	•								
SPECIES I	–	+	*	*	*	*	*	+	–	–	•	•							
SPECIES H		•	•	–	–	+	*	*	*	*	*	+	–	–	•				
SPECIES G							–	+	*	*	*	+	–						
SPECIES F		•	•	•	–	–	–	+	*	*	*	*	*	*	+	+	–	–	–
SPECIES E											•	+	*	*	–	–			
SPECIES C									•	•	–	–	+	*	*	*	*	+	–
SPECIES B											•	–	–	+	+	*	*	*	*
SPECIES D															–	+	*	*	+
SPECIES A																		+	*
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9

NOTE: Symbols represent ranges in the values of the weighted species means (WSM); (•)≤0.5, or half the WSM; (–)≤1.0, equal to the WSM; (+)≤2.0, or twice the WSM; (*)>2.0, greater than twice the WSM.

Figure 3-7. Hypothetical two-way table based on data plotted in the dendrograms presented in Figures 3-5 and 3-6.

Calculation of weighted species means standardizes species occurrences among samples to correct for uneven sampling of different habitat types. Based on the biological distinctiveness of each sample, the calculation assigns more weight to undersampled habitats and less weight to oversampled habitats (Smith, 1976).

truncated, the complete name can be found in the Master Taxon Code List presented in Volume 6-Appendix B.

Sampling station and taxon groupings were made by comparing dendrograms and two-way tables at each successive split within the data set. Since the data sets were not split on the basis of a predetermined, fixed, similarity level (distance measure value) the splitting process remains largely subjective. In this study the splitting of groups was stopped when obvious patterns in occurrence on the two-way tables became less readily discernable (cf. Boesch, 1977). Station and taxon groupings identified from the different dendrograms are not directly comparable, for different data sets were split at different similarity levels.

To facilitate interpretation of the cluster analysis results from this study, site maps are presented showing the clustered groups as overlays. Figure 3-8 is presented as an example, based on the dendrogram in Figure 3-5; station positions are purely hypothetical in this example. Note that the map indicates not only the group assignment for each station, but also the hierarchy of group membership, by showing the smaller groups within their parent clusters. Further, the line pattern of each cluster group indicates the order in which that group was split off within the dendrogram. Figure 3-9 indicates the line patterns used and their definitions.

Finally, it is important to note that only taxa identified to genus or species level were included in the cluster analyses. Inclusion of imprecisely identified groups of taxa would violate model assumptions in a manner similar to that discussed in previous sections. Readily available computer resources also dictate a finite limit (256) to the number of entities (samples or species) that can be used in the cluster analysis (Smith, 1981a). Fortunately, cluster analysis is a sufficiently powerful procedure that a small subset of the total taxonomic pool is usually adequate to define and portray the broader ecological patterns in question. A practical limit of about 90 to 150 taxa was chosen for this study, with dominant taxa being selected for the analyses based on either their abundance or frequency of occurrence. Exact selection criteria and species-list truncation levels for these dominant taxa are noted and discussed in the appropriate live and soft bottom report sections.

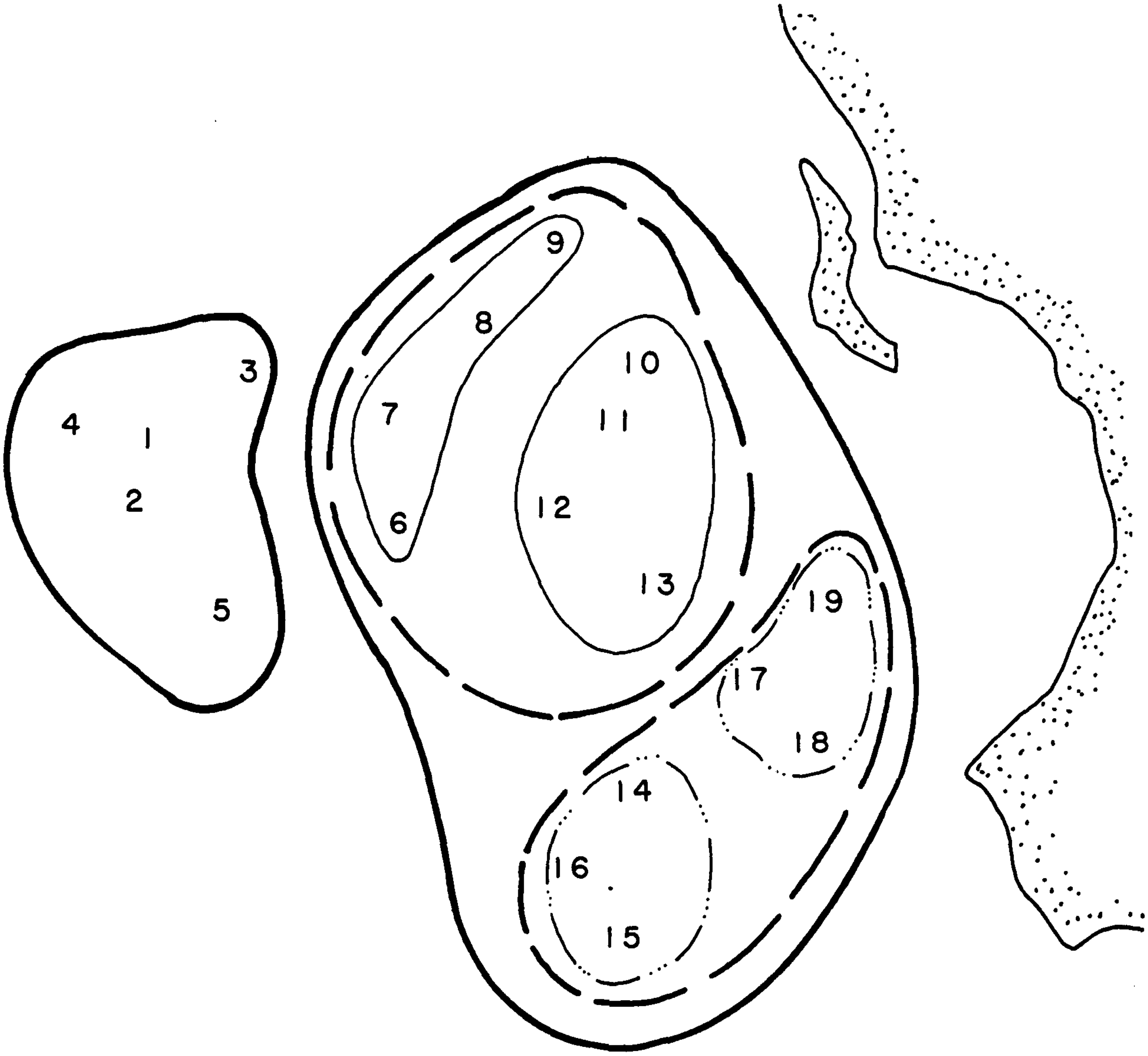

Figure 3-8. Example of a site map with cluster group hierarchy overlay. (Line pattern definitions shown in Figure 3-9; groups taken from dendrogram presented in Figure 3-5.)

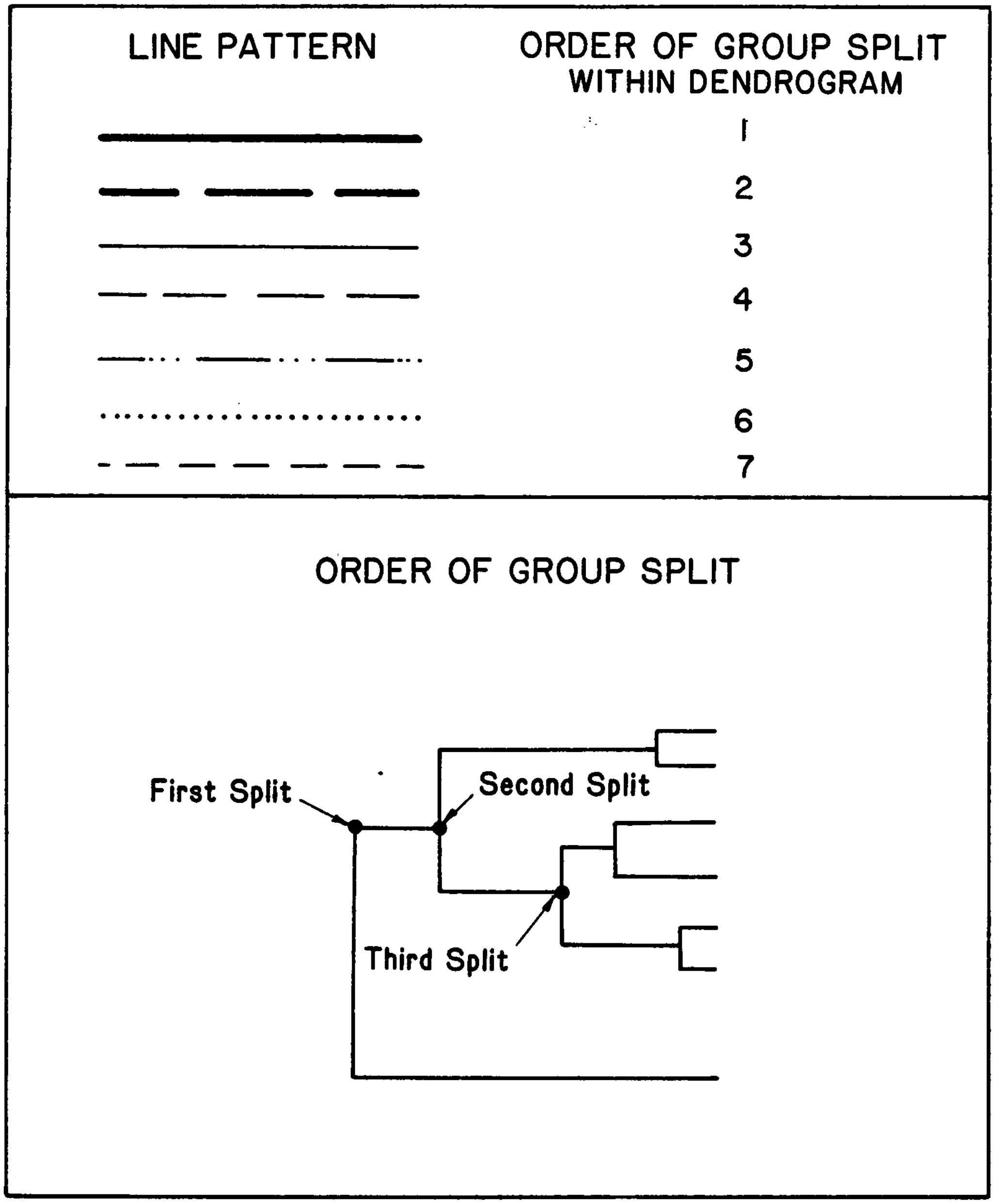

Figure 3-9. Line patterns used on site map overlays and their definitions.

Inter-Sample Distances: Zero Adjusted Distance (ZAD) Index

There are many distance indices for measuring the dissimilarity among sets of sample pairs (Clifford and Stephenson, 1975). In all of these, the underlying model is that the distance index measures biological change, and that the distance between two samples increases as the amount of biological change increases. In actuality, all distance measures reach a maximum value at a certain point and then either remain constant or decline, even though the amount of biological change continues to increase (Figure 3-10; Beals, 1973; Swan, 1970).

These severe inaccuracies stem from fundamental differences between the underlying assumptions of distance indices and the actual properties of ecological data. All distance indices are based upon the assumption that species importance values (abundance, biomass, presence/absence, etc.) vary linearly as biological change takes place. In practice this assumption is rarely met (Beals, 1973; Austin, 1980) since species abundances tend to change in a non-linear, non-monotonic fashion as overall biological change is taking place, usually along pertinent environmental gradients (Austin, 1976; Beals, 1973; Swan, 1970). In addition, the species abundances are truncated -- i.e., species counts reach a value of zero and remain zero as environments more unfavorable to the species in question are sampled (Swan, 1970). As a result, distance indices lose their sensitivity to larger magnitudes of actual biological change. Another hidden assumption in most if not all distance indices is that the abundance of each species changes at the same rate as overall biological change takes place. This assumption is rarely met, because the slopes of species abundance curves along environmental gradients can be radically different. This contributes to increased variance in the distance measure.

The ZAD Index -- A new distance index designed to reflect these ecological realities was used in the present study. This measure, called the Zero Adjusted Distance, or ZAD index (Smith and Bernstein, in prep.), cannot be described by a simple formula, since its calculation involves several successive steps. The total information contained in a set of species importance values is obtainable only by viewing the data from several different perspectives.

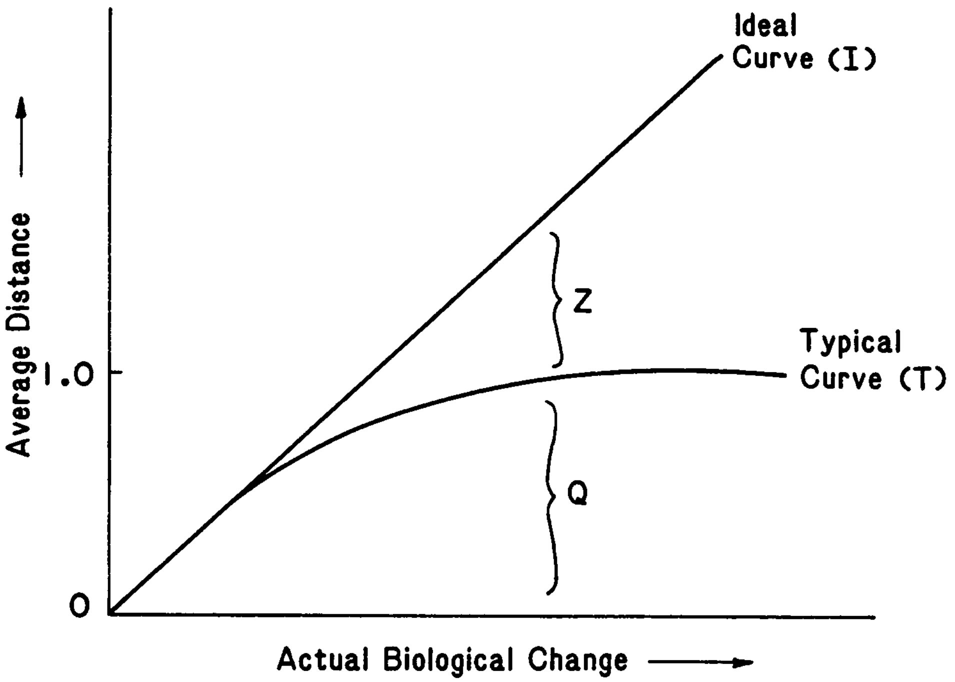

Figure 3-10. Relationship between the two components of the Zero Adjusted Distance (ZAD) distance index and the ideal distance curve, (I). The quantitative component (Q), levels off at 1.0, while the zero adjustment component (Z), continues to increase with increasing biological change.

Figure 3-10 shows the relationship between a typical distance index (T) and the ideal distance measure (I), which should increase linearly with increasing biological change between samples. The ZAD index approaches the problem of deriving accurate distance values by calculating two separate components of the distance curve and then summing them. These calculations are performed in separate steps. The first is to calculate precise and accurate shorter distances (Q) directly from the species importance values. The calculations here attempt to compensate for the problems caused by non-linear, non-monotonic changes in species abundance, and by unequal rates of change in abundance among species. The second step adjusts for the leveling off of curve T in Figure 3-10 by adding a steadily increasing component to Q in order to reach the ideal distance curve, I. This second component, termed Z, is calculated separately from the inter-species distances. Thus, Q is most important for estimating the shorter distances, while Z increasingly contributes more as the distances become longer.

Calculation of Q -- The quantitative component (Q) of the inter-sample distance is based on the quantitative species differences, and is calculated as follows:

$$Q_{ij} = \frac{\sum_{k=1}^{s} [W_{ijk} B_{ijk} |X_{ki} - X_{kj}|]}{\sum_{k=1}^{s} [W_{ijk} B_{ijk} \mathrm{MAX}(X_{ki}, X_{kj})]}$$

Where s is the number of species, and i and j are the two samples being compared. The X's are species importance values transformed by a square root and standardized by the species maximum. The absolute value of the difference in abundance of species k at two sites i and j ($|X_{ki} - X_{kj}|$) is termed the X difference. The transformation makes changes in importance values more linear as overall biological change occurs (Smith, 1976) and reduces variability in the rates of change of different species. The standardization removes the irrelevant effect of scale on X differences, since these will otherwise be larger in more abundant species irrespective of the amount of overall biological change.

B_{ijk} is a measure of the relevant "breadth" or range of habitats over which species k is distributed. This term helps correct for the uneven contributions to the distance index of species with different breadths. The specific method for calculating B involves determining the range of the species in an ordination space computed from a component of the Z_{ij} values. These calculations are somewhat complex, since a species may have different breadths on either side of its peak, or along different gradients of biological or environmental change. Full details are provided in Smith and Bernstein (in prep.).

The W_{ijk} values are designed to correct for distortions due to non-monotonic changes in species abundance (Beals, 1973) by giving more weight to those X differences that convey better information about the actual amount of biological change. The most reliable X differences will occur with species which have both values (in the two samples being compared) on the same side of their peak value (Smith, 1976). This is because their importance values will increase monotonically with the true amount of biological change.

Determining the relationship between the samples being compared and the species peaks is a complex procedure, since, as with the B values, the ordination space created from a component of the A_{ij} values must be utilized. Details are provided in Smith and Bernstein (in prep.).

The denominator for the Q_{ij} equation is the maximum possible value the numerator could obtain if there were no species in common in the two samples being compared. Division by this maximum value scales the Q values from 0 to 1.

Zero-Adjustment Component -- The calculation for this component also requires several steps. For each zero value in the data matrix an estimate of the degree to which the species in question is "missing" must be calculated. The method used is conceptually the same as that proposed by Swan (1970) to measure "degree of absence" of species not occurring in a sample. A more sensitive technique has been utilized here; this method calculates the "degree of absence" as follows:

$$M_{ki} = \sum^{X_{mi}>0} X_{mi} \cdot D_{km} \Big/ \sum^{X_{mi}>0} X_{mi}$$

where M_{ki} is the degree of absence of species k in sample i, and X_{mi} is the square-root transformed, species maximum standardized value of species m in sample i. Species m occurs in sample i and species k does not occur in sample i. D_{km} is the inter-species distance between species k and species m. M_{ki} is actually the weighted average distance from species k to all other species which occur in sample i.

Once determined, the M values are used to calculate independent estimates of the between-sample distances. These estimates are expressed as follows:

$$Eij= \frac{\sum_{k=1}^{s} M_{ki}\ M_{ki} + \sum_{k=1}^{s} M_{kj}\ M_{kj}}{\sum_{k=1}^{s} M_{ki} + \sum_{k=1}^{s} M_{kj}}$$

where only those species occurring in one of two samples are considered in sums. This estimate is simply a weighted average of the M values, with each M weighted by its own value. This gives more weight to the larger M Values. Only the largest fifty percent of the distance values are used in the weighted average.

It can be seen that the contribution of E must increase exponentially as Q levels off (Figure 3-10). However, E will tend to vary linearly with the true amount of biological change, since it is calculated using inter-species distances. To make the contribution of E exponential, it must be multiplied by a factor which is dependent upon the rate at which Q levels off. Such a factor (F) can be calculated as follows:

$$F_{ij} = \text{MAX}\ (1,\ 3Q_{ij}^{2}).$$

Tests with simulated data show that F values sufficiently compensate for the leveling off of Q.

Thus, the Zero-Adjustment Component (Z) can be represented by:

$$Z_{ij} = F_{ij}\ E_{ij},$$

and the final ZAD distance (D_{ij}) as:

$$D_{ij} = Q_{ij} + F_{ij}\ E_{ij}.$$

Theroetically, D should approach the ideal distance line in Figure 3-10. Tests with simulated data show this to be the case. Analyses with actual survey data have also shown good results when subjectively compared with analyses using other distance indices.

Inter-Species Distances

The inter-species distance matrix is used in the computation of E, and provides an independent estimate of the longer inter-sample distances. Three steps are involved in calculating inter-species distances:

- Data Transformation and Standardization
- Calculation of Inter-Species Overlap
- Calculation of Relative Habitat Preference.

Data Transformation and Standardization -- Species importance values are first transformed by a square root, and then standardized by a species maximum standardization. This dampens the larger chance fluctuations in the more abundant species, and scales all species abundances from 0 to 1.

Calculation of Inter-Species Overlap -- The Bray-Curtis distance index can be used to measure the distributional overlap of the species, since the distances are inversely proportional to the overlap. Bloom (1981) has demonstrated the suitability of the Bray-Curtis index for this purpose. Overlap values may be distorted by uneven sampling of the different temporal and spatial habitats in the survey area (Colwell and Futuyma, 1971). This can be corrected for somewhat by reusing each sample in the overlap calculations. The number of times a sample is reused is proportional to the calculated sample distinctiveness (Smith, 1976; Smith and Guggenheim, in prep.).

Calculation of Relative Habitat Preference -- The "overlap" distances can be converted to distances which measure the relative habitat preference of the species. Once this is done, the distance values will be proportional to the dissimilarity of the habitats in which the species being compared are found.

The inter-species distance matrix from the previous step is subjected to the TWO-STEP procedure described in Austin and Belbin (1982) and modified by Smith (1981a). This technique should work well for species which are in similar or moderately similar habitats. The distances between species in the more dissimilar habitats will still tend to be too short. To correct for this, the STEP-ACROSS procedure originally conceived by Williamson (1978) and generalized by Smith (1981b) is used. Here the longer distances are recalculated from the shorter distances.

3.4.3 Physical Data Analysis

Table 3-6 lists all physical data sets which were collected during Years One and Two of the Southwest Florida Shelf Ecosystems Study. As can be seen, these data consisted of either hydrographic or sediment parameters. As much of their treatment was descriptive (see Sections 4.0 and 5.0), extensive computer processing and analysis were not performed on every individual data set. Subsequent to preliminary analysis of the biological data sets, weighted discriminant analyses were conducted using selected physical data to examine possible relationships between environmental variables and the observed benthic community structure across the shelf. The selection and refinement of physical data in preparation for these higher level analyses are described below.

3.4.3.1 Physical Data Selection

Not all of the physical variables measured were appropriate for correlation analyses with biological variables (e.g., weighted discriminant analysis, Section 3.4.4). Four general criteria limited the selection of physical or environmental data used:

Table 3-6. Listing of physical data sets and computer analyses performed.

	Computer Processing / Analyses Performed			
Physical Data Set	Computerized Database	Principal Components Analysis	Simple Correlations	Weighted Discriminant Analysis
Chlorophyll a (Acid Method)	X		X	
Chlorophyll a (Fluorometer)	X		X	
Chlorophyll a (Trichromatic)	X		X	X
Dissolved Oxygen (Hydrolab)	X		X	
Dissolved Oxygen (Titration)	X		X	X
Inorganic Nitrogen	X	X	X	X
Nitrite	X	X	X	X
Phosphate	X	X	X	X
Silicate	X		X	X
Photometer Readings				
Phaeopigments (Acid Method)	X		X	
Phaeopigments (Fluorometer)	X		X	X
Salinity	X		X	X
Temperature (Hydrolab)	X		X	
Temperature (Reversing Thermometer)	X		X	X
Temperature (Transmissometer)	X		X	
Transmissometer Readings	X		X	X
Yellow Substance Values				
Sediment Grain Size	X	X	X	X
Sediment Hydrocarbons				
Sediment Trace Metals				

- Model Limitation
- Data Relevance
- Data Quality
- Intercorrelation of Variables.

Model Limitation

There is a limit to the number of physical variables which can be analyzed in discriminant analysis; the number of variables cannot exceed the number of observations taken. As the number of variables used approaches this limit (or if there is high intercorrelation among the variables), one step of the discriminant analysis process, the inversion of the within-group covariance matrix, will yield a singular matrix -- i.e., an invalid result.

Data Relevance

This simply refers to the selection of appropriate physical variables which are most probable correlates with the biological variables measured. For example, mean sediment grain size would be chosen over mean surface wind velocity for a study of benthic infauna. Obviously selection is based upon existing general understanding of the system in question. In this study, near-bottom readings have been chosen over surface and intermediate depth values for the water column data measurements (e.g., chlorophyll, salinity, etc.) used in subsequent analyses.

Data Quality

Data quality can be greatly affected by field and equipment conditions, field and laboratory procedures, personnel experience, etc. All determine the reliability of the data obtained. Different sampling methods which measure the same parameters can also produce different results. Thus, data may vary greatly in terms of accuracy. For obvious reasons, all data should be carefully scrutinized and if suspect, discarded.

Intercorrelation of Variables

Intercorrelated variables provide redundant results in correlation analyses and should therefore be reduced or eliminated. Further, use of highly correlated physical variables has been shown to adversely affect the results of discriminant analysis (Smith, 1976). Highly correlated variables can be reduced using principal components analysis (Section 3.4.3.3), or eliminated based on correlation values from a correlation matrix.

3.4.3.2 Estimation of Missing Physical Data

Weighted discriminant analysis requires that physical variables be measured at all sites where biological measurements are made (Smith, 1976). Frequently however, problems with field conditions, equipment, etc. prevent adequate sampling of all variables at all locations. This results in a physical database with missing values that must be replaced using a data estimation procedure.

In the present investigation, missing values were estimated for those parameters which had fewer than fifty-percent of their total measurements missing. Parameters with more than fifty-percent of their values missing were not included in the correlation analysis. The estimation procedure used was part of the EAP program developed by Smith (1981a). For each variable with missing values, a series of univariate regression equations was calculated for each of the other physical variables in the analysis. Obviously, for each dependent variable, all the variables in the database were not equal in their predictive ability. This predictive ability was measured by the t test for $b>0$. This method derives the best estimate of the missing values for each variable by taking a weighted average of the estimates of each equation. The weight used was t^2, which more closely approximates the corresponding probabilities than does t alone. The weighted average of estimates can be summarized as follows:

$$\mathrm{WAE} = \Sigma\ \mathrm{EST}\ (t^2)\ /\ \Sigma\ t^2$$

where: WAE = Weighted average of the estimates
EST = Estimate by one variable

Some values for (nitrite+nitrate) were interpolated for the live bottom weighted discriminant analysis. In order to make measured values of what was presumed to be nitrate compatible with the interpolated values of (nitrite+nitrate), the measured values of nitrite were added to the measured values of nitrate. Later, it was determined that the variable presumed to be only nitrate was already (nitrate+nitrite); thus the nitrite component of the variable was twice its correct value for the measured variables. Since the values of nitrite compared to nitrate are quite small, it was determined by the principal investigators and data analysts that the slightly incorrect values used had no significant effect on the results of the analysis.

3.4.3.3 Principal Components Analysis

Principal components analysis (PCA) is used to derive a reduced number of linear combinations -- principal components -- from a given set of variables. These components can then be substituted for the original variables in analyses which would otherwise be hindered by use of large numbers of variables (Smith, 1976; SAS Institute, 1982). In the present study, physical variables (a number of which were highly correlated) were subjected to PCA prior to weighted discriminant analysis. Specifics of these analyses will be discussed in Section 8.0. A brief explanation of PCA is provided below:

Assume the simplest case; two variables plotted against each other in two-dimensional Euclidean space (Figure 3-11(a)). A new origin is established at the center of the points. An axis can now be drawn through this new origin. The points of intersection of the perpendiculars (or projections) of points onto the axis are called point scores (Figure 3-11(b)). PCA operates by establishing subsequent axes such that the variance of the point scores is maximized. Each axis is orthogonal to the previous axis; hence, each axis in independent. Clearly, the number of axes cannot exceed the number of variables in the space. Also, the number of axes cannot exceed the number of points minus one. Each axis explains a portion of the total variance in the n-dimensional space. The amount of variance explained by an axis is a measure of the importance or amount of information contained within each set of scores for that axis. An axis explaining 90 percent of the total variance is clearly more important than one explaining only one percent (Smith, 1976).

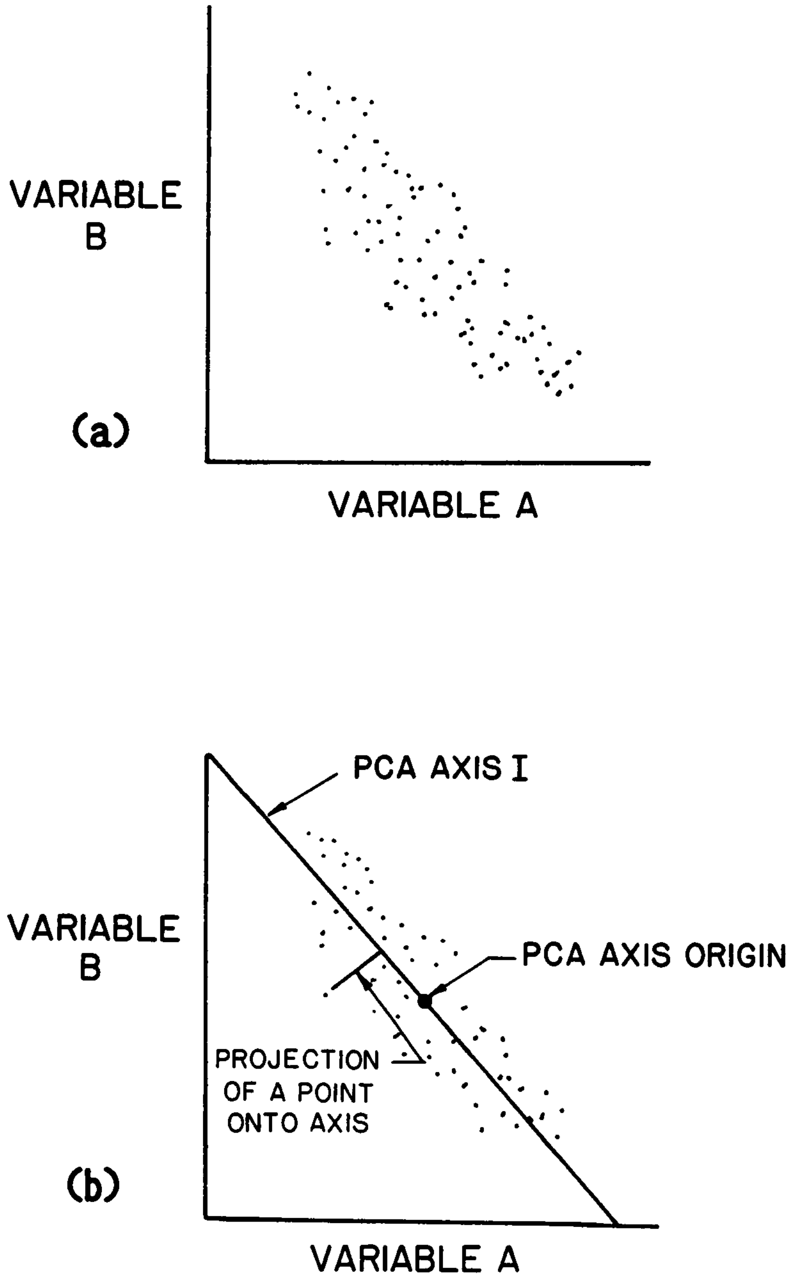

Figure 3-11. Two variable example of PCA axis and origin location, and projection of a point onto axis (see text).

The score for each point is dependent on the original coordinates of the point and the amount of axis rotation with respect to the original coordinate system. In general:

$$S_I = a_1X_{1I} + a_2X_{2I} + \ldots + a_nX_{nI}$$

$$= \sum_{j=1}^{v} a_jX_{jI}$$

Where:
S_I = scores on axis I
v = number of variables
X_{ji} = centered measurement of variable j in point i
a_j = constant for variable j

The set of a's for an axis is called an eigenvector. There is a separate eigenvector for each axis. The sum of squares of the scores on an axis is called the eingevalue of that axis; this is the value that the PCA process maximizes. Since the variables have been standardized to the same scale, the eigenvector elements give the relative importance of the different variables in determining the scores on the particular axis. Multiplication of these elements by the square root of the eigenvalue for the axis gives a vector of correlations between the axis scores and the variable values. A matrix of these correlations (i.e., all axes and variables included) is called the factor matrix, and is most important in the interpretation of PCA. A factor matrix may appear as follows:

	AXIS I	AXIS II	AXIS III
VARIABLE A	-.95	-.13	-.05
VARIABLE B	-.28	-.22	.99
VARIABLE C	-.13	.97	-.07

The correlation between Axis I scores and Variable A is -.95, meaning that sites toward the negative end of Axis I will tend to have higher values of Variable A. The relative "importance" of each variable on each axis may be inferred from the factor matrix by virtue of the amount of variance it explains on that axis. For example, Variable A is most important on Axis I, Variable C on Axis II, and Variable B is most important on Axis III. The axes explaining the majority of the overall variance in the space are chosen to represent the original variables. In the example, suppose Axes I and II explain 95% of the overall variance. We would deem Axis III as relatively unimportant and ignore it. The new variables would then be the Axis scores for Axes I and II; the number of variables has been reduced from 3 to 2. The next step is to label the axes with names descriptive of the variable(s) responsible for the greatest weighting. For example, if variable A is salinity, Axis I could be labelled "Salinity Factor" a new variable whose values are the Axis I scores.

Typically, PCA is run on logical subsets of physical data. In this project, sediment grain size and nutrient data were chosen as two subsets

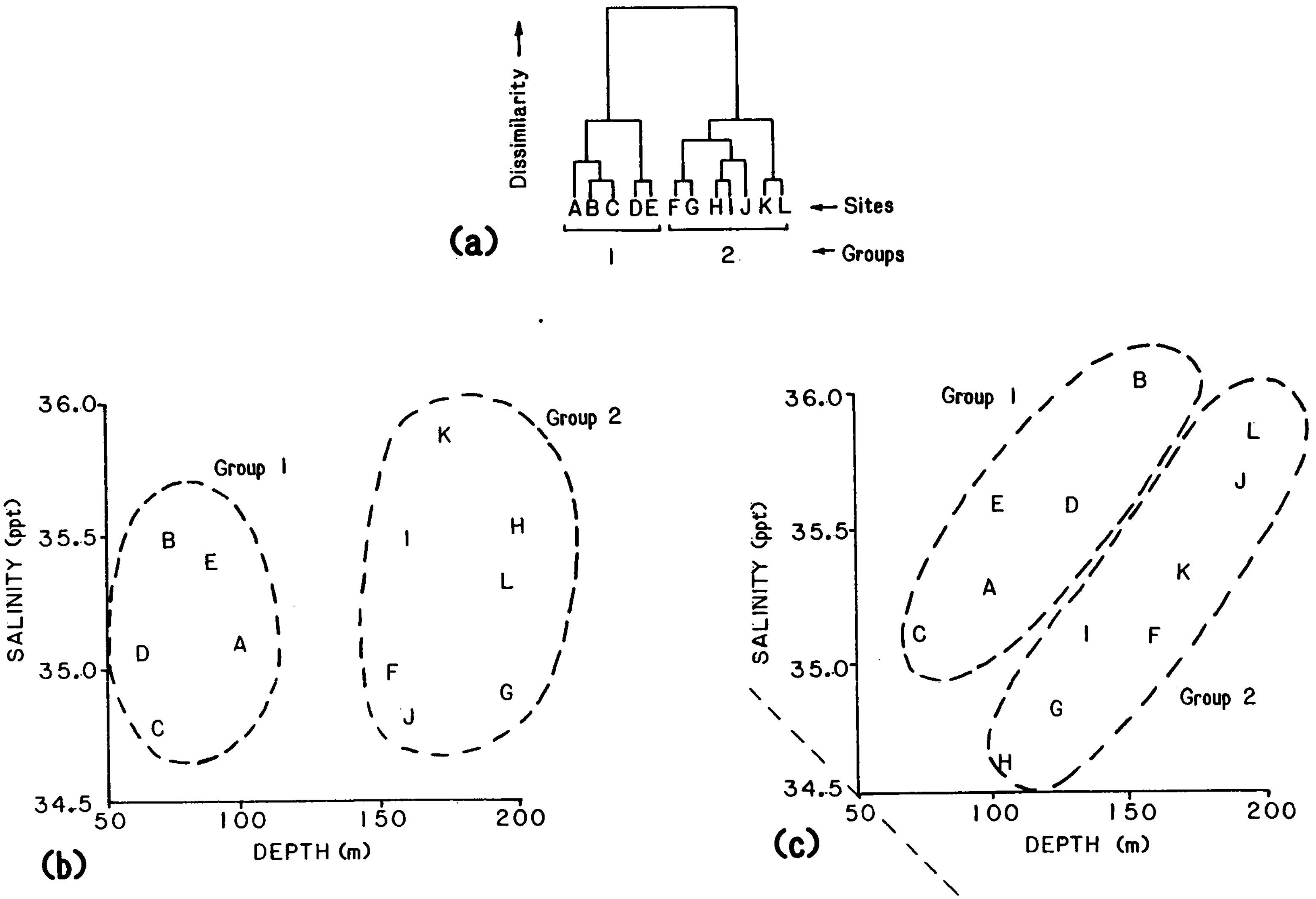

Figure 3-12. The geometry of discriminant analysis (see text).

probably not one of the environmental variables that might explain the biological separation of the two groups. Figure 3-12(c) shows another hypothetical plot with different salinity and depth values now assigned to the sites. Taken individually, the variables salinity and depth do not appear to separate the groups in this case. Considering both variables simultaneously, however, there is a strong separation, indicating that group separation is correlated with both salinity and depth.

The mathematical mechanism used by discriminant analysis to make such determinations involves the establishment of a "discriminant axis" in the environmental space, such that when the sites are projected onto this axis, they are maximally separated. In Figure 3-13, this axis could be represented by the dashed line that crosses the origin. If lines were traced from each of the sites in the space onto the axis, the points of intersection of the traces on the axis would separate the groups better than if they had been traced onto an axis in any other position. In Figure 3-12(b) the discriminant axis would be practically coincident with the x-axis (depth), in order to maximally separate the groups. This technique can handle more than 2 site groups. In Figure 3-13, two discriminant axes are required to separate the three site groups, x, y, and z. The method can also handle more than two environmental variables. With "n" environmental variables, an axis is found in n-dimensional space which maximally separates site groups.

Group separation is quantified by assigning scores to the projections of the sites onto the discriminant axis -- "discriminant axis scores." The relative strength of separation of groups is a function of these scores. For example, Figure 3-14 shows two hypothetical points, X and Y, in two-dimensional space and their point scores. Based on axis scores and the scales of the environmental variables, discriminant coefficients are generated for each discriminant axis, indicating the relative weight of each variable on the axis. The "coefficient of separate determination" is the discriminant coefficient used in this study. A measure of the "composite" variance in the environmental space explained by each axis is also calculated, thereby indicating the relative importance of each discriminant axis in explaining group separation. This statistic is referred to as a composite, as both within-group and

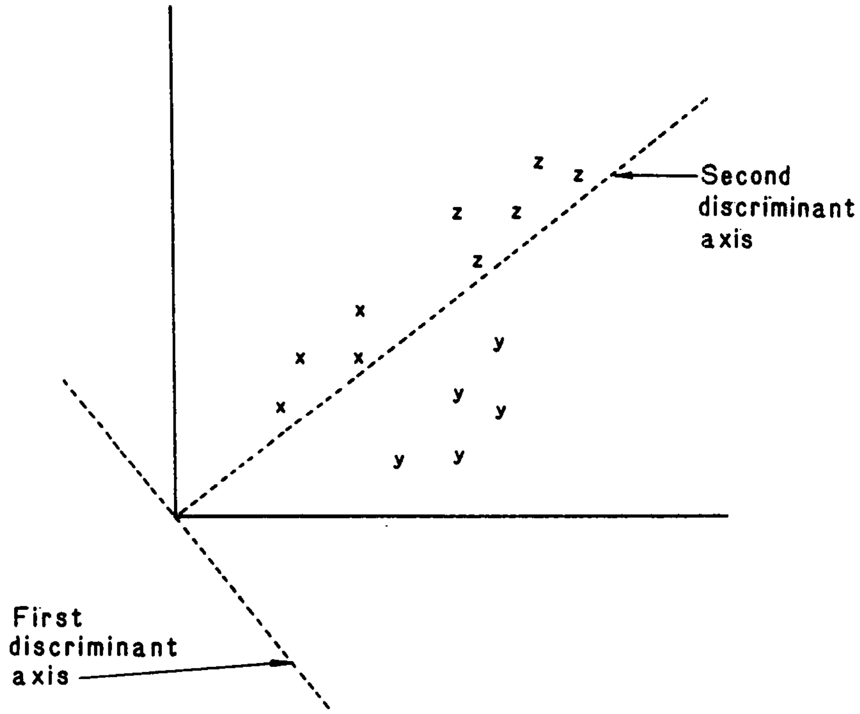

Figure 3-13. Discriminant analysis with three groups. Note that two discriminant axes are required to maximally separate the three groups. The first discriminant axis separates groups X and Z from group Y, and the second axis separates groups X and Y from group Z.

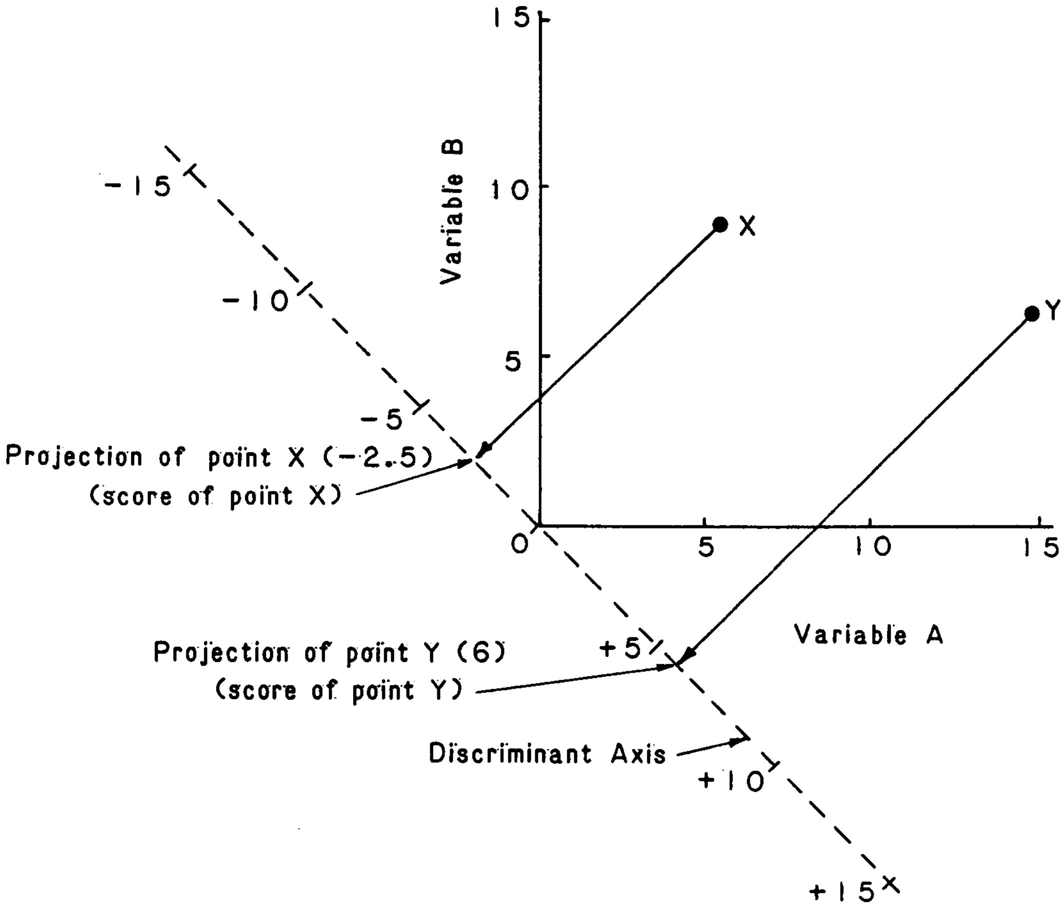

Figure 3-14. An illustration of the idea of scores as a projection of points (sites) onto a discriminant axis.

between-group variances contribute. If it is found, for example, that the first two discriminant axes explain over 95 percent of the "variance" in the space, the interpreter will probably choose to ignore subsequent axes.

Weighted discriminant analysis differs from standard discriminant analysis in that it considers relative biological distances among the groups, weighting separation of biologically dissimilar groups more strongly than similar groups (Smith, 1976).

The weighted discriminant analyses presented in this study include the coefficients of variation for each axis and environmental variable, and the cumulative percent of variance explained by each axis, as well as plot overlays. These plots are views of the site groups in environmental space, as viewed in two dimensions across two of the discriminant axes. Groups are circled and labeled, and the values of environmental variables can be overlayed onto the site positions. Since space prohibits the printing of the actual environmental parameter value, a relative value is printed, ranging from 1 to 9, based on the minimum and maximum values of the variable.

4.0 HYDROGRAPHY

4.1 INTRODUCTION

Hydrographic parameters play an important role in determining the biological and ecological features of a marine ecosystem. To assess the ecological characteristics of the southwest Florida continental shelf more accurately, hydrographic data were collected during Year Two Summer (July 16 - August 5, 1981) and Winter (January 28 - February 15, 1982) Cruises in support of benthic biological data collection.

Hydrographic measurements included temperature, salinity, dissolved oxygen, transmissivity, light penetration, nutrients, and chlorophyll a. Temperature, salinity, and dissolved oxygen are interrelated 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 to separate water masses. Although densities are not reported in this text, the term pycnocline is used to denote 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. Water clarity can affect the growth of marine algae 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 nutrient concentrations available to phytoplankton. The concentrations of these important nutrients may limit or stimulate the growth of various phytoplankton species. Chlorophyll a measurements are indicative of the standing crop of phytoplankton. The phytoplankton are the basis for pelagic food chains and indirectly contribute to benthic production as well.

This section of the report is a continuation of the Year One water column data analysis. A general description of the oceanography on the southwest Florida shelf is presented in the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983) and has not been duplicated here. The present analysis details the results of Year Two Summer and Winter Cruises and then summarizes the results of all four cruises that were conducted during the two-year field study period. Together these data represent only four short sampling periods in specific geographic areas of the shelf and they are therefore of limited use in inferring broad seasonal trends for the region.

The Year Two Summer and Winter Cruises followed a different sampling scheme from that used during the Year One Fall 1980 and Spring 1981 Cruises. During Year One, hydrographic data were collected from all thirty benthic sampling stations on both cruises. Financial constraints reduced the number of hydrographic stations to fifteen on each of the Year Two cruises. Allowance also had to be made for sampling the deeper-water (100 to 200m depths) portions of study transects A through E, not included in the previous Year One sampling program.

The final Year Two hydrographic sampling pattern therefore included three stations along each east-west study transect. Ten previously sampled Year One stations were reoccupied; and one new station was added at the offshore end of each study transect at the water depth of approximately 150m. This provided inner shelf, middle shelf, and outer shelf/slope sampling locations (Figure 4-1).

Since the distances between sampling stations were greater than in Year One, broader interpolation had to be used to develop hydrographic contours across the shelf. Wherever reasonable, Year Two interpolation was designed to maintain continuity between the Year One and Year Two data sets.

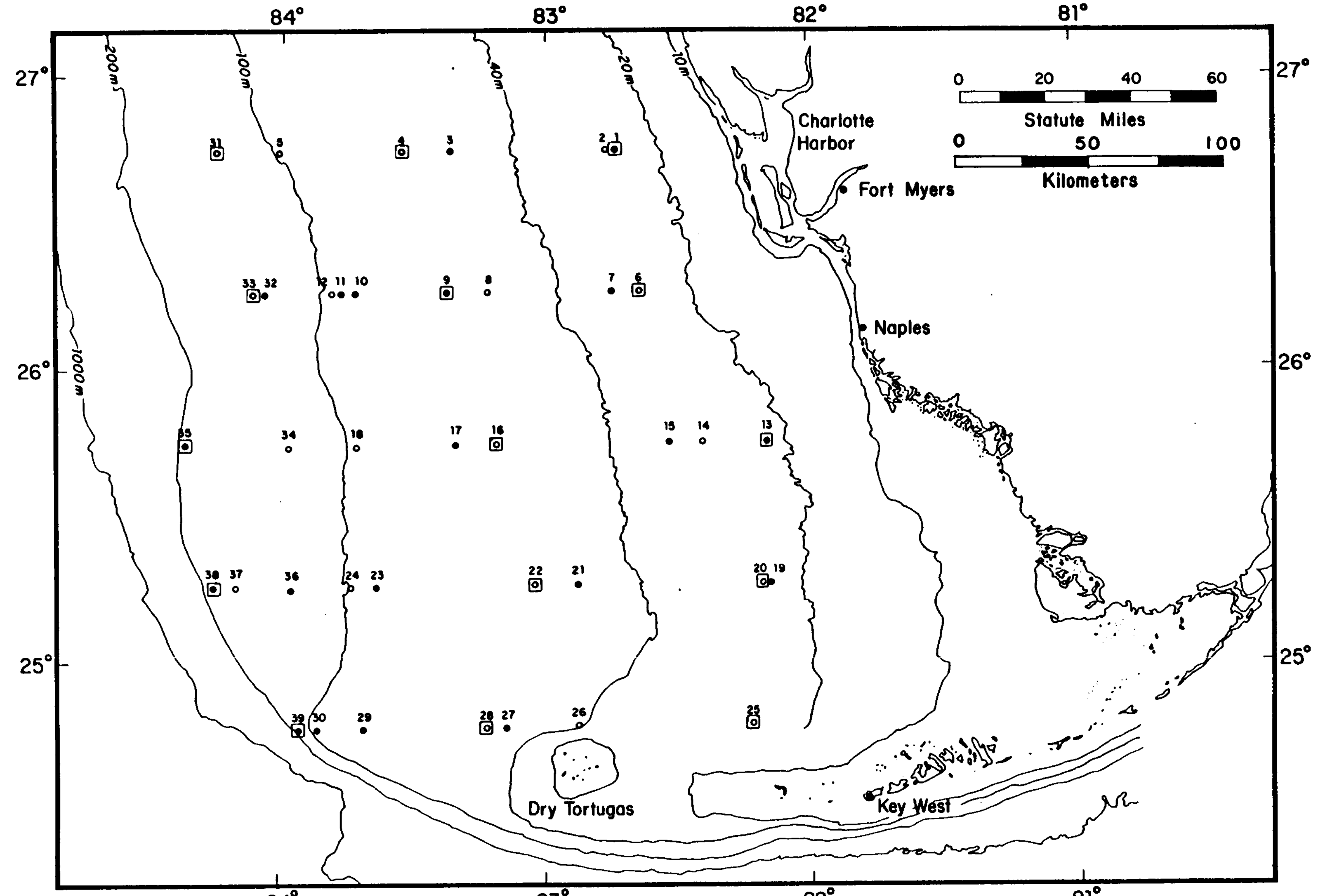

Figure 4-1. Year Two hydrographic sampling stations (□).

4.2 MATERIALS AND METHODS

4.2.1 Weather and Wave Conditions

Observations of weather and sea conditions were recorded every four hours and at the time of sampling on station. Observations included weather elements (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 judgment of an observer were coded according to the 1972 World Meteorological Organization Guidelines. All data were recorded in a Marine Coastal Weather Log (NOAA Form 72-5b). Times were recorded as local times and later converted to Greenwich Mean Time.

4.2.2 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 (Figure 4-2). The manufacturer's stated accuracies are ± 2% of range (0 to 100m) for depth, ± 0.25°C for temperature, ± 0.5% of full scale (0 to 100 μmho/cm) 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. Temperature was calibrated at two depths using an ASTM thermometer. All measurements were made at 10m intervals throughout the water column, with the deepest reading usually recorded within 1.5m of the bottom.

One successful hydrocast was also performed at each station using five-litre Niskin bottles spaced at 10m intervals. The near bottom bottle was placed at 1.5m 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. 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.

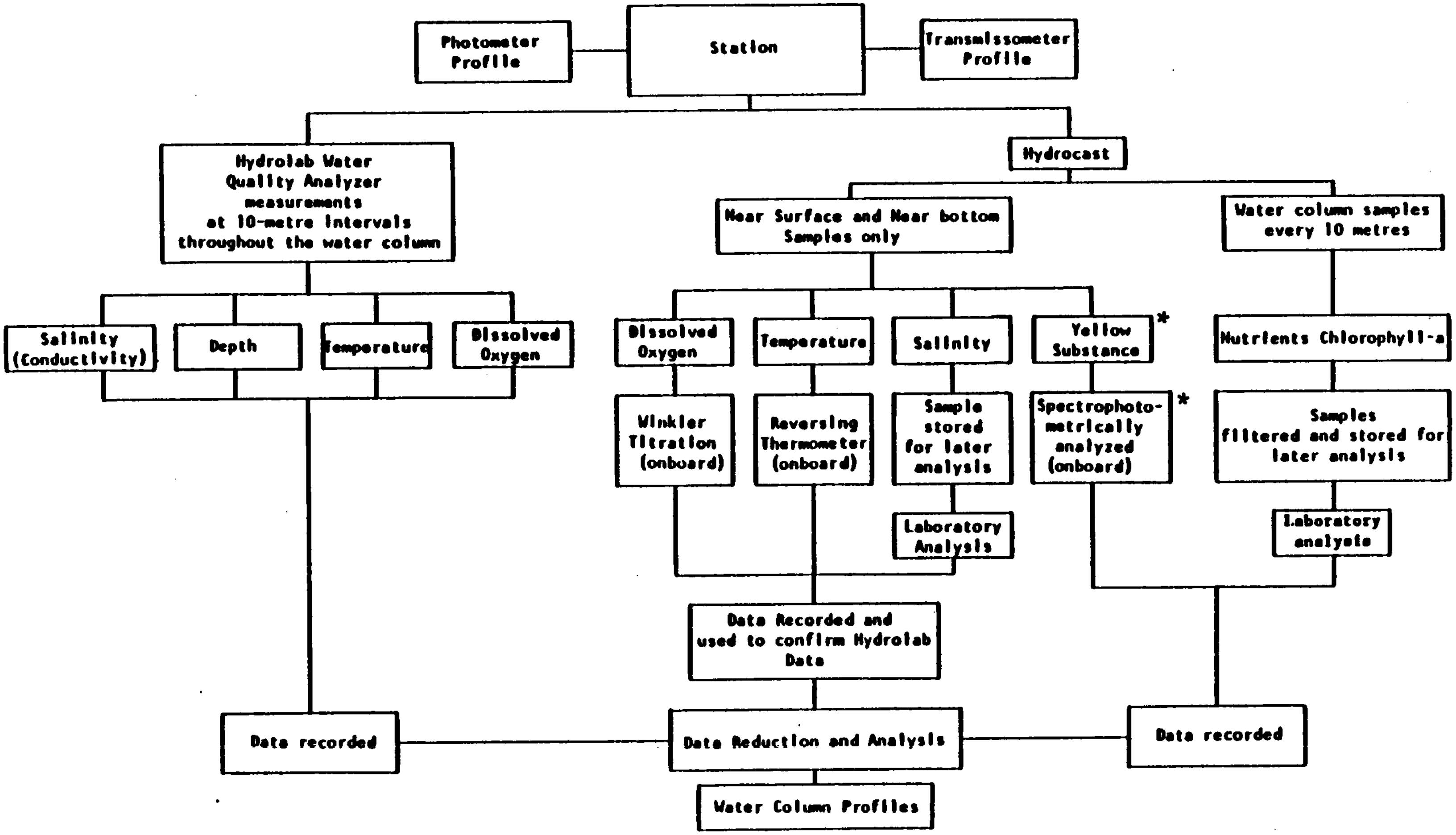

Figure 4-2. Summary of field and laboratory methodology for hydrographic parameters (* measured during Year One only).

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

The hydrocast salinity samples were stored in glass bottles and analyzed in the laboratory using a Guildline Autosal Model 8400 induction salinometer.

4.2.3 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 (300m) for depth. One successful lowering was made at each station. Transmissivity was recorded at five-metre intervals throughout the water column and within 1.5m of the bottom.

4.2.4 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. Readings were taken at five-metre intervals throughout the euphotic zone.

4.2.5 Nutrients

Water samples for nutrients (phosphate, nitrite, nitrate, and dissolved silica) were collected by hydrocast at each station (Figure 4-2). Samples were obtained using five-litre Niskin bottles at 10m intervals throughout the water column. The deepest sample was usually collected within 1.5m of the bottom. Approximately 200ml of water from each bottle were filtered (0.45μm pore size, 47mm diameter Nuclepore filters) and the filtrates frozen in four-ounce polyethylene bottles.

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

4.2.6 Chlorophyll a

Water samples for chlorophyll a were collected from each Niskin bottle in the hydrocasts (Figure 4-2). 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 a dark desiccator at -20°C. There is mounting evidence that the standard methods of filtration (i.e., glass fiber filters) allow pico- and ultraplankton to pass through the filters. This suggests that most measurements of primary productivity (i.e., Carbon-14) and chlorophyll may be erroneous. However, the standard methods were used in this study in order to allow comparison with published literature values.

In the laboratory, the filters were extracted and analyzed using procedures outlined by Strickland and Parsons (1972c). The analysis methods included: (1) fluorometry for chlorophyll a and phaeophytin; (2) spectrophotometry using the trichromatic equation for chlorophyll a; and (3) spectrophotometry using the acidification method for chlorophyll a and phaeophytin.

4.3 RESULTS

4.3.1 Weather and Wave Observations

No inclement weather problems were encountered during the Summer Cruise. Wind directions were primarily from the south and east. Wind speeds were generally in the 9 to 18km/hr (5 to 10kn) range, with occasional maxima to 37km/hr (20kn) from the southeast. Air temperatures averaged about 29°C with a relatively steady barometric pressure of about 1009mb. Eight brief periods of intermittent showers were recorded. Wave heights varied from 0.3 to 0.6m; swell heights were usually less than 0.9m, except for brief periods when they reached as high as 1.5 to 2.1m.

Approximately 20 hours of Winter Cruise time delay were experienced between January 29 and 31, 1982 because of inclement weather. Winds from the east-southeast between 46 and 74km/hr (25 to 40kn) were accompanied by 2.7 to 3.6m swell and 0.6m wind waves. Following that initial cruise period, winds dropped to generally less than 37km/hr (20kn) with 0.9 to 1.5m swell running from the east or northeast. Air temperatures averaged about 24°C with a barometric pressure of about 1016mb.

4.3.2 Temperature

Temperatures during the Summer Cruise (Figure 4-3) ranged from a maximum of 30.6°C in the surface mixed layer (Transect A) to a minimum of 12.6°C below the thermocline (Transect E). Temperatures in the surface mixed layer (10 to 30m depth) were relatively uniform across the transects at 28.0 to 30.6°C. The thermocline extended to the 25 to 35m isobaths on Transects C through E, whereas on Transects A and B the thermocline extended shoreward of the near-shore stations (~25m isobath). The surface-to-bottom change in temperature at the offshore stations was 13° to 17°C. The compaction of isolines suggests a moderately sharp thermocline on all transects.

Temperature during the Winter Cruise (Figure 4-4) ranged from 24.5°C (Transect C) in the surface mixed layer to 14.0°C (Transect E) below the thermocline. Temperatures in the mixed layer increased by approximately 3°C from Transect A to E. The mixed layer extended to approximately the 60m isobath on Transects A and B and to the 20 to 40m isobaths on Transects D and E; Transect C had a mixed layer that varied from 10 to 13m depth. The thermocline was only weakly developed. The shoreward edge of the thermocline ranged from the 40 to 60m isobath. Transects A and C had only a 4°C maximum difference between surface and bottom whereas at the other transects the difference was between 6 and 10°C.

4.3.3 Salinity

Salinities measured during the Summer Cruise (Figure 4-5) varied from 35.5 o/oo on Transect A to 36.5 o/oo on Transect C. Low salinity pockets were observed at the mid-shelf station on Transects A, B, and D; the pockets

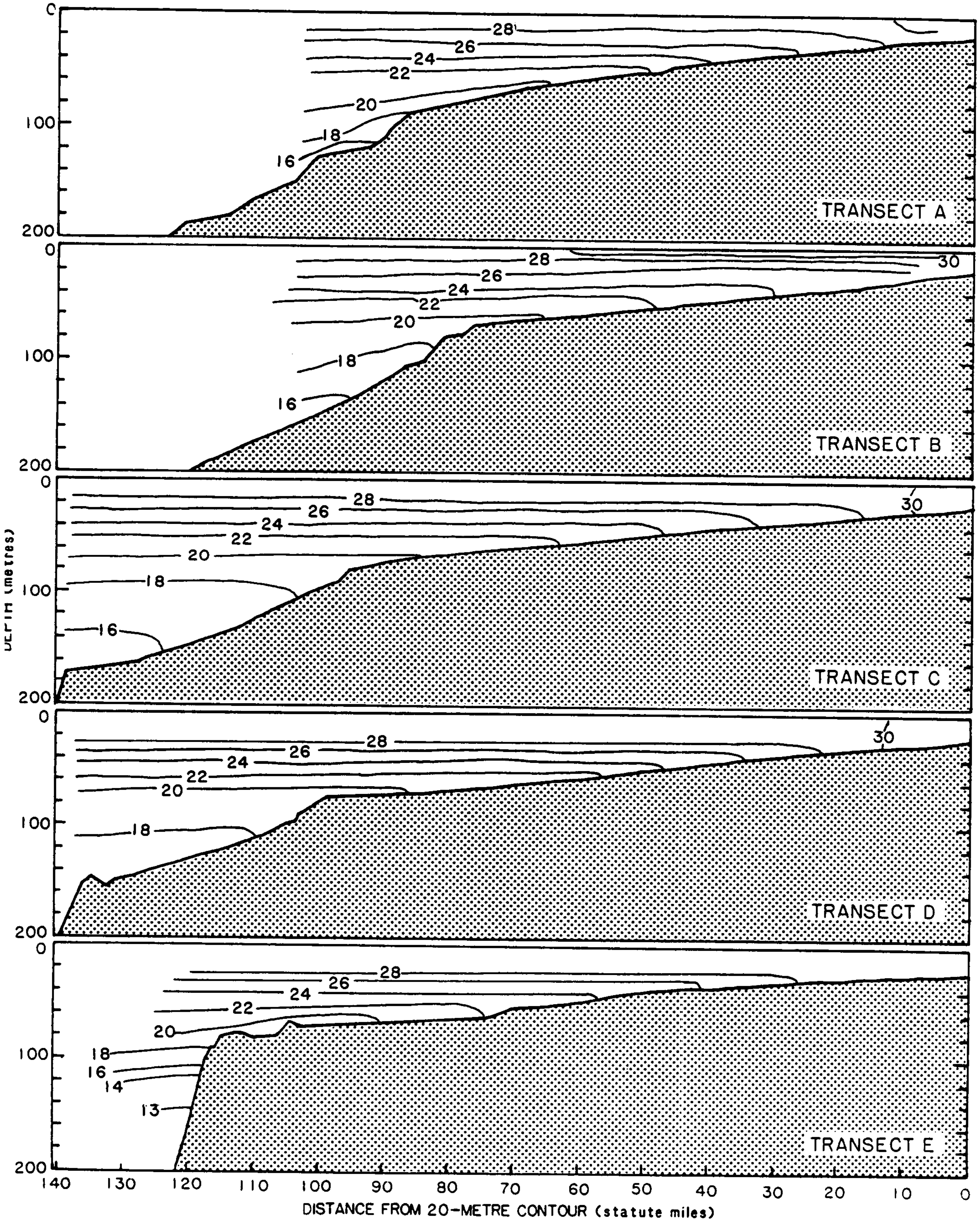

Figure 4-3. July-August 1981 temperature (°C) cross-sections.

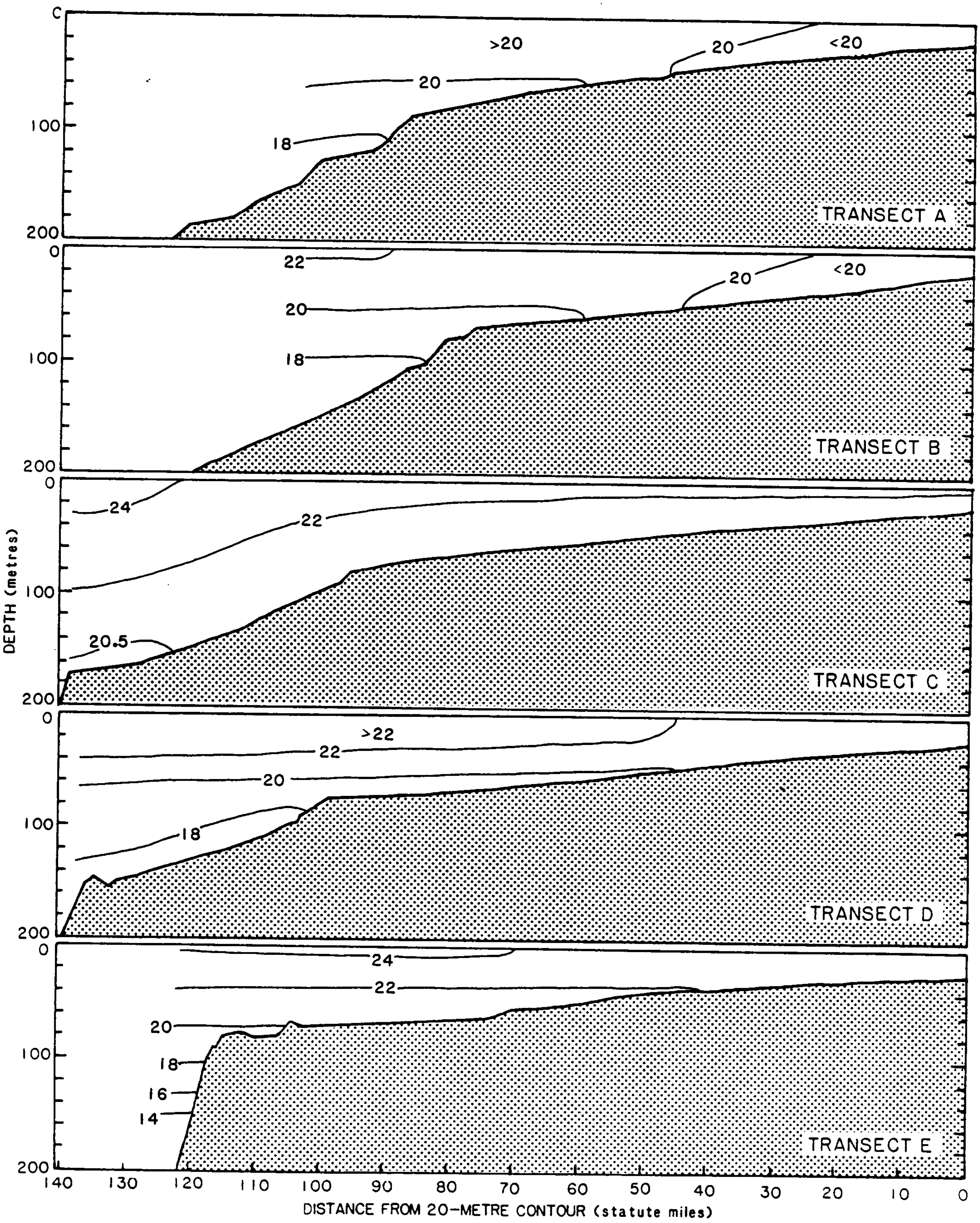

Figure 4-4. January-February 1982 temperature (°C) cross-sections.

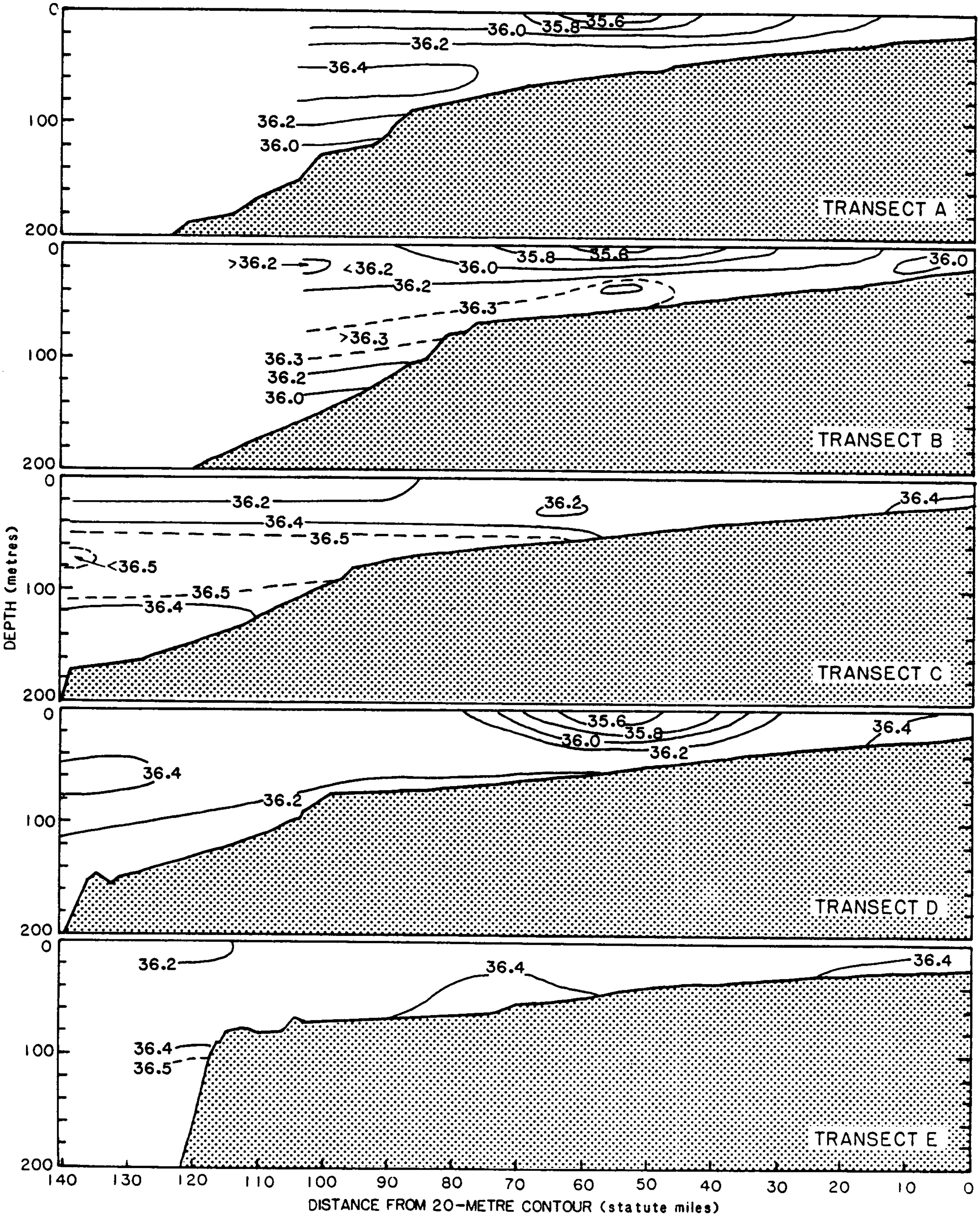

Figure 4-5. July-August 1981 salinity (o/oo) cross-sections.

extended to 10 to 30m depths. There was no corresponding pattern in the temperature profiles. Surface salinities decreased in an offshore direction. Intrusions of higher salinity water (36.4 o/oo) were observed at the offshore stations on Transects A, B, D, and E. These intrusions varied in depth (only Station 39 was near-bottom) and had no consistent temperature pattern. Near-shore salinities of Transects C, D, and E were high (>36.4 o/oo) but these stations had summer coastal water temperatures of 29 to 30°C. At the near-shore stations on Transects A and B, where the bottom thermocline was evident, the salinity profiles did not indicate any areas of high salinity.

Near-shore salinities during the Winter Cruise (Figure 4-6) ranged from 36.37 o/oo on Transect E to 36.59 o/oo on Transect D. On all transects the near-shore salinities were the highest, and surface salinities decreased in an offshore direction. On Transects A through D, the near-shore 36.4-0/00 isohaline patterns suggest an offshore movement of the cooler, higher-salinity waters. An intrusion of high salinity water was observed at Station 35 on Transect C at the 60m depth. The surface waters at Station 35 had the lowest salinity observed (35.9 o/oo).

4.3.4 Transmissivity

During the Summer Cruise, transmittance was consistently high and varied little with depth (Figure 4-7). Maximum transmittance (96%) was measured at the surface on Station 39; minimum transmittance was 87%, noted at Stations 1, 13, 22, and 25. Water clarity was generally lower near the bottom, but no well-developed nepheloid layer was observed.

Winter transmittance values (Figure 4-8) ranged from 64% (turbid) at Station 33 to 95% at Stations 33, 38, and 28. Low transmittance values near the bottom at Stations 33 and 25 suggest a current capable of sediment resuspension. Water clarity generally decreased near the bottom on all transects. Transmittance was not consistently related to either water temperature or salinity.

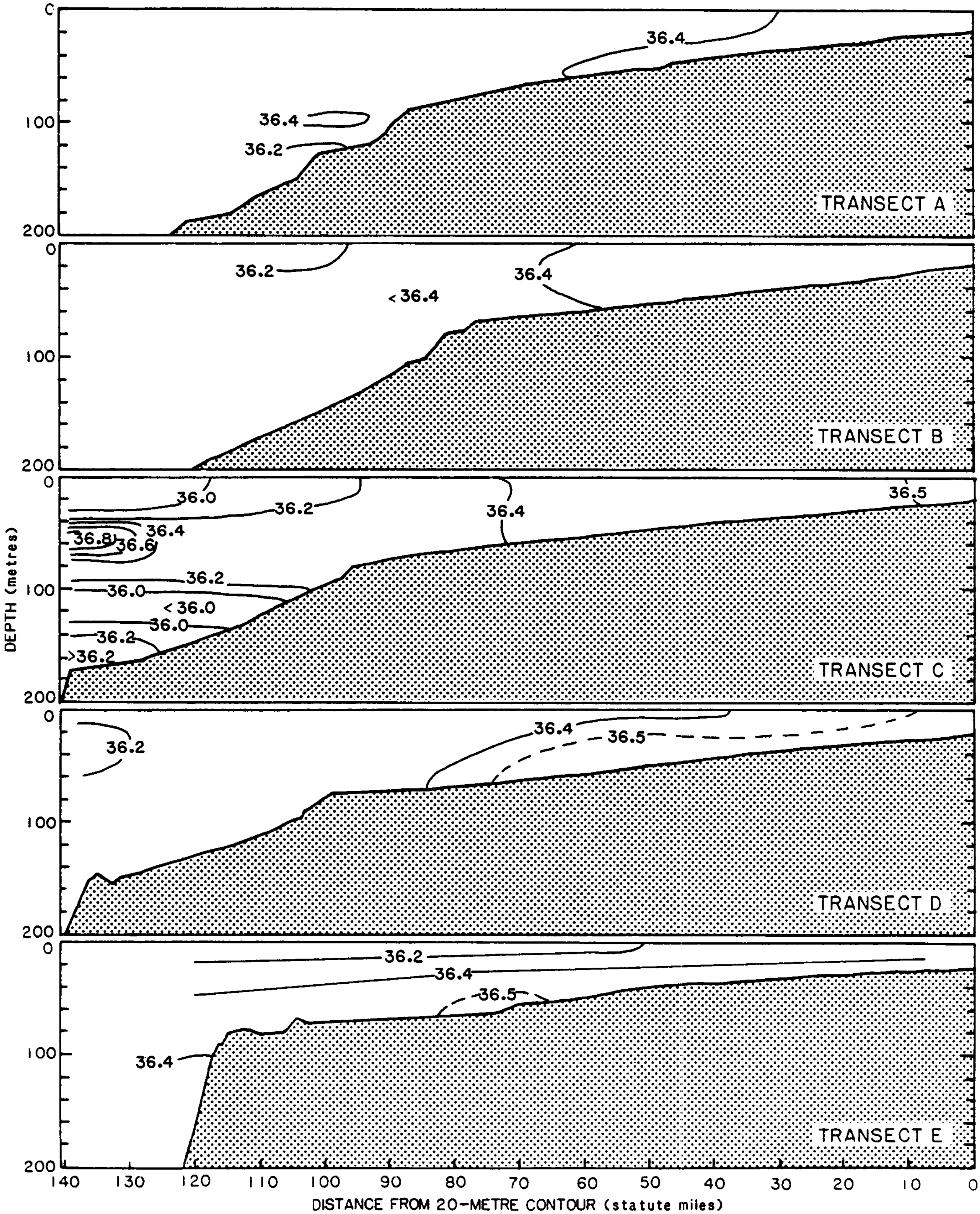

Figure 4-6. January-February 1982 salinity (o/oo) cross-sections.

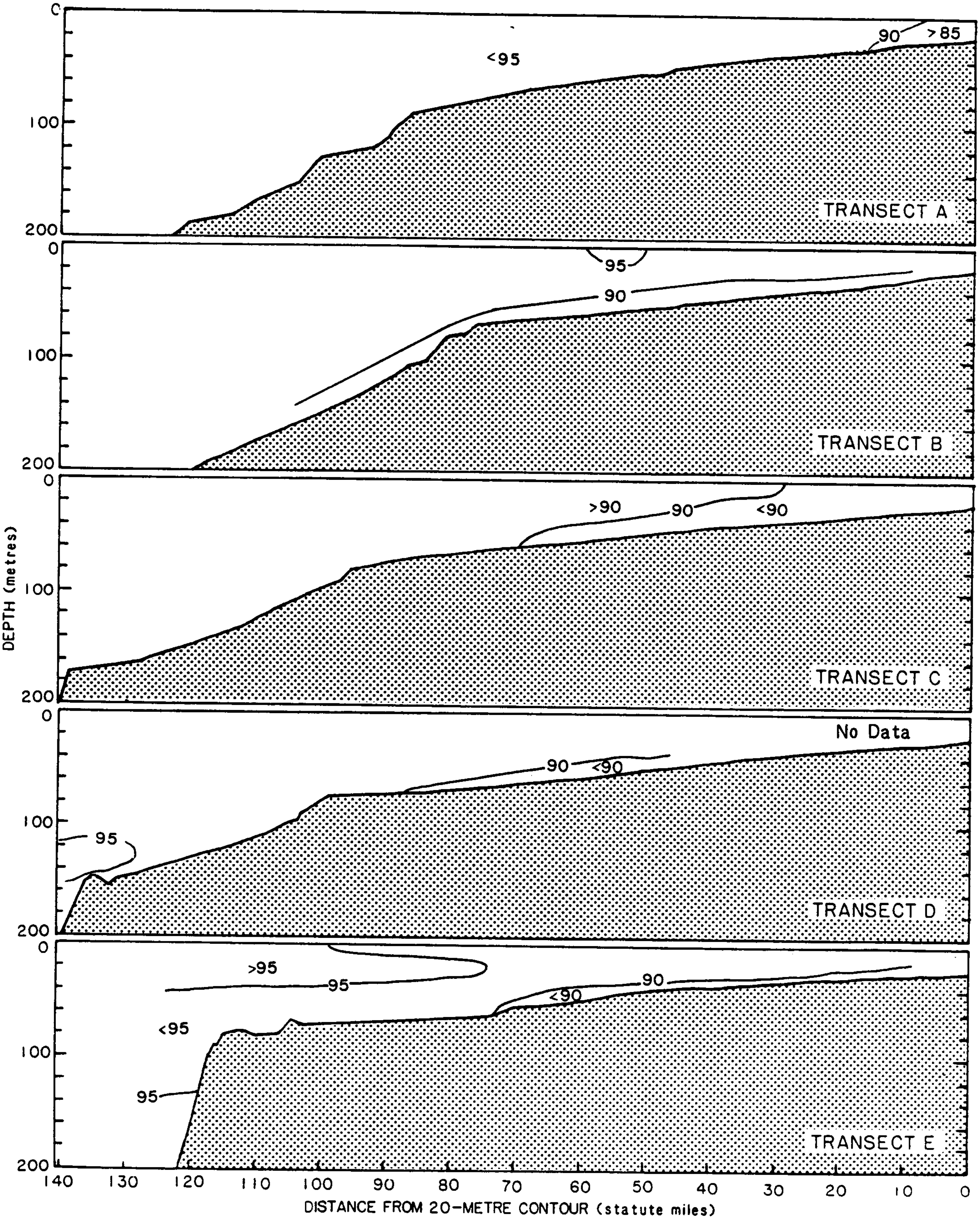

Figure 4-7. July-August 1981 transmissivity (%T) cross-sections.

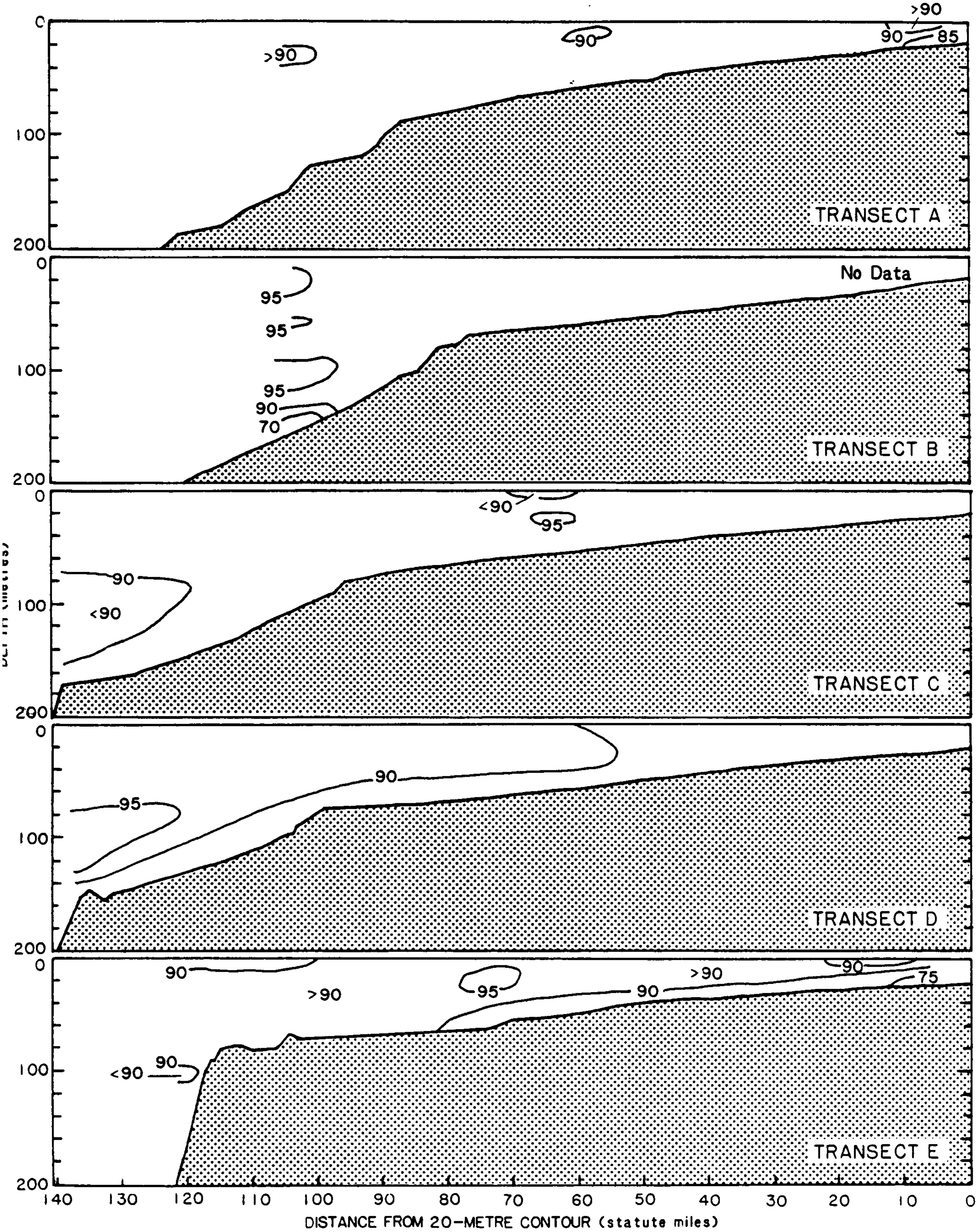

Figure 4-8. January-February 1982 transmissivity (%T) cross-sections.

4.3.5 Dissolved Oxygen

Summer dissolved oxygen values (Table 4-1) ranged from 6.72 ml/l to 3.90 ml/l. Low values were found near the bottom at the offshore station on all transects. These values are consistent with those of previous research and are typical of waters found below the salinity maximum in the eastern Gulf of Mexico. The mid-shelf stations all exhibited a slight increase in oxygen near the bottom, whereas at the near-shore stations oxygen values were homogeneous throughout the water column.

The winter oxygen values (Table 4-1) ranged from 6.96 to 4.30 ml/l. The lowest values were found near the bottom at the offshore stations. The mid-shelf and inner shelf stations were essentially homogeneous throughout the water column with respect to oxygen levels. Values at Station 35 (offshore) did not show the near-bottom decrease in oxygen typical of the other offshore stations. This deviation was consistent with the salinity and temperature results at this station.

4.3.6 Light Penetration

The photometer data have been reviewed and the winter data omitted because of apparent and uncorrectable errors. The summer data are presented (Table 4-2) as profiles for the stations sampled. The one-percent light penetration level occurred at between 50 and 70m depth. At inner and mid-shelf stations the one-percent level was not reached prior to bottom interception.

4.3.7 Nutrients

During the Summer Cruise, concentrations of dissolved micronutrients, phosphate (PO_4-P), nitrite and nitrate (NO_2-NO_3-N), and silica (SiO_2) were minimal in the upper 40 to 60m on all transects. PO_4-P (Figure 4-9) ranged from 0.0 µM (below detection) in the mixed layers to 1.2 µM (Station 39) near the bottom. All of the offshore stations had gradually increasing values of PO_4-P below the thermocline. Mid-shelf and inner shelf stations were homogeneous and <0.1 µM except for occasional small increases (<0.2 µM) near the bottom.

Table 4-1. Year Two dissolved oxygen concentrations.[1]

Cruise	Transect	Station	Depth (M)	Near-Surface oxygen (ml/l)	Near-Bottom oxygen (ml/l)
SUMMER	A	1	24	5.94	6.25
		4	56	5.71	6.14
		31	142	5.71	4.17
	B	6	26	5.88	6.72
		9	56	5.69	6.08
		33	146	5.83	4.02
	C	13	20	5.99	5.82
		16	54	5.72	6.30
		35	159	5.84	4.46
	D	20	22	5.68	5.61
		22	52	5.84	6.08
		38	159	5.83	4.14
	E	25	24	5.47	5.67
		28	58	5.81	6.02
		39	152	5.80	3.90
WINTER	A	1	24	6.91	6.95
		4	56	6.66	6.55
		31	142	6.66	4.37
	B	6	26	6.93	6.96
		9	56	6.72	6.64
		33	146	6.71	4.41
	C	13	20	6.96	6.79
		16	54	6.70	6.57
		35	159	6.39	6.39
	D	20	22	6.92	6.80
		22	52	6.62	6.44
		38	159	6.64	4.51
	E	25	24	6.71	6.69
		28	58	6.60	6.50
		39	152	6.59	4.30

[1] Values represent the means of two replicates.

Table 4-2. Summer Cruise photometer data. Values represent percent light remaining (% of ambient) at stations and depths indicated.

Depth (m)	Station						
	1	20	9	28	33	35	39
1.5	44	45	50	35	51	51	40
5	34	29	32	28	33		26
10	17	18	20	24	23	23	22
15	12	12	15	21	19		16
20	6	7	11	18	15	20	12
25	5	5	9	16	11		8
30			6	14	9	11	6
35			5	12	7		5
40			3	10	6	9	3
45			2	9	5		2
50			1	8	4	7	1
55				7	3		
60						4	
65							
70						1	

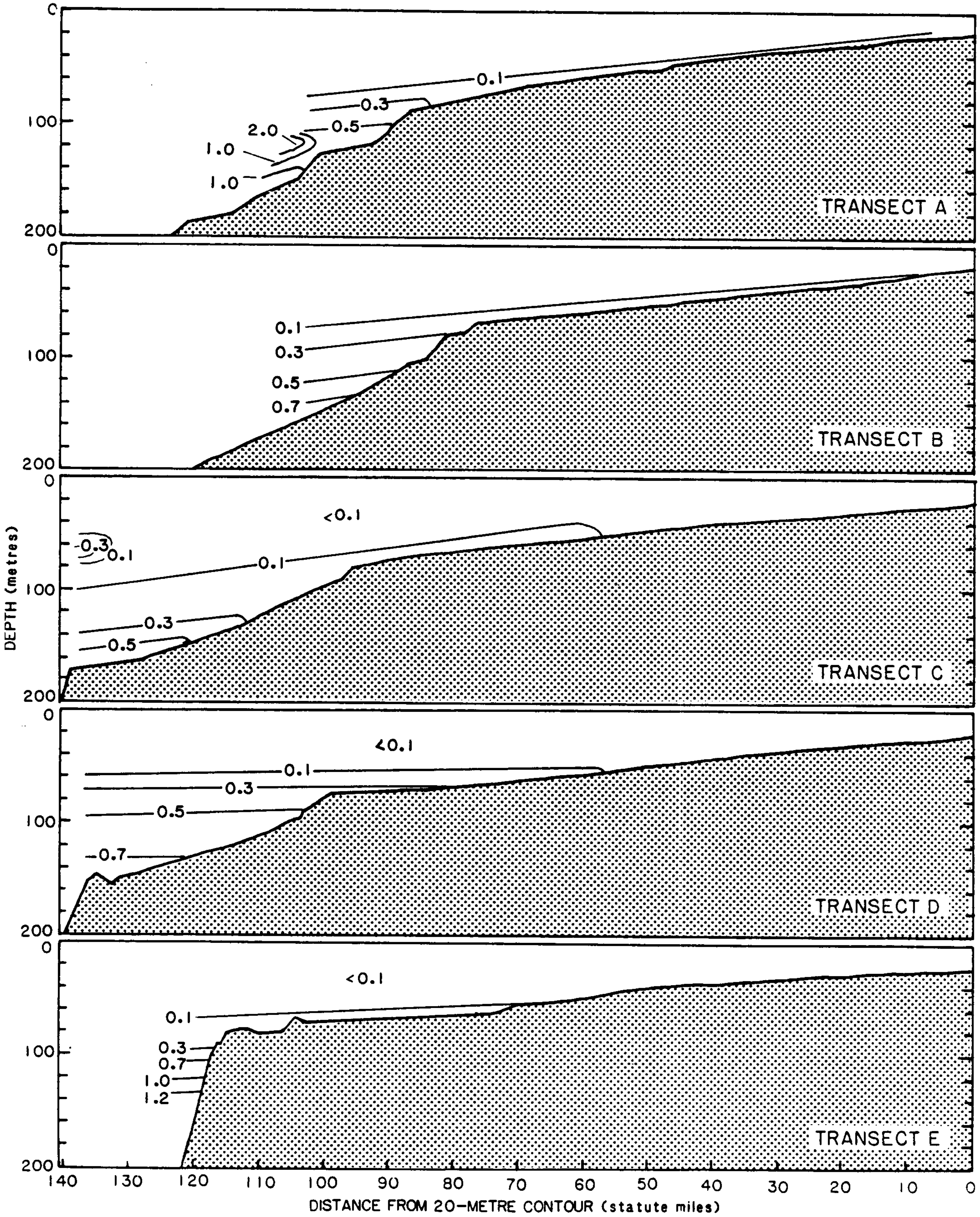

Figure 4-9. July-August 1981 phosphate (μM) cross-sections.

The concentrations of NO_2-NO_3-N (Figure 4-10) ranged from 0.0 μM (below detection limits) in the surface mixed layer to 20.4 μM below the thermocline at Station 39. The mixed layer ranged from 0.0 μM to 0.3 μM and generally averaged less than 0.2 μM. The offshore stations all had higher values at corresponding depths compared to the mid-shelf and inner shelf stations. For example, at the 57m depth at Station 33, NO_2-NO_3-N was 3.8 μM whereas the 58m depth at Station 9 on the same transect was 0.3 μM. A pulse of high NO_2-NO_3-N was found at the 60 to 80m depths at Station 35. An increase in PO_4-P was also observed and corresponded to the NO_2-NO_3-N increase.

Dissolved silica values (Figure 4-11) ranged from 0.4 μM in the mixed layer to 10.5 μM near the bottom, below the thermocline at Station 39. The mixed layer values ranged from 0.4 μM to 1.5 μM. At the mid-shelf stations on Transects C, D, and E, Silicate values in the mixed layer were lowest for those transects. Below the thermocline, Silicate increased gradually with decreasing temperature and increasing depth. A high Silicate pocket was observed near the bottom at Station 6 and throughout the water column at Station 25.

Phosphate (PO_4-P) during the Winter Cruise (Figure 4-12) ranged from 0.0 μM (below detection) in the mixed layer to 1.0 μM below the thermocline. The surface and mixed layer values were <0.1 μM with the exception of Station 31, where values as high as 0.3 μM were observed. PO_4-P increased gradually below the thermocline. This did not occur at Station 35, where values did not exceed 0.22 μM. This station also did not have as pronounced a thermocline as did the other study transects.

Nitrate (NO_2-NO_3-N) during the Winter Cruise (Figure 4-13) ranged from a minimum of 0.0 μM (below detection limits) in the mixed layer to a maximum of 16.1 μM below the thermocline (Station 39). Mixed layer values ranged from 0.0 to 0.3 μM. As expected, NO_2-NO_3-N increased below the thermocline with decreasing temperatures. As observed for PO_4-P, the concentrations of NO_2-NO_3-N at Station 35 did not decrease with depth as observed at the other offshore stations.

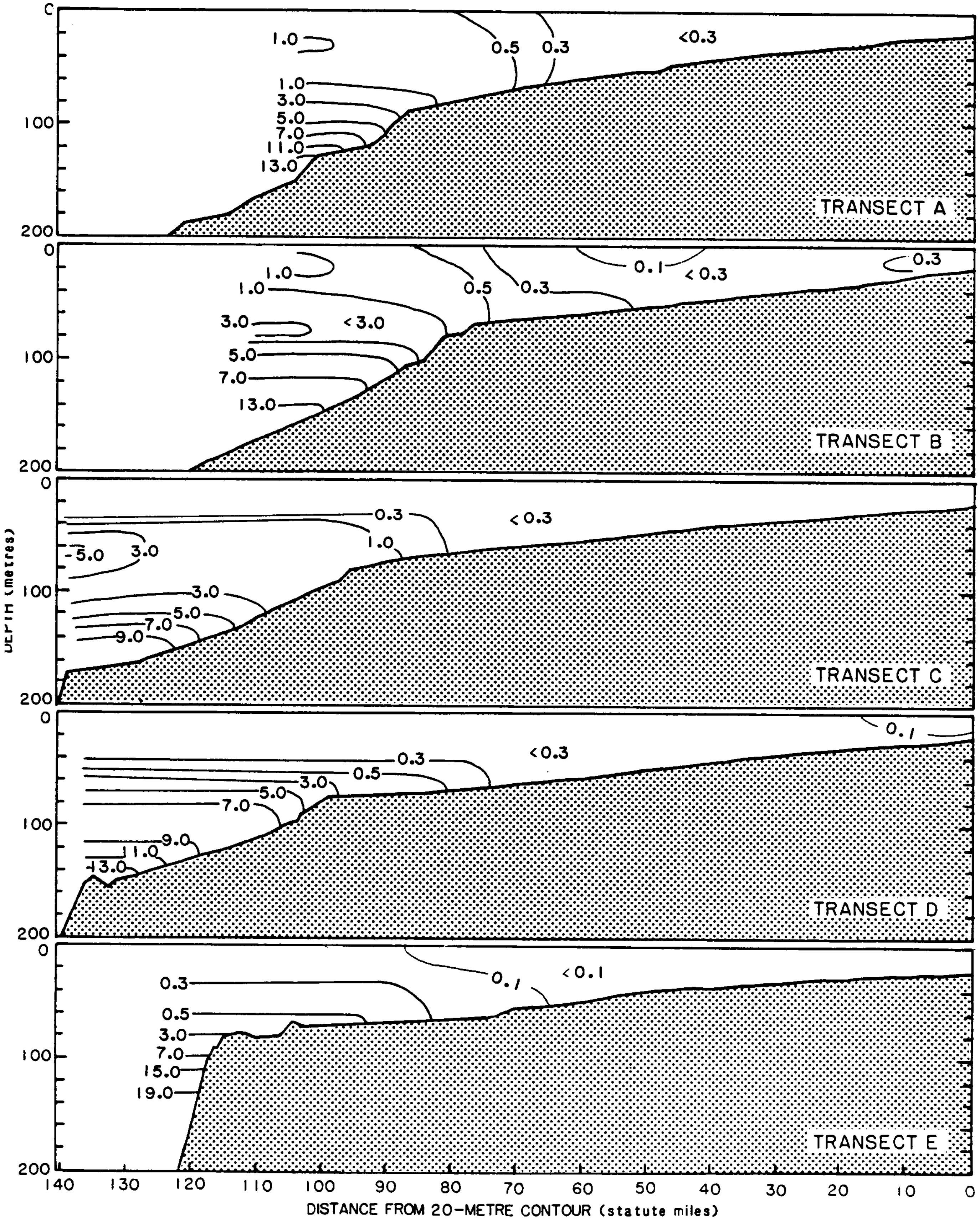

Figure 4-10. July-August 1981 nitrite + nitrate (μM) cross-sections.

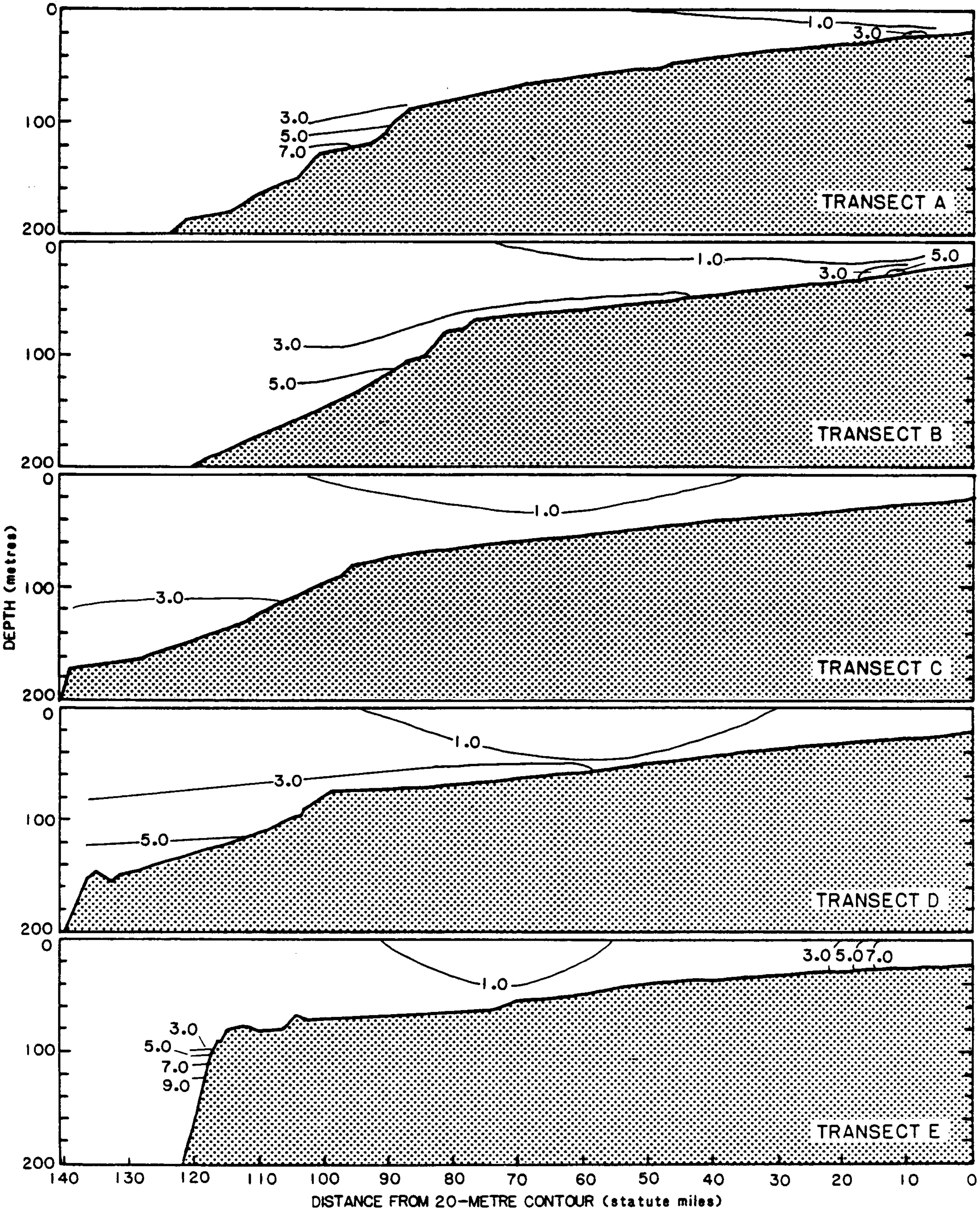

Figure 4-11. July- August 1981 dissolved silica (μM) cross-sections.

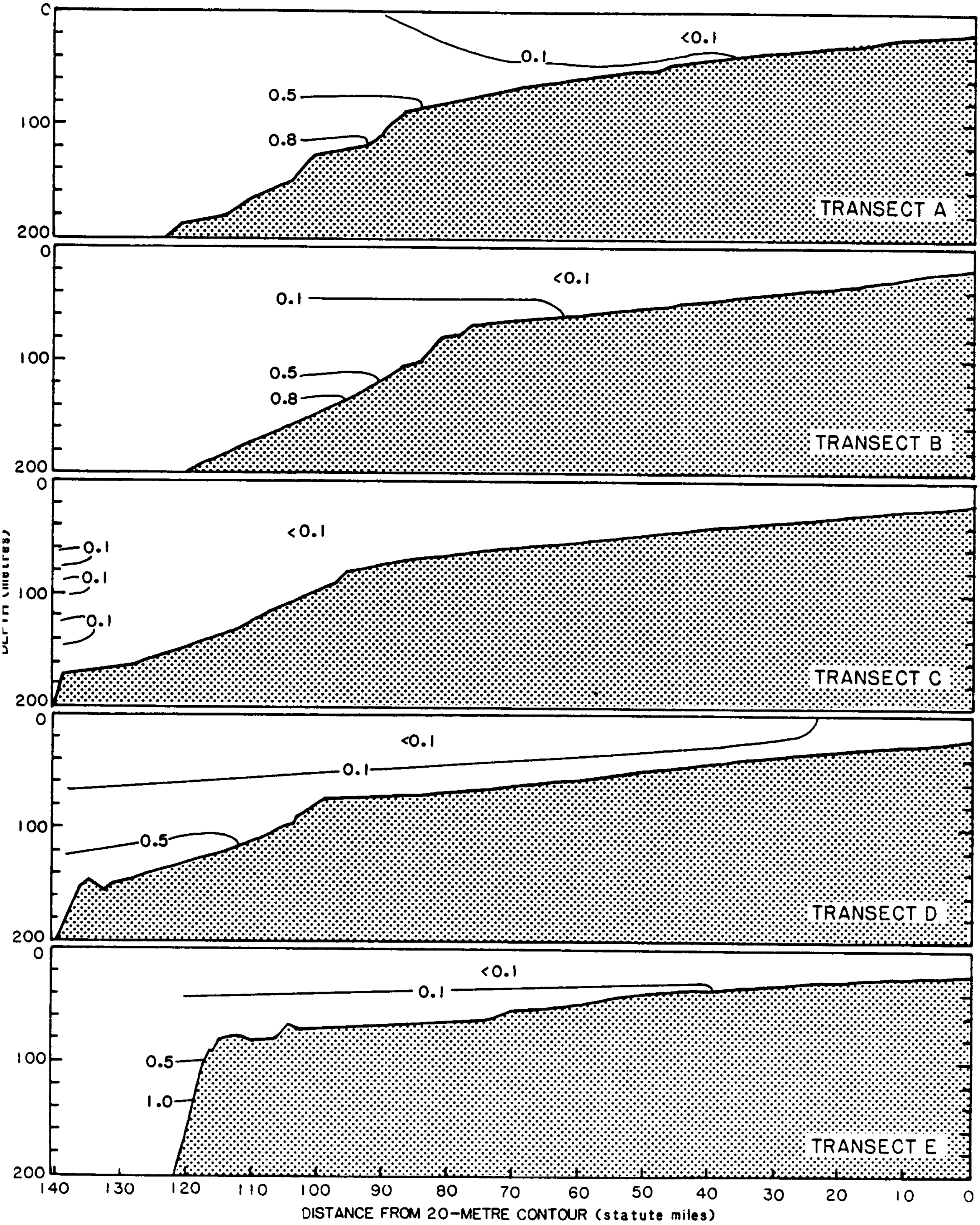

Figure 4-12. January-February 1982 phosphate (μM) cross-sections.

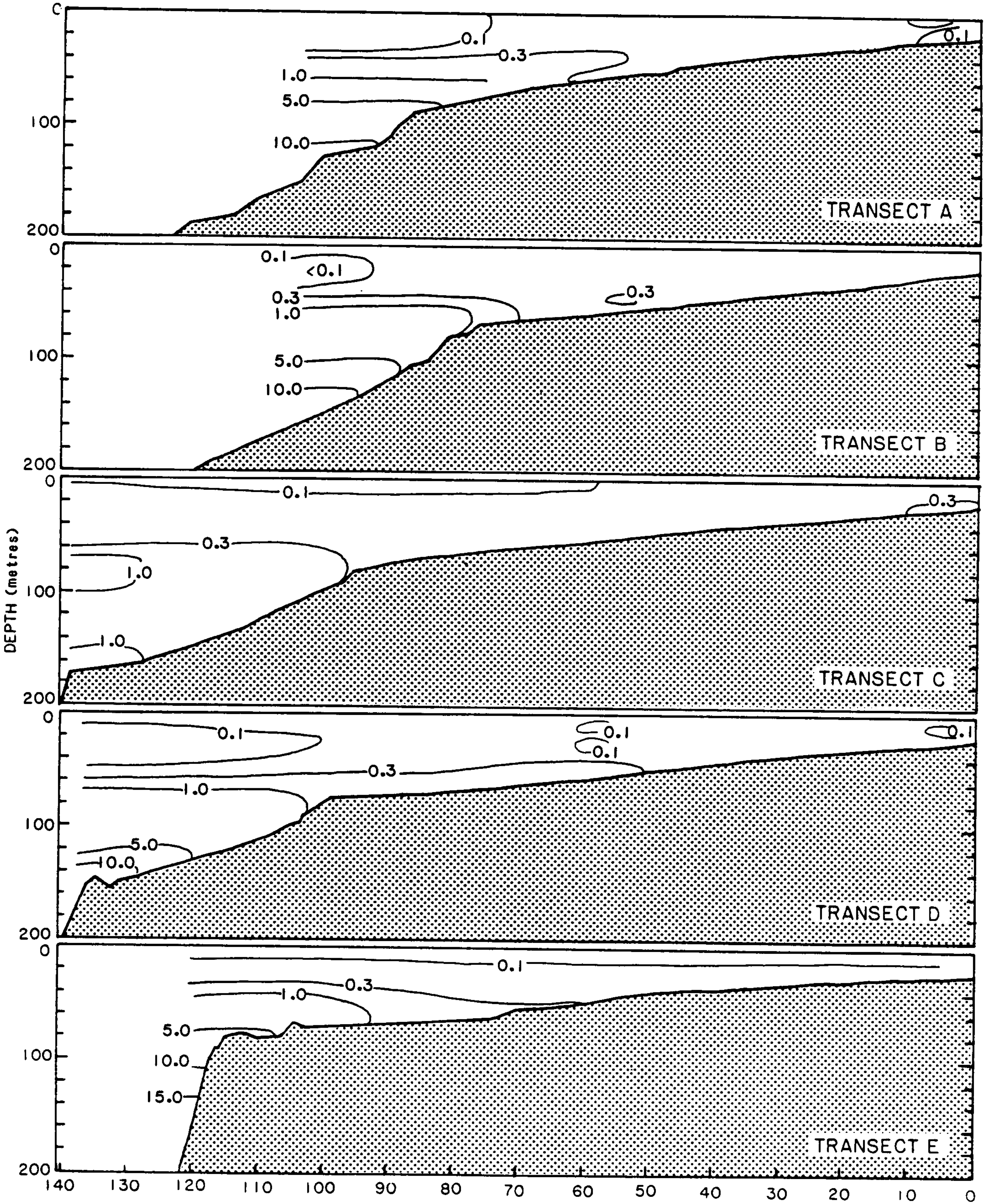

Figure 4-13. January-February 1982 nitrite + nitrate (μM) cross-sections.

Winter Cruise dissolved silica values (Figure 4-14) ranged from 0.5 μM in the surface mixed layer to 9.0 μM below the thermocline at Station 31. The mixed layer values ranged from 0.5 to 1.0 μM. Similar to the other nutrients measured, the values of Silicate at Station 35 did not increase with depth as at the other offshore stations; this phenomenon was associated with the lack of a strong thermocline. An anomalously high value for Silicate (9.0 μM) was observed near the bottom at Station 4 and corresponded to high values observed at offshore Station 31.

4.3.8 Chlorophyll a

On the Summer Cruise chlorophyll a (Figure 4-15) ranged from a minimum of 0.03 mg/m^3 to a maximum of 1.2 mg/m^3 at Station 35 (117m depth). The surface mixed layer on all transects at the offshore and mid-shelf stations had concentrations less than 0.3 mg/m^3 and often less than 0.1 mg/m^3. There was a near-bottom increase in Chl a at the mid-shelf stations yielding levels which ranged from 0.4 to 0.5 mg/m^3. The inner shelf stations had higher overall values throughout the water column. A higher Chl a pocket (0.83 mg/m^3) was observed near the bottom at Station 6 and another at Station 25 (0.66 mg/m^3). The offshore stations all had chlorophyll a maxima at mid-depths with Stations 31, 33, 38, and 39 at 37 to 94m, 74 to 104m, 47 to 117m, and 50 to 90m, respectively. The mid-depth concentration maxima ranged from 0.23 to 1.0 mg/m^3. Station 35 on Transect C had Chl a maxima from 37 to 67m and from 97 to 127m. The shallow maximum was 0.76 mg/m^3 and the deep maximum was 1.2/mg m^3.

During the Winter Cruise, Chl a concentrations (Figure 4-16) ranged from a minimum of 0.05 mg/m^3 to a maximum of 0.73 mg/m^3 at mid-depth at Station 38. The surface mixed layer at all stations ranged from 0.05 to 0.3 mg/m^3. Near-bottom increases were observed at the inner and mid-shelf stations. Mid-shelf Stations 16 and 22 had the highest near-bottom increases (0.73 and 0.53 mg/m^3, respectively). The offshore stations all had subsurface maxima, but these were not as well defined as those in the Summer Cruise. The maximum observed concentrations (mg/m^3) at Stations 31, 33, 35, 38, and 39 were 0.46 (32m depth), 0.50 (44m), 0.31 (67m), 0.53 (57m), and 0.33 (48m), respectively. An unusual secondary maximum was observed at 137 to 147m depths at Station 35.

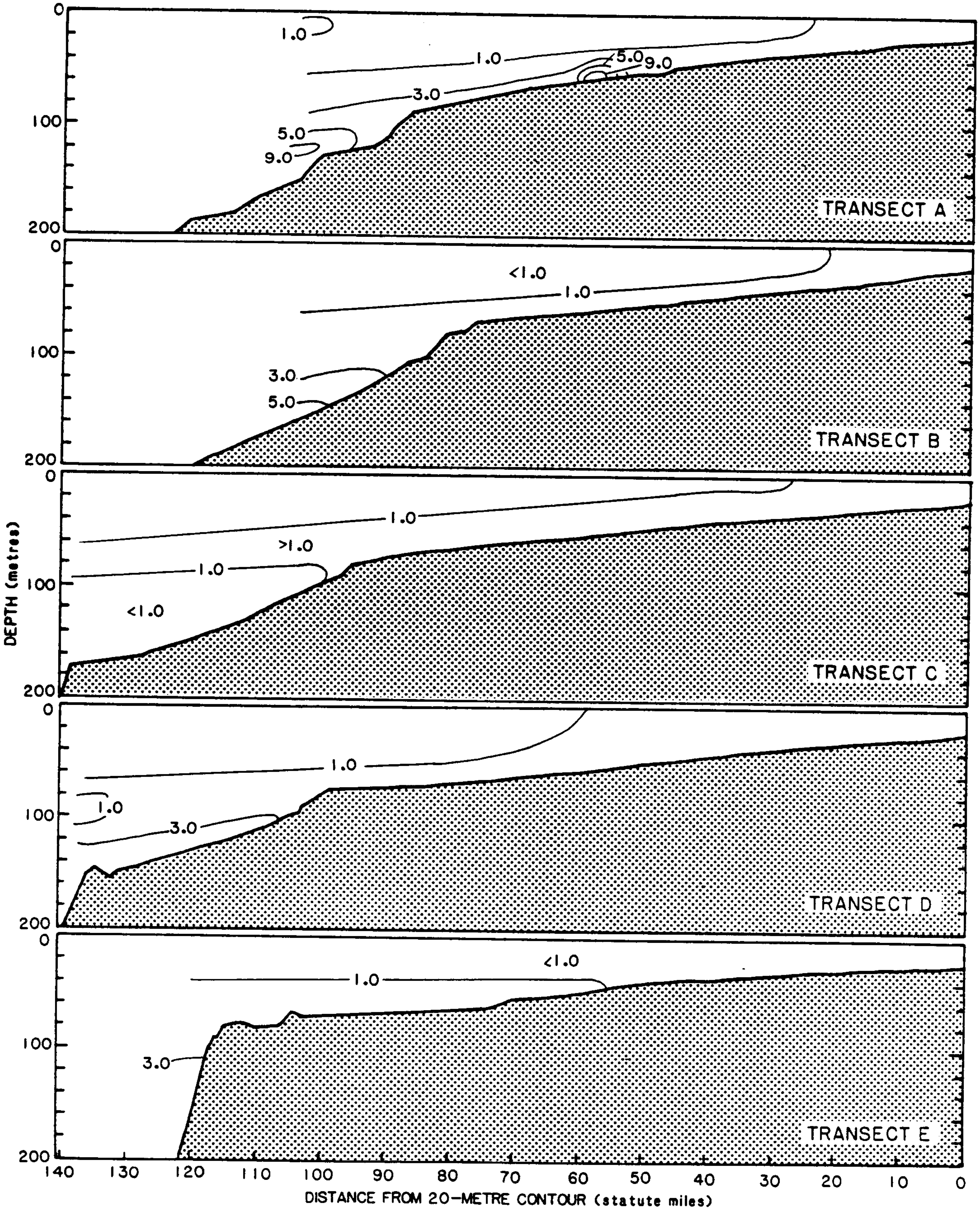

Figure 4-14. January-February 1982 dissolved silica (μM) cross-sections.

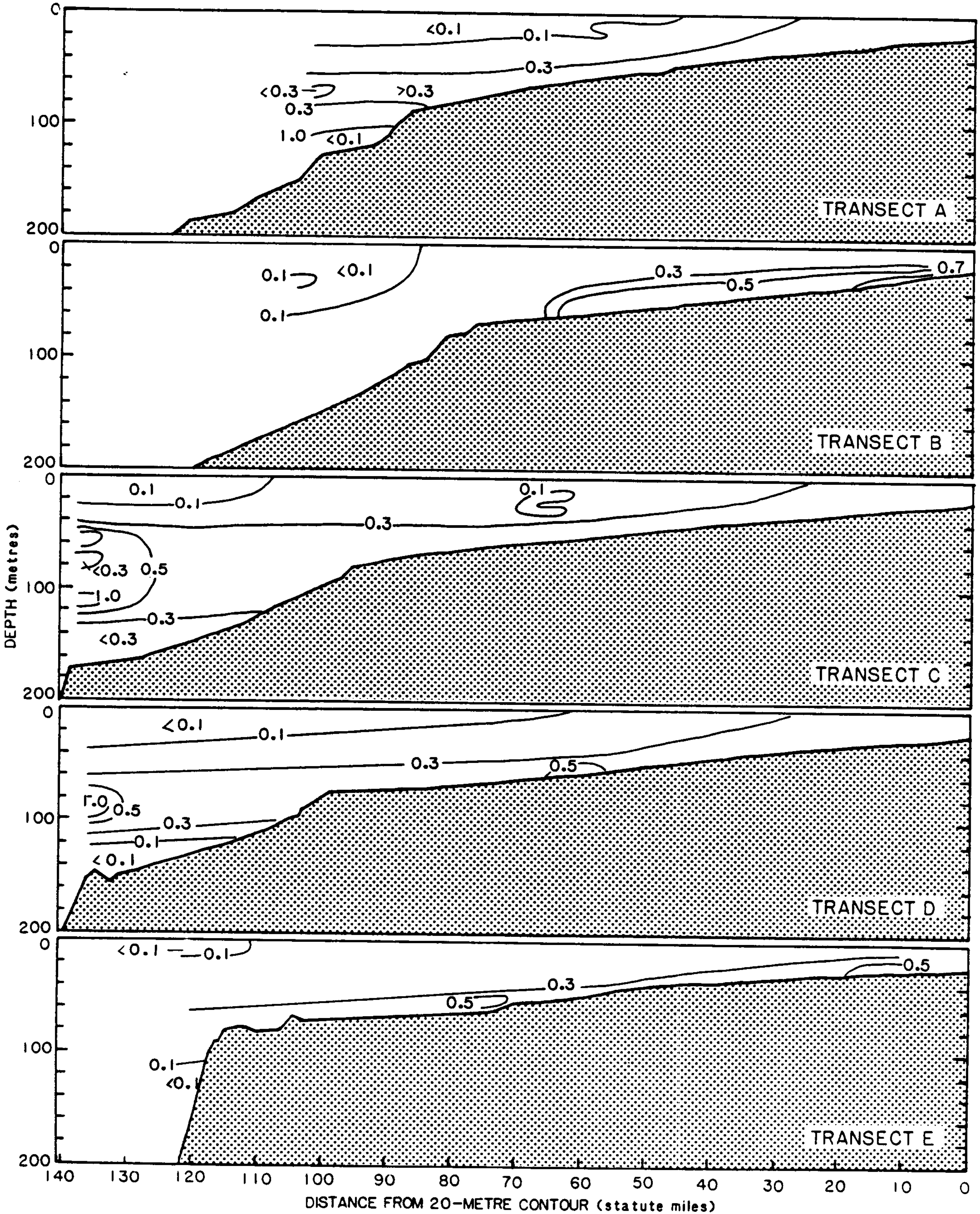

Figure 4-15. July-August 1981 chlorophyll a (mg/m^3, trichlorometric method) cross-sections.

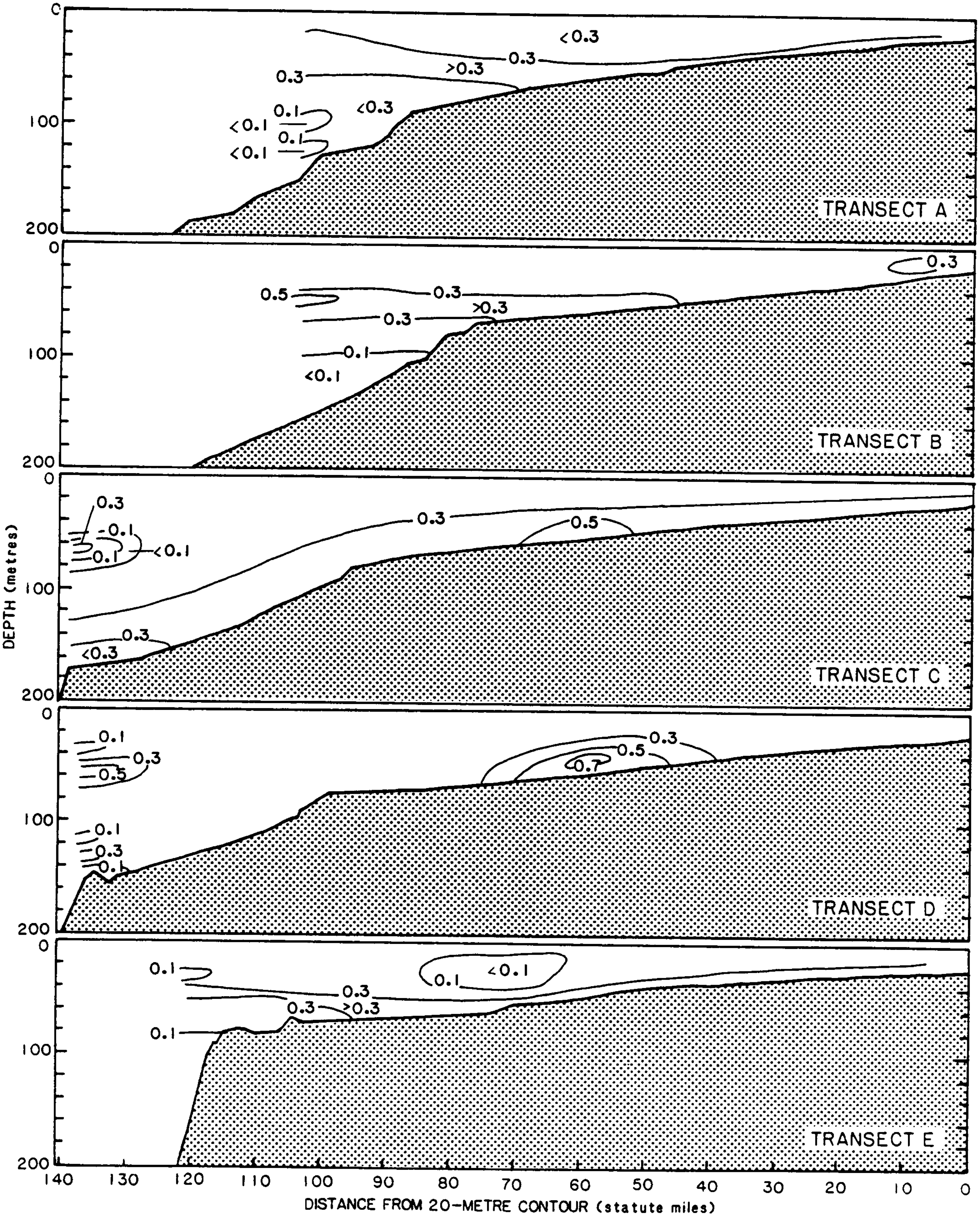

Figure 4-16. January-February 1982 chlorophyll a (mg/m^3, trichlorometric method) cross-sections.

4.4 DISCUSSION

The cruises discussed above are representative of a summer (July-August 1981) and a winter (January-February 1982) sampling period. The spring and fall sampling periods documented in detail in the Year One Final Report will now be reviewed in relation to the two sampling periods discussed in this report.

4.4.1 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 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 is not necessarily accurate, however. Maul (1977) confirmed a seasonal growth and decay but also found significant year to year variability. Molinari et al. (1977), using satellite data, found the current to extend well into the Gulf (above 26°N latitude) during the winters of 1974 through 1977, further documenting variability.

Molinari et al. (1975) defined Loop Current waters as those having a salinity maximum of >36.5 o/oo. These higher salinities are generally associated with the Subtropical Underwater (SUW) which is normally found below the 100m depth within the Loop Current structure. Leipper (1970) used the depth of the 22°C isotherm (150 to 220m) to define the boundary of the Loop Current; while Austin (1971) 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 Current 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 dynamics of the west Florida shelf 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 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; Haddad and Carder (1979) noted extreme bottom turbidities associated with these impingements.

A seasonal surface flow was grossly defined for the west Florida shelf during Project Hourglass (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 a majority of landings on the Florida east coast. Spring and summer releases had a high percentage of returns from the Florida west coast. 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 (Figure 4-17). 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/second. There were no returns from the Florida Bay system or on the Gulf of Mexico side of the Florida Keys and Dry Tortugas chain.

Results from the Texas A&M University, Surface Drifter Project (Parker et al, 1979), carried on from 1975 through 1978, reconfirm the general drift patterns

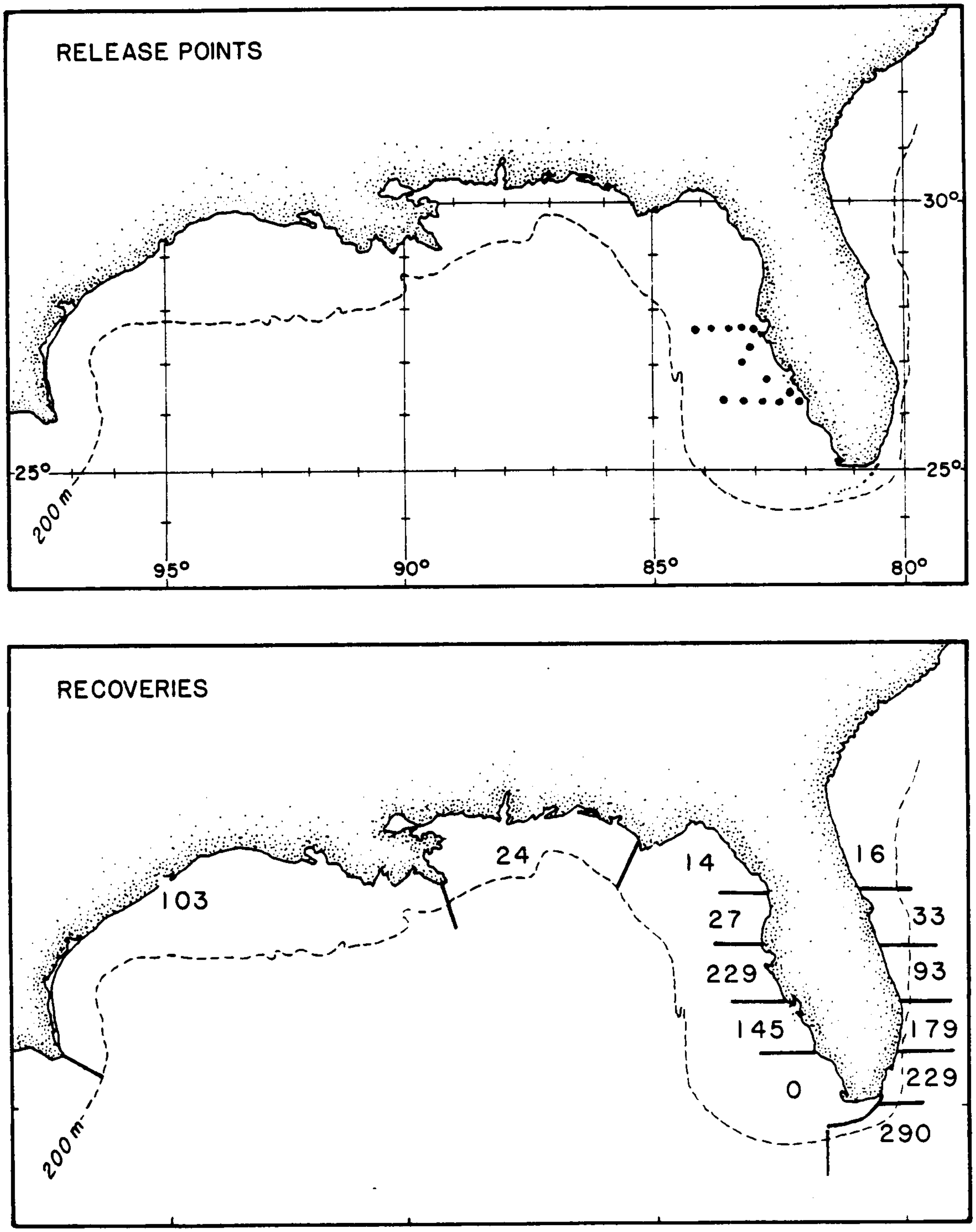

Figure 4-17. Project Hourglass: drift bottle release points and recoveries, 1965-67 (based on Williams et al, 1977).

identified during Project Hourglass (Williams et al, 1977). Recoveries from over 15,000 Woodhead surface drifters released in the Gulf of Mexico and Caribbean Sea, were concentrated on the Texas Gulf Coast and the south and east coasts of Florida and the Keys. Only a very few drifters were recovered from the Florida Gulf Coast.

The Loop Current is known to reach speeds of >200cm/s, about 4kn. For currents along the west Florida shelf, Mooers and Price (1975) and Niiler (1976) have found extreme velocities of 100cm/s associated with storms, but flow was generally <20cm/s. 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 to 1977. A salinity range of 26.7 o/oo to 39.2 o/oo was observed along the Florida Bay mainland in the 1930s, while hypersaline conditions (41 to 66 o/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) found surface concentrations of seagrass blades in the study area and determined their source to be the extensive seagrass beds within the shallow waters of Florida Bay. He 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 any Everglades input, surface transport 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.

4.4.2 Summer Cruise Summary

Satellite thermal imagery showing the position of the Loop Current was not available for the Summer Cruise. During summer the sea surface in the Gulf of Mexico becomes essentially isothermal and Loop Current boundaries become indiscernible. In addition, atmospheric moisture increases during the summer, and interferes with the sea surface signature. Thermal imagery is thus generally unuseable from June through October. Ocean color imagery such as that from the Coastal Zone Color Scanner would be useful in determining Loop Current interaction with the study area, but this type of imagery is not yet generally available.

It is often possible to document impingement of Loop Current waters onto the southwest Florida shelf by shipboard measurements of water temperature and salinity. A salinity maximum (36.5 o/oo) and the 22°C isotherm have been used as indicators of Loop Current waters (Molinari et al., 1975; Leipper, 1970).

The temperature and salinity data for the Summer Cruise do not provide any strong evidence for direct Loop Current impingement on Transects A, B, D, and E. There was a high salinity intrusion (36.5 o/oo) on Transect C that appeared to have reached the 57m isobath and corresponded to 18 to 22°C waters.

The shallow mixed layer (25m) on the mid-shelf and offshore stations indicated a summer thermal stratification with no intense mixing. The inner shelf stations on Transects A (Station 1) and B (Station 6) were also stratified; those on Transects C (Station 13), D (Station 20), and E (Station 25) were not. Thermal stratification at Stations 1 and 6 was associated with more southerly salinities than those found on the three more southerly transects Figure 4-1). Stations 1 and 6 were geographically closer to the Charlotte Harbor estuarine system and the coastal environment may have been different than for those transects in the Florida Bay area. The temperature and salinity were higher at Stations 13, 20, and 25 (36.4 o/oo), reflecting summer heating and evaporation in the Florida Bay area. The Summer Cruise took place during the beginning of one of the most severe droughts that Florida has experienced; as a result, the shallow expanses of Florida Bay received a reduced freshwater input. Diversion of freshwater from Florida Bay due to Everglades channelization may have also reduced freshwater input to the Bay.

Low salinity pockets (<35.6 o/oo) were observed in the upper 30m of mid-shelf Stations 4, 9, and 22. These low salinity pockets are not uncommon on the shelf (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983; Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983) and may represent entrained coastal Mississippi water (Atkinson and Wallace, 1975).

The lowest temperatures (12 to 14°C) observed during the Summer Cruise occurred near the bottom at offshore Station 39. Associated with these low temperatures were anomalously high salinities (36.4 to 36.5 o/oo). The evolution or origin of this water-mass type has not been described for the eastern Gulf of Mexico.

Dissolved oxygen values associated with given water temperatures and salinities were comparable to those found during the fall and spring sampling. The offshore stations all exhibited near-bottom decreases in oxygen with decreasing temperatures below the mixed layer. No oxygen depletion was observed at any station.

High transmissivity values (generally >90%) indicated very clear waters over the entire study area. A slight increase in turbidity was observed at the inner shelf stations, probably due to coastal influences such as mixing, increased phytoplankton growth and high resuspension potential. There were no indications of intense bottom resuspension due to currents. There was very little structure in the transmittance contours and relationships to other measured variables were not consistent.

Dissolved nutrients were limiting in the surface mixed layer during the Summer Cruise. PO_4-P was less than 0.1 µM above the thermocline and did not exceed 1.2 µM below the thermocline. PO_4-P concentrations increased with depth and decreasing temperatures. NO_2-NO_3-N concentrations were generally less than 0.3 µM in the mixed layer. The offshore stations on Transects A and B had higher concentrations (0.5 to 1.0 µM) near the surface, but nutrients were still limiting for phytoplankton growth as observed in Chl _a_ values at these stations. Large increases in NO_2-NO_3-N concentrations occurred with decreasing temperature and increasing depth.

Station 39 (Transect E, offshore) had a near bottom NO_2-NO_3-N concentration of 20.4 µM. This was the highest nitrogen value measured during all Southwest Florida Shelf Ecosystems Study cruises to date. A high NO_2-NO_3-N pocket was observed at the 60 to 70m depth on Station 35 (Transect C, offshore) and corresponded with an increase in PO_4-P. This also coincided with a high salinity structure. It was suggested previously that this transect was being influenced by the Loop Current and perturbation associated with this influence may have introduced the nutrients from cooler, deeper waters into shallower depths.

Silicate concentrations were generally >1.0 µM throughout the water column. Concentrations were <1.0 µM at the mid-shelf stations and generally represented the minimums for each transect. A near-bottom increase was observed at Station 6, suggesting possible bottom sediment resuspension. This corresponded with a slight decrease in transmittance but did not indicate intense mixing. Silicate at Station 25 was >8.0 µM throughout the water column. This was also observed in the Fall and Spring Cruise data and appears to be a typical anomaly for this station. Concentrations of silicate also increased below the thermocline, as was observed with the other nutrients.

The high concentrations of nutrients at the shelf break are significant because of their potential availability to the photic zone. The nutrients are apparently upwelled from depths well below the salinity maximum. The Year Two Modification Contract Summer Cruise data (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983) provided a deeper sampling regime that revealed strong upwelling with pronounced doming of the nutrient isopleths. This upwelling penetrated to the 80m isobath; more intense upwelling would make these nutrients available to the phytoplankton within the photic zone.

The contribution of the nutrients to phytoplankton abundance is reflected in the Chl a concentrations throughout the water column. During the Summer Cruise the offshore stations had Chl a maxima at subsurface depths. The upper depths of the maxima (using 0.3 mg/m^3 isolines) were found at 50 to 80m, with the higher concentrations often extending below 100m. When comparing these depths to the one-percent light attenuation depths (50 to 70m) at the offshore stations, it is apparent that the phytoplankton standing crop was maximizing at or below the one-percent attenuation depths and at the top of the nutricline. Above these depths the waters were nutrient-limited and Chl a values decreased to <0.1 mg/m^3. Station 35 had a high Chl a maximum (>0.5 mg/m^3) between 37 and 127m depths, which corresponded to a salinity maximum and a high NO_2-NO_3-N pocket. This was undoubtedly the result of upwelling from greater depths, bringing nutrients into the photic zone and stimulating phytoplankton growth.

The mid-shelf stations did not appear affected by higher offshore nutrients, but a near-bottom increase in Chl a was observed at all stations. These increases were noted below the thermocline; near-bottom nutrient regeneration could be responsible. Resuspension of benthic microalgae and/or deposited phytoplankton debris could also contribute to these high near-bottom values. The surface waters of the inner shelf stations were higher in Chl a than the corresponding mid and outer shelf waters. This probably reflects coastal influences and greater mixing potential, which prevented stratification of the waters and produced subsurface Chl a maxima. The inner shelf station with the greatest near-bottom increase in Chl a and lowest near-surface concentration was also the station that was thermally stratified (Transect B, Station 6).

4.4.3 Winter Cruise Summary

Satellite derived positions of the Loop Current during the Winter Cruise are depicted in Figure 4-18; outer shelf stations are included to provide a pictorial relationship between the sample area and Loop Current influence. It is apparent that the Loop Current was interacting with the outer study area during the Winter Cruise. A Loop Current filament had penetrated the study area and was affecting Stations 33 (Transect B) and 35 (Transect C) directly (Figure 4-18b) during sampling dates February 6 and 7, respectively. The effect of this filament was most readily observable at Station 35, where warmer Loop Current waters penetrated to the bottom. Outer shelf Stations 31, 38, and 39 were not being affected by the filament directly (Figure 4-18b) while sampled, but were certainly being affected by the dynamics of the system. A large meander of shelf water was influencing Stations 38 and 39. This type of meander is common for this area and may have enhanced upwelling at these two southern stations. Upwelling was occurring at Station 35, even though the bottom temperatures were 3 to 6°C cooler at the other stations. Vertical sections through the Loop Current (Nowlin, 1971) typically locate the 20°C isotherm at 150m. The actual impingement of the current at this station simply upwelled water from shallower depths. The fact that a 36.5 o/oo salinity maximum was observed at this station provides additional supportive evidence that Loop Current waters were affecting this area. Along with this intrusion, a decrease in nutrient concentrations and subsequently a general decrease in subsurface Chl a was noted. Near-bottom oxygen values (~6.0 ml/l) also suggested no deep-water upwelling decrease in subsurface Chl a. It is apparent that the Loop Current proper, when flowing along the shelf slope isobaths, induces upwelling of colder nutrient-rich waters, but when directly impinging on a given location can suppress this deep water upwelling. It can be assumed that as the Loop Current (both the Loop Current proper, and associated filament eddies) moves toward or away from the shelf in conjunction with the alongshore flow, deep water upwelling can be further suppressed or enhanced.

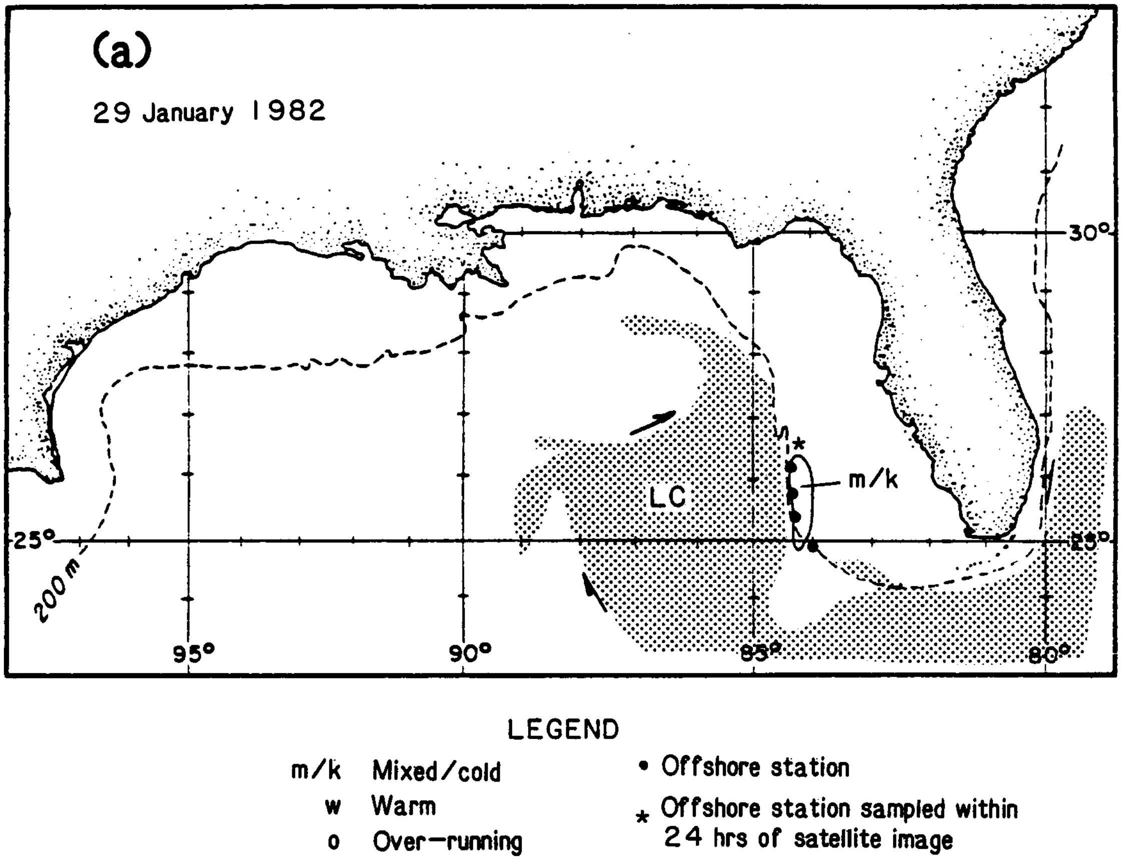

Figure 4-18. Loop Current (LC) positions during the Winter Cruise, as depicted by thermal imagery from the National Earth Satellite Service GOES satellite

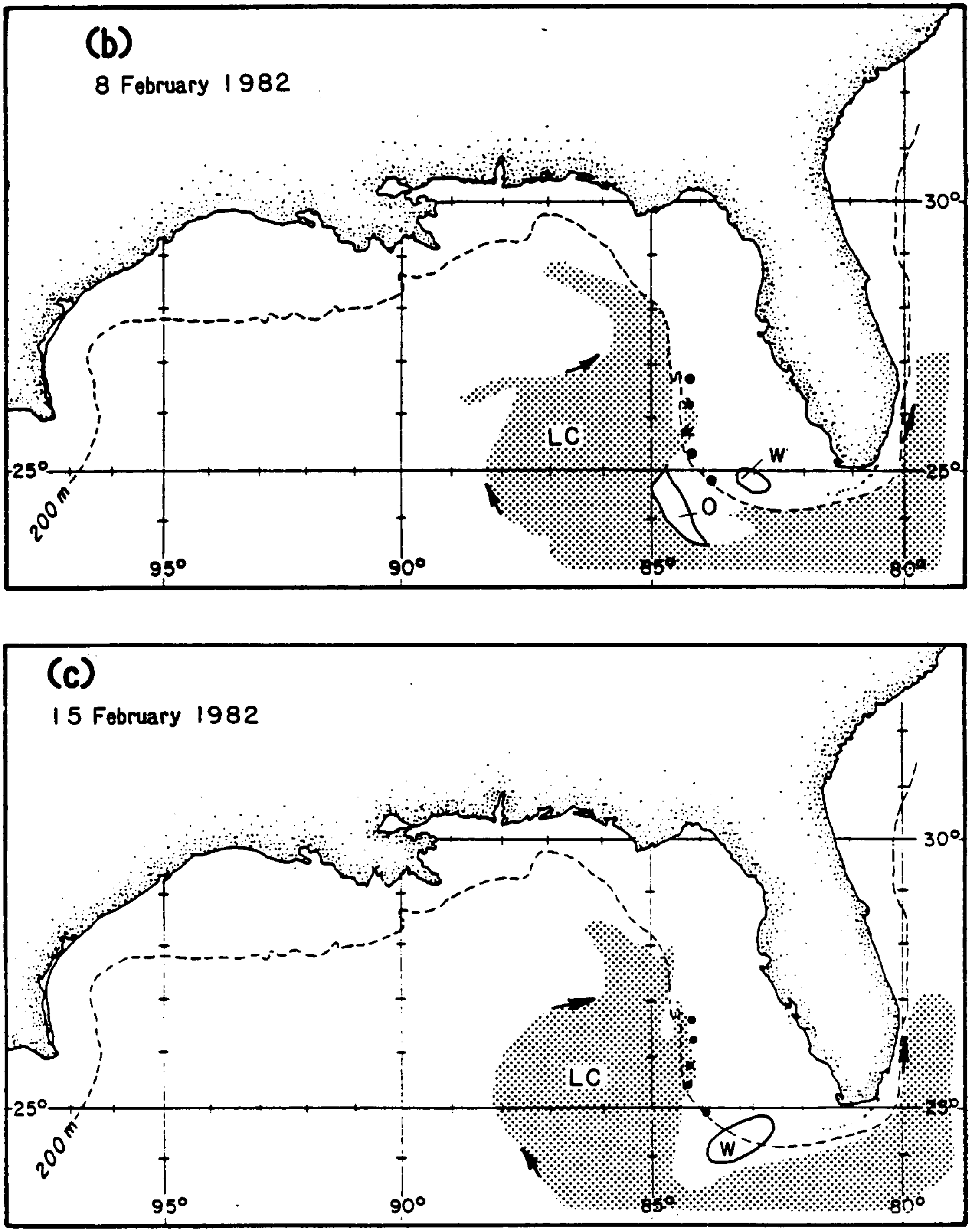

Figure 4-18 (Continued).

During the Winter Cruises, the surface thermal mixed layer generally extended to 30 to 40m depths at the outer shelf stations, while the mid-shelf stations on Transects A, B, and C had minor stratification (Δ T = 1-2°C) from surface to bottom. The mid-shelf stations on Transects D and E were more stratified (Δ T= 3-4°C) primarily due to warmer surface waters at those stations. Bottom temperatures at the mid-shelf station only ranged from 19.5 to 21.6°C and did not suggest any major bottom influences at any of the mid-shelf stations. Similar patterns were observed in salinity values. On Transects A, B, and C, where only mild vertical stratification in temperature was noted, the salinities were either homogeneous or mildly stratified (Δ S o/oo = 0.02-0.04 o/oo). On the southernmost two transects, salinities were more vertically stratified (Δ S o/oo = 0.20-0.37 o/oo). The inner shelf stations were vertically homogeneous in temperature. Temperatures increased in a southern direction along the transects (outer, mid, and inner shelf stations), reflecting the climatological effects at the more southern latitudes in addition to the Loop Current effects. Salinities were essentially homogeneous at the inner shelf stations. The salinities at the mid-shelf and inner shelf stations were predominantly 36.4 o/oo. At Stations 13, 20, 22, and 28 the values exceeded 36.5 o/oo. When related to the temperatures of 18 to 23°C, it might be suggested that these stations had been impacted by Loop Current waters. But it must be reinforced that the stations on each transect are ~60 miles apart and the Loop Current would thus be influencing salinities ~120 miles across a shallow sloping shelf. Because of the dynamic structure of the Loop Current, this may be possible as either a direct, massive influence or large eddy shedding. The former is not suggested from the thermal imagery or salinity isolines. Eddy shedding on such a massive scale has not been documented previously and is not likely. The most likely explanation centers on the fact that during this time period Florida had been experiencing one of the severest droughts in its history. The shallower stations would have experienced evaporative water loss, thereby increasing salinities. Winter cooling (Florida also experienced a mild winter in 1982) would have lowered water temperatures more rapidly near-shore. This, when combined with the higher salinities, could produce density imbalances and one might expect a downwelling of near-shore waters towards the shelf break. This is suggested in several isolines in the salinity profiles. Why the temperatures were in the 18 to 22°C range is climatologically explainable, but why the salinities fell within that narrow range for tagging the Loop Current-associated waters and were not higher is both interesting and -- if not just coincidental -- without explanation.

Transmittance values were high throughout the study area, suggesting clear waters. There were slight decreases in clarity near the bottom. Offshore Station 33 had a sharp near-bottom nepheloid layer (high turbidity), suggesting currents dynamic enough for bottom sediment resuspension. Inner shelf Station 25 also had a near-bottom nepheloid layer; this was most likely induced by local tidal action. As a whole, during the Winter Cruise the study area had only minor transmittance fluctuations and values of 90% transmittance were predominant.

Nutrients collected during the Winter Cruise were generally low in the photic zone, where utilization of the nutrients by phytoplankton is possible. The top of the nutricline was consistent among the three measured variables and ranged from 40 to 70m in depth. The nutricline was generally below the bottom of the surface mixed layer and related well to temperature decreases.

Phosphate (PO_4-P) concentrations in the surface layers (40 to 70m) were consistently <0.1 μM at all locations except for Stations 31 and 20. Offshore Station 35 had no defined near-bottom increase in PO_4-P which was coincident with the impingement of warmer Loop Current waters; this appears to have suppressed the upwelling of higher nutrients associated with the deep, cooler waters off the shelf. At all other offshore stations, PO_4-P increased below the thermocline to a maximum of 1.0 μM at 14°C on Station 39. The mid-shelf stations had minor stratifications of PO_4-P near the bottom, but levels were still <0.3 μM.

NO_2-NO_3-N concentrations followed patterns similar to these exhibited by PO_4-P data. In the mid-depth surface layers (40 to 70m) concentrations were generally <0.3 μM. Near-surface concentrations were often >0.1 μM. Nutricline increases in NO_2-NO_3-N concentrations were orders of magnitude greater than the surface-water levels. A maximum concentration for the study area was observed at Station 39 (16.1 μM, corresponding to 14.0°C). As was observed with PO_4-P, Station 35 exhibited no strong gradients, with the bottom sample having a concentration of only 1.3 μM.

Dissolved silicate (SiO_2) was relatively more abundant in the surface waters than the other nutrients, ranging from 0.5 to 1.6 μM. Increases were observed below the thermocline, although the magnitude was less than that observed for NO_2-NO_3-N. A local high (9.0 μM) was observed near the bottom at Station 4 and may be the result of bottom sediment resuspension.

When Chl a concentrations were compared with nutrient concentrations, it was apparent that the Winter Cruise Chl a maximum (at the outward mid-shelf stations) occured in conjunction with the location of the top of the nutricline. If the 0.3 mg/m^3 level is used as a basis for the maximum envelope, then the Chl a maxima were found between 34 and 84m and the envelopes extended from 15 to 40m in vertical widths. Offshore Station 35 had a Chl a maximum at 60m and a secondary maximum at 127m. This was related to the warm water Loop Current impingement reflected in all the measured variables. Whether this was an actively growing phytoplankton population or one recently displaced from shallower depths is debatable, but measured phaeopigments (not included in this report) do not suggest Chl a degradation. Near-bottom increases were observed at the mid-shelf stations in conjunction with temperature decreases and nutrient increases. Station 22 had the maximum Chl a concentration (0.73 mg/m^3) for the entire Winter Cruise and corresponded to the lowest mid-shelf temperature, highest mid-shelf salinity and highest midshelf NO_2-NO_3-N concentrations. The inner shelf stations generally had near-bottom increases in Chl a, but they were less than those observed mid-shelf. This was most likely due to mixing events during the winter, destabilizing the Chl a maximum. Also potential nutrient availability was not as great at these shallower stations. The severe drought occurring during 1981-82 may have decreased any coastal water influence to the area, further decreasing the standing crop in the area. Overall, Chl a values were low during the Winter Cruise and no obvious local upwellings into the mixed layers were observed.

4.4.4 Seasonal Summary Overview

The cruise by cruise discussions presented above for the Summer 1981 and Winter 1982 Cruises, and in the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983) for the Fall 1980 and Spring 1981 Cruises, summarize the important features observed during each cruise. The purpose of this section is to draw together the data from all four cruises and present a seasonal characterization of the southwest Florida Shelf study area.

Such a seasonal characterization remains tenuous however, especially if absolute numerical ranges for the hydrographic parameters are to be considered. None of the data collected are synoptic. The four "seasons" sampled were not sequential, but rather represented three different calandar years. Futher, data from each cruise were collected from different stations, sampled in a different sequence, and over a time frame that varied from 14 to 30 days (see Cruise Logs, Volume 5 - Appendix A.1). While multiyear sampling and repetitive data points are unavailable, some major comparative features and trends are apparent. Regional climatological data and historical hydrographic data, when available, can also help in defining or confirming these trends.

The approach taken for this seasonal overview has been to replot measurements for each key parameter, from each shelf cross section (i.e., study transect), on a seasonal basis. Thus one can readily compare how water temperatures, for example, changed along Transect A during each of the four seasonal sampling cruises. It is important to keep in mind that the contours extrapolated from the Year Two summer and winter data sets were based on fewer stations, and are thus less reliable, than those from the Year One fall and spring data sets.

4.4.4.1 Temperature

Temperature is the most readily addressed parameter on a seasonal basis. Figures 4-19 through 4-23 provide an insight into the ranges. Surface values range from 28° to 30°C in the summer to ~20°C in the winter. The strongest thermoclines were observed in the spring and summer data. This is typical as the spring warming surface waters mix vertically into the water column.

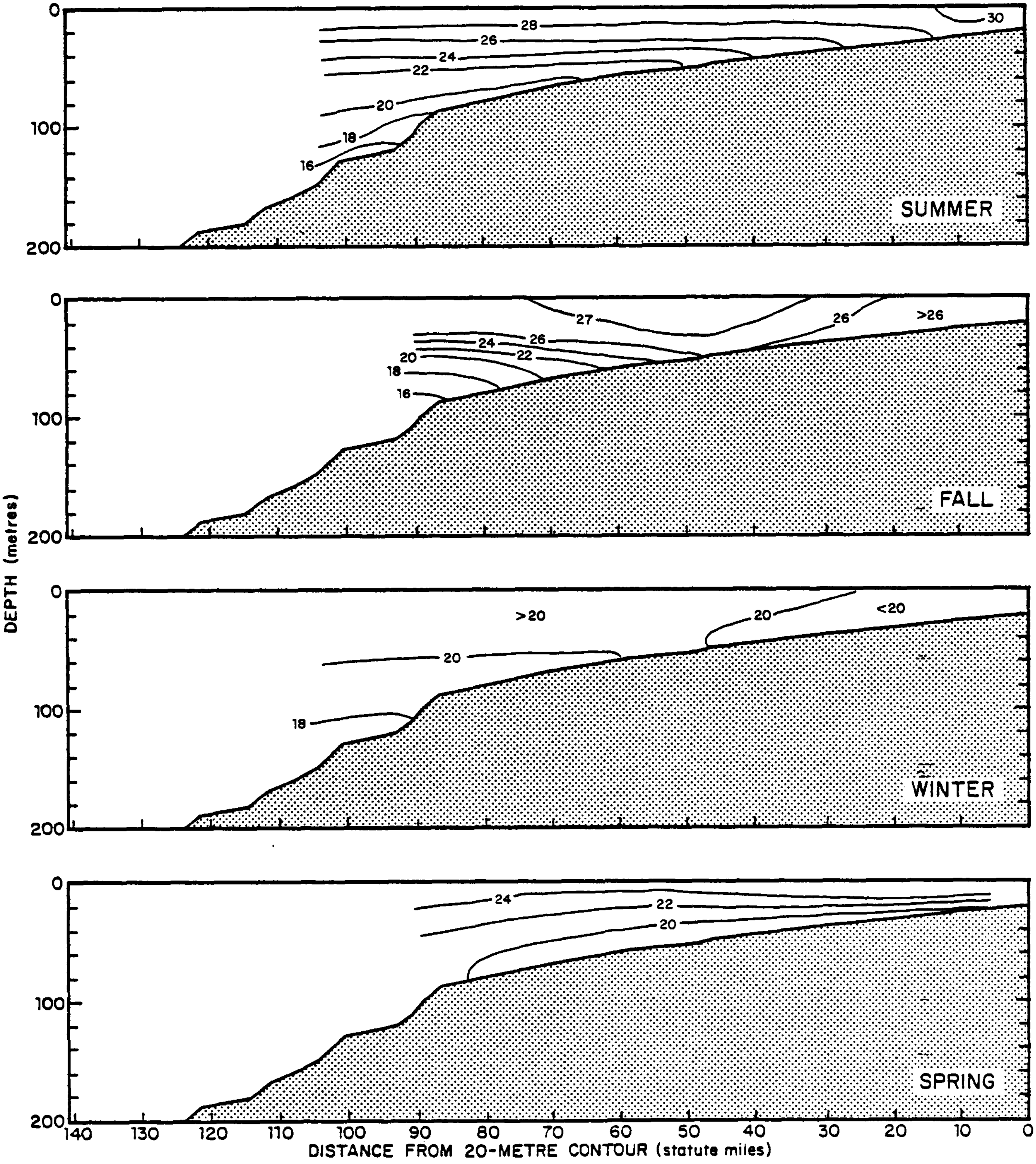

Figure 4-19. Seasonal temperature (°C) distributions on Transect A

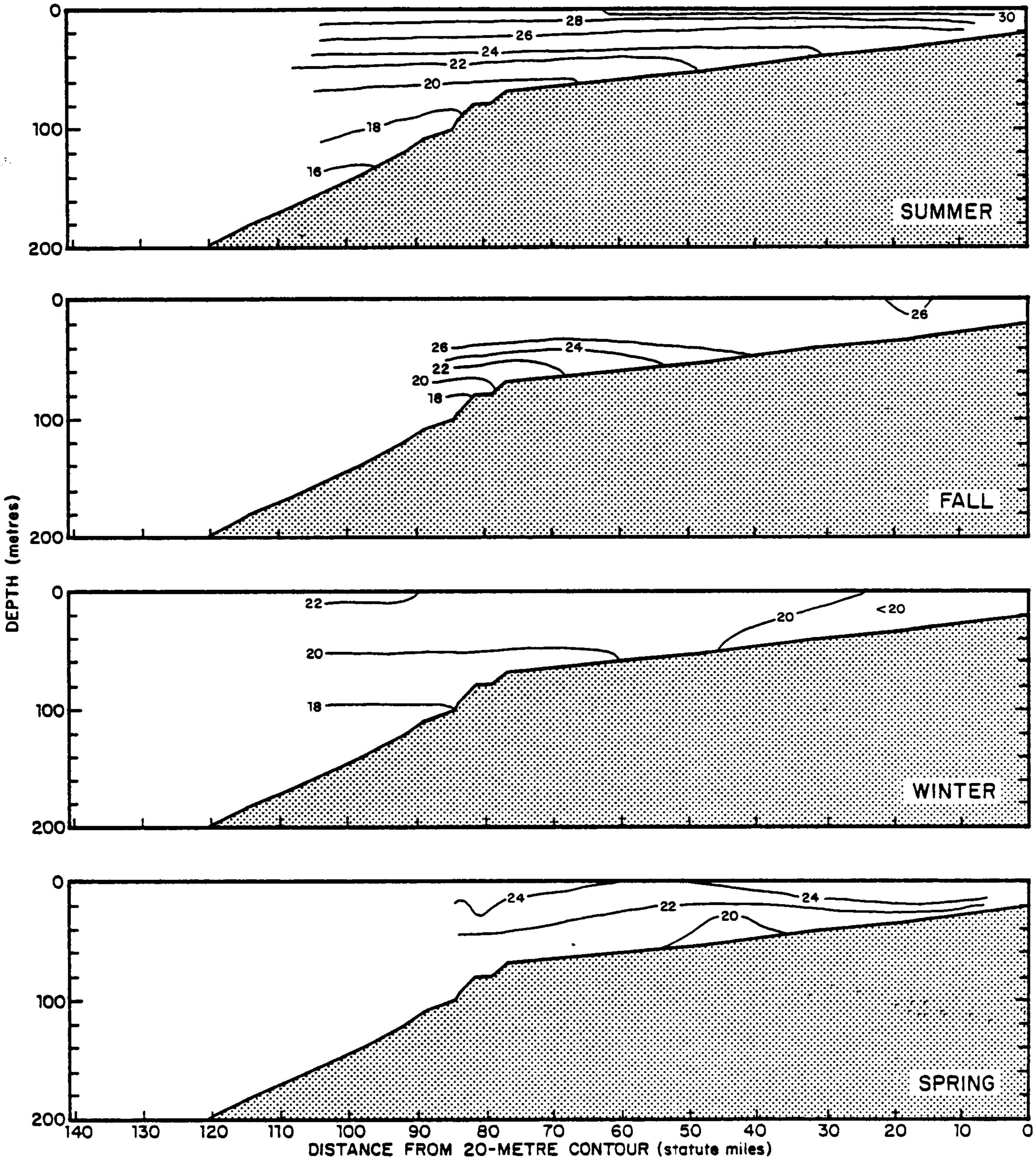

Figure 4-20. Seasonal temperature (°C) distributions on Transect B

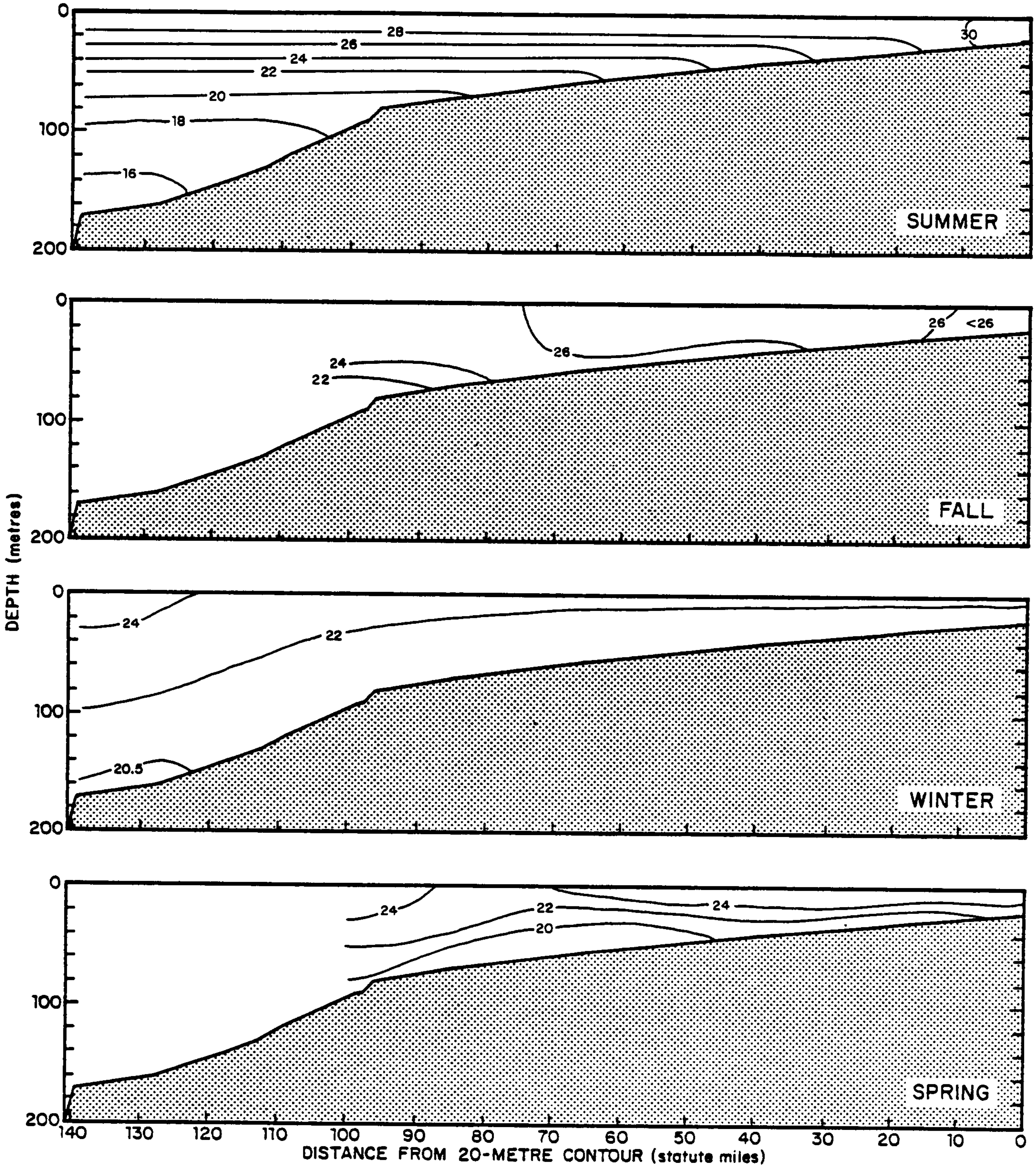

Figure 4-21. Seasonal temperature (°C) distributions on Transect C

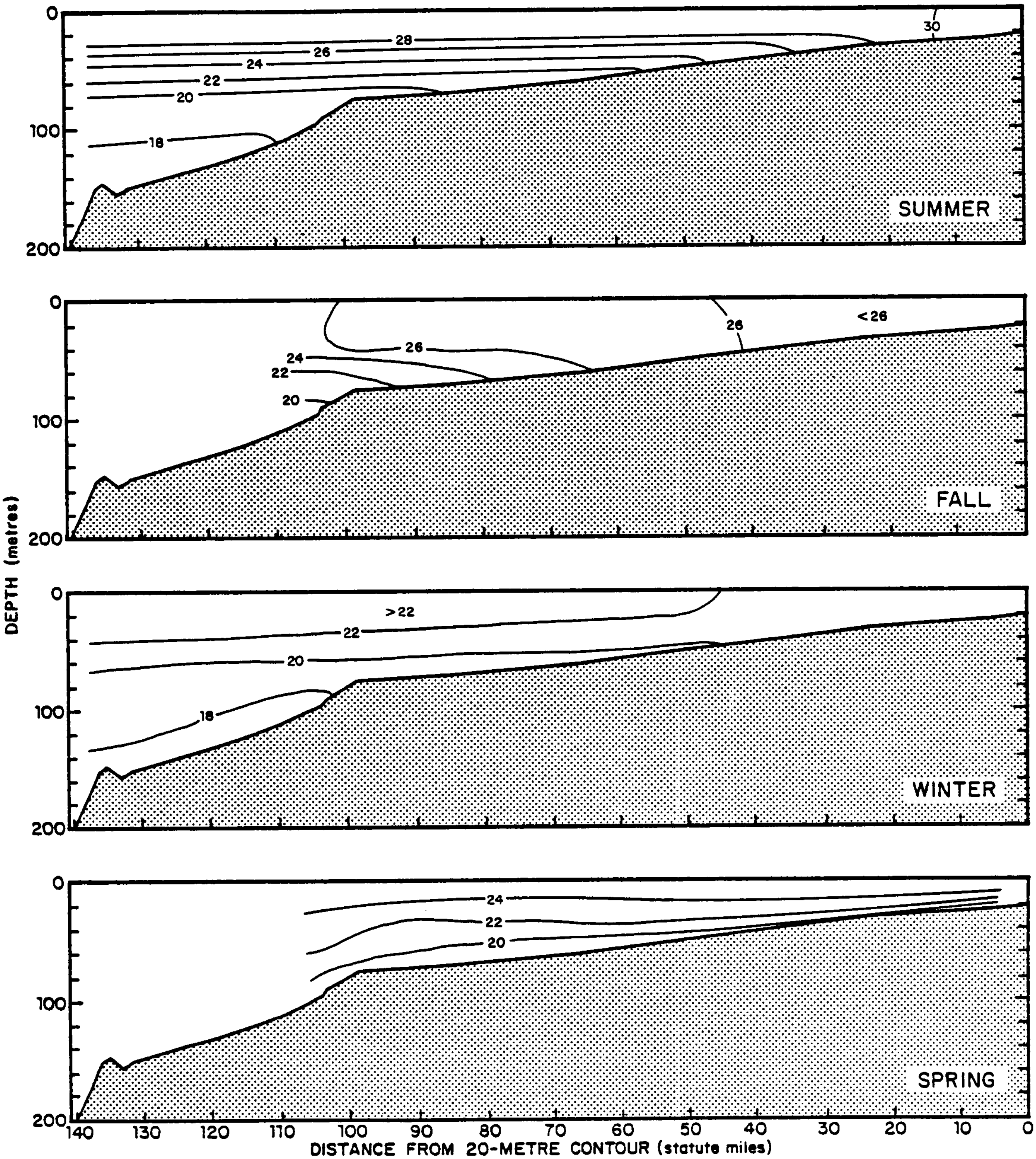

Figure 4-22. Seasonal temperature (°C) distributions on Transect D

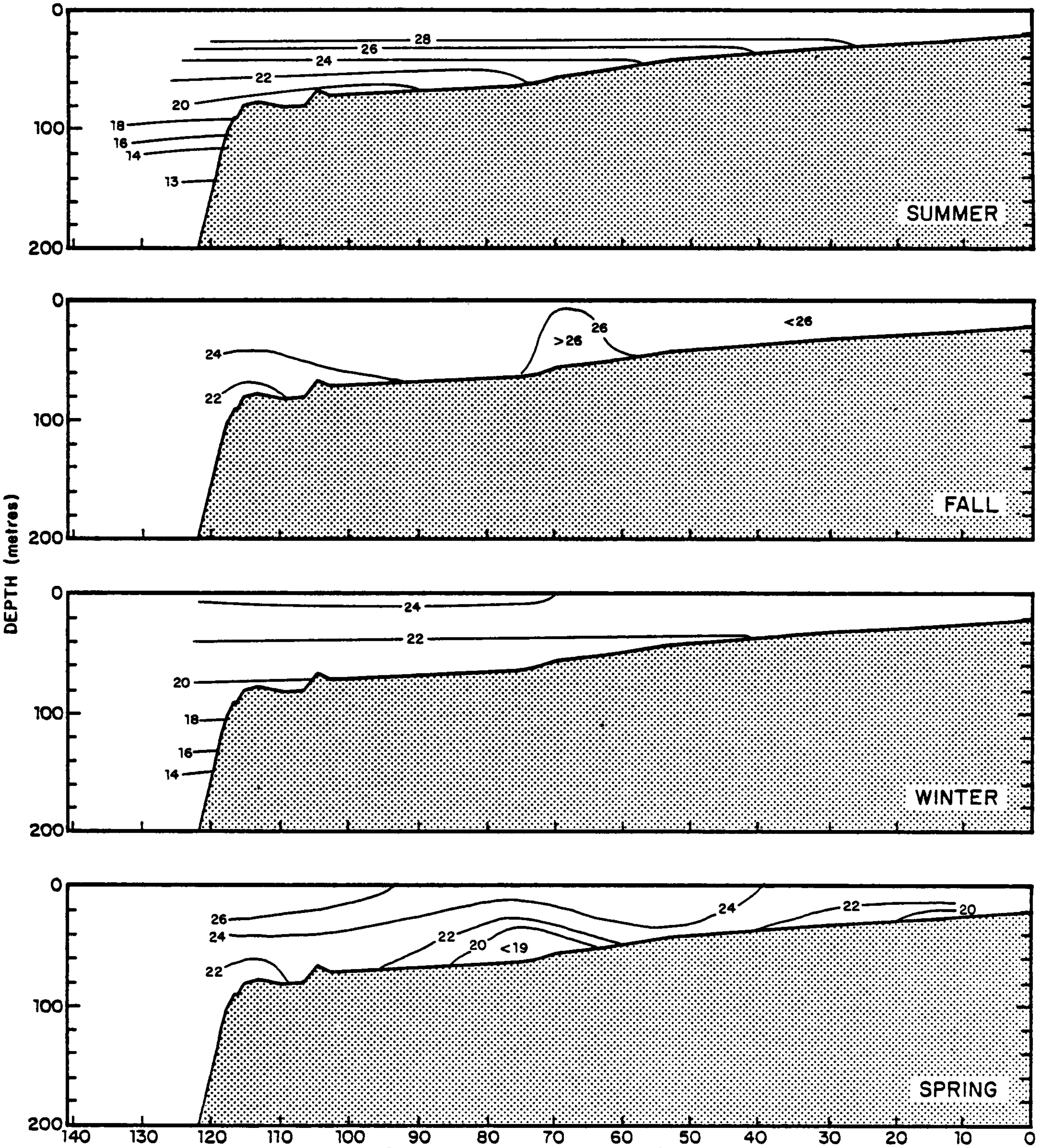

Figure 4-23. Seasonal temperature (°C) distributions on Transect E.

During the Spring Cruise the thermocline was shoreward of the inner shelf (20m isobath) stations. As summer heating intensified, the shoreward extent of the thermocline was mixed out to deeper isobaths (~20 to 30m). A strong thermocline was observed at the mid-shelf stations (50m isobath) during the Spring and Summer Cruises. The locations of the thermocline during these cruises suggest that no intense mixing events occurred. Haddad (1982) has observed the shoreward extent of the thermocline (at 27 to 28° latitiude) to be mixed from the 20m isobath out to the 50m isobath as a result of hurricane passage. He also observed shoreward movement of the summer thermocline from the 30m isobath to the 20m isobath, a distance of 20km, in less than two weeks. It is apparent that although spring and summer thermocline development is assured, the location of the frontal edge is subject to mesoscale and local events.

The fall temperature data reflect the transition to the winter environment. Cold fronts begin to penetrate the study area, cooling the surface waters and mixing the thermocline in a shoreward direction. During the winter regime the mixed surface layer extends deeper, from the 10 to 30m depths found during the spring, summer, and fall regimes, to 40 to 60m depths.

The thermocline frontal edge was found at 50m during the Winter Cruise. At 80m depths, the thermocline was observed during all seasons. There was minimal temperature fluctuation at these depths relative to seasonal climatological patterns. Fluctuations were more likely influenced by mesoscale circulation patterns which affect the upwelling of cooler waters from depth onto the shelf.

4.4.4.2 Salinity

Salinity distributions (Figures 4-24 to 4-28) exhibited no real seasonal influences. The total range of salinity varied only approximately 2 o/oo (35 to 37 o/oo) over the entire study area. Salinity distributions generally coincided with temperature patterns.

Lower salinity lenses (relative to the surrounding waters) were observed on the mid to outer shelf during the Summer, Fall and Winter Cruises. The most significant lenses were observed ruing the Fall Cruise, extending to 20m in

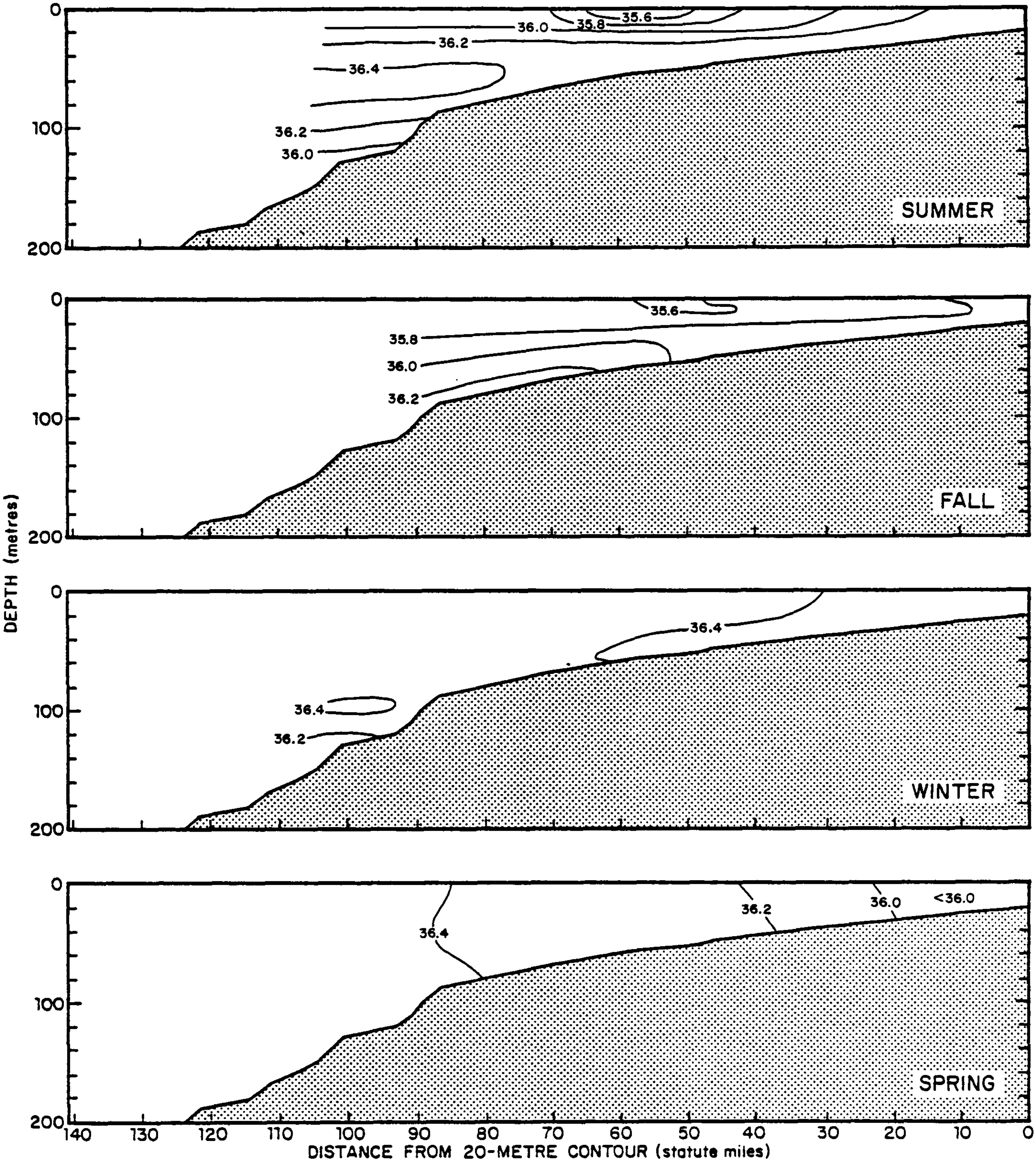

Figure 4-24. Seasonal salinity (o/oo) distributions on Transect A.

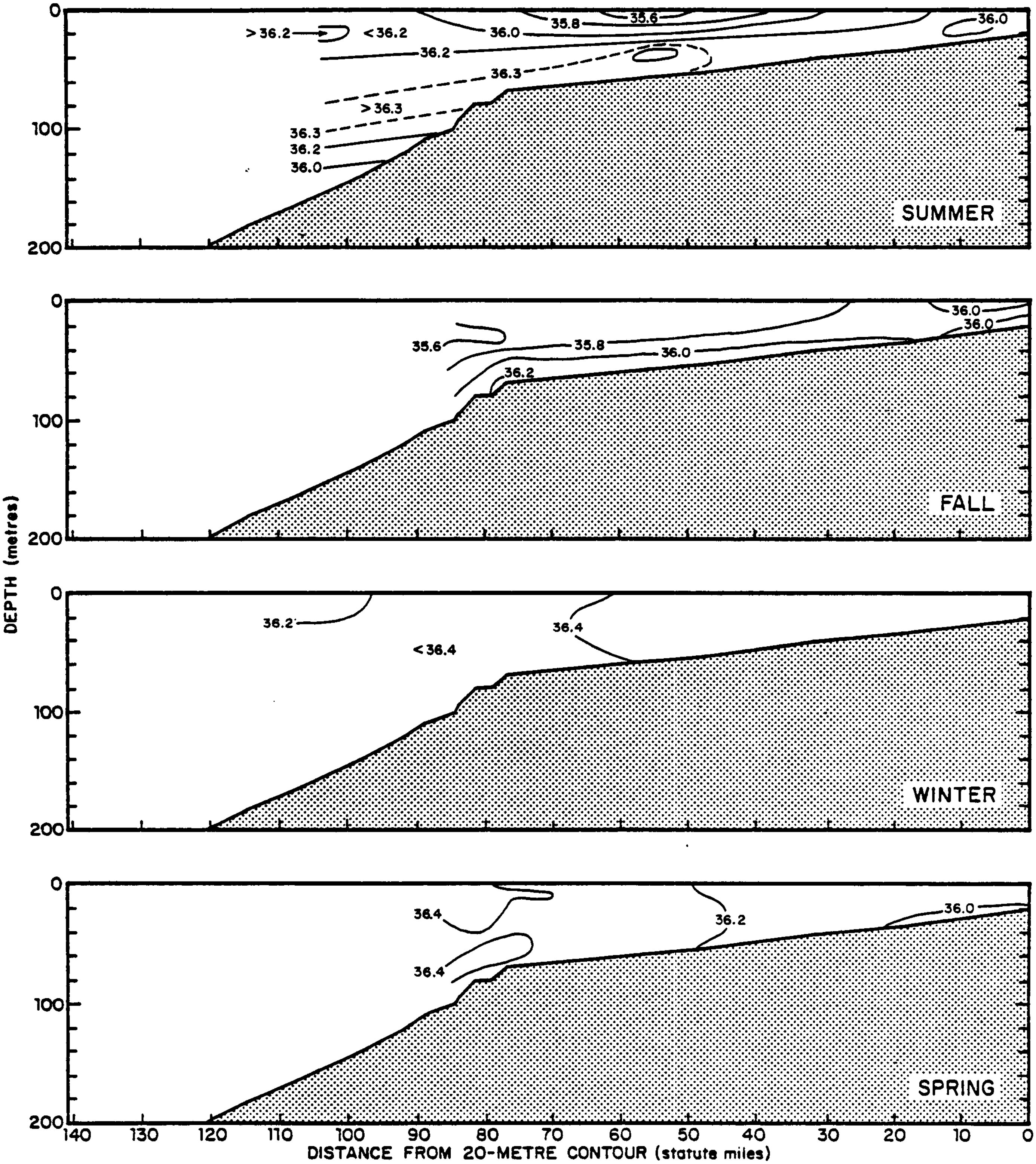

Figure 4-25. Seasonal salinity (o/oo) distributions on Transect B.

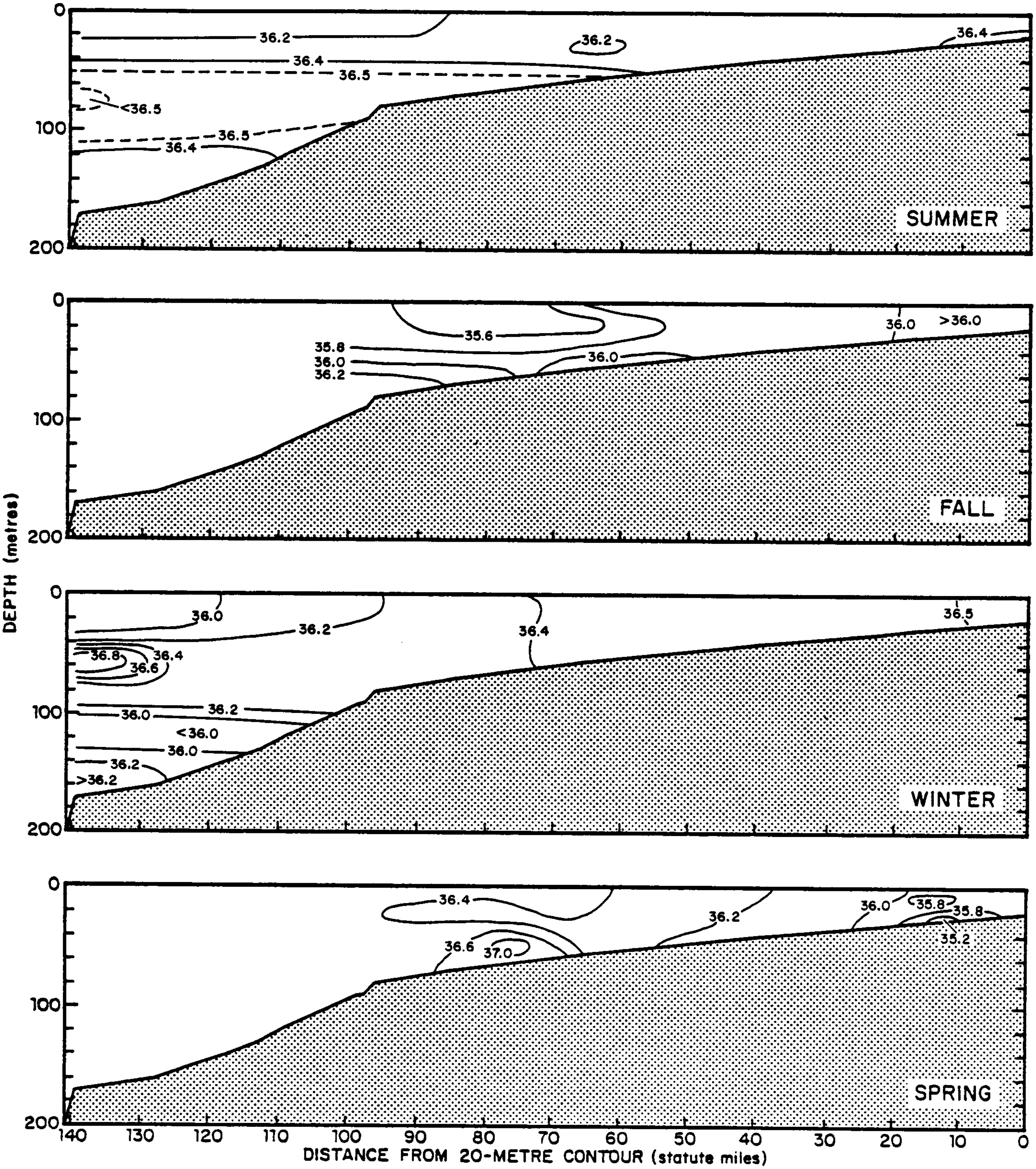

Figure 4-26. Seasonal salinity (o/oo) distributions on Transect C

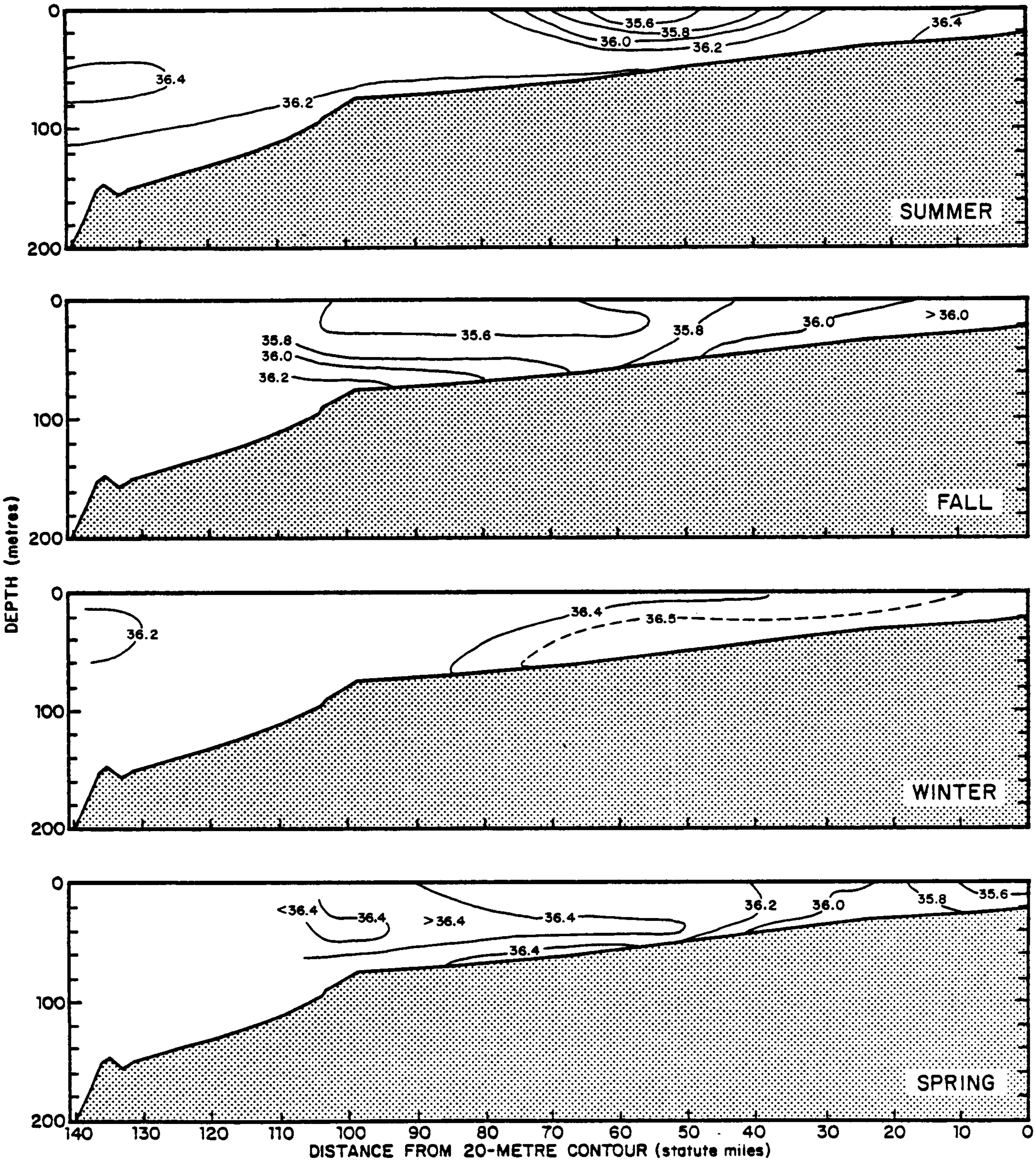

Figure 4-27. Seasonal salinity (o/oo) distributions on Transect D

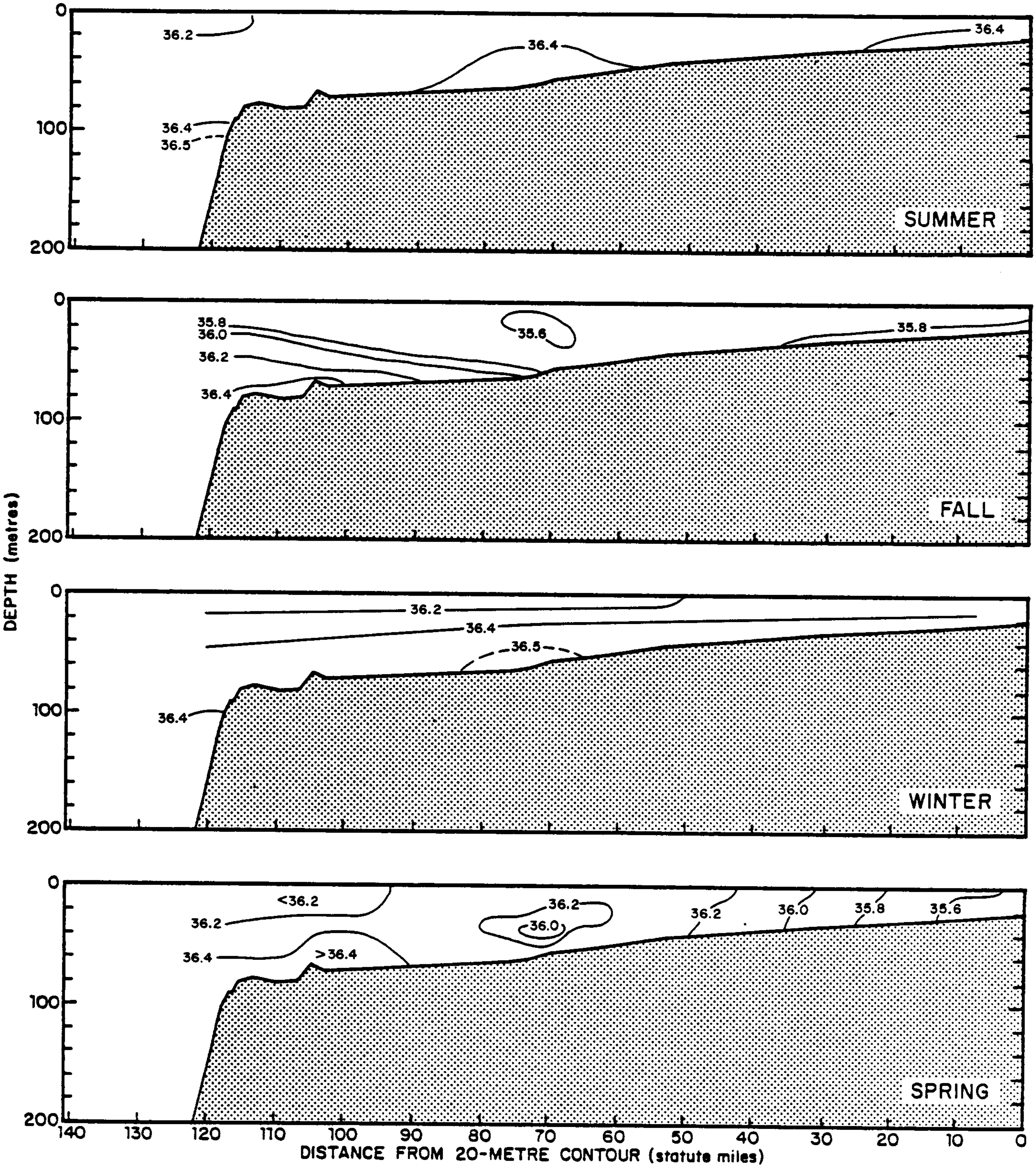

Figure 4-28. Seasonal salinity (o/oo) distributions on Transect E

depth and having minimum salinities of <35.6 o/oo. Also during the Summer, Fall, and Winter Cruises, the general trend in the upper 40m was an increase in salinity in the shoreward direction. This has been observed historically, but is not commonly described in the literature of the west Florida shelf. The fall trend may be explained by the existence of the offshore low-salinity lens. The 36.0 o/oo salinity levels near-shore would not be considered anomalous. However, during the Summer and Winter Cruises, near-shore salinities of >36.4 o/oo were encountered and may be attributed to the severe (100-year) drought occurring in Florida during this study. This would suggest evaporative loss in the shallower waters as the source of these high salinity anomolies.

The Fall and Spring Cruises exhibited "normal" salinity patterns relative to seasonal climatological events. Fall salinities were stratified while the spring salinities were partitioned in a cross-shelf direction, as the result of winter mixing. The halocline boundaries generally coincided with the thermocline isolines.

4.4.4.3 Transmissivity

Transmittance values (generally >90%) indicated the predominance of clear waters over the entire study area (Figures 4-29 to 4-33). The Winter Cruise measurements showed the least amount of variation, probably as a result of winter mixing events. The greatest isoline structure was observed during the Fall Cruise. This cruise also yielded the lowest transmittance values. This decrease in water clarity correlated with higher chlorophyll a values, suggesting phytoplankton increases as a major contributor to the reduced transmittance. In fact, a toxic dinoflagellate bloom was reported in the area at that time and may have contributed to the fall results. There were occassional significant near-bottom increases in turbidity, suggesting bottom resuspension from current activity. However these followed no seasonal pattern nor were they consistant at any given station location.

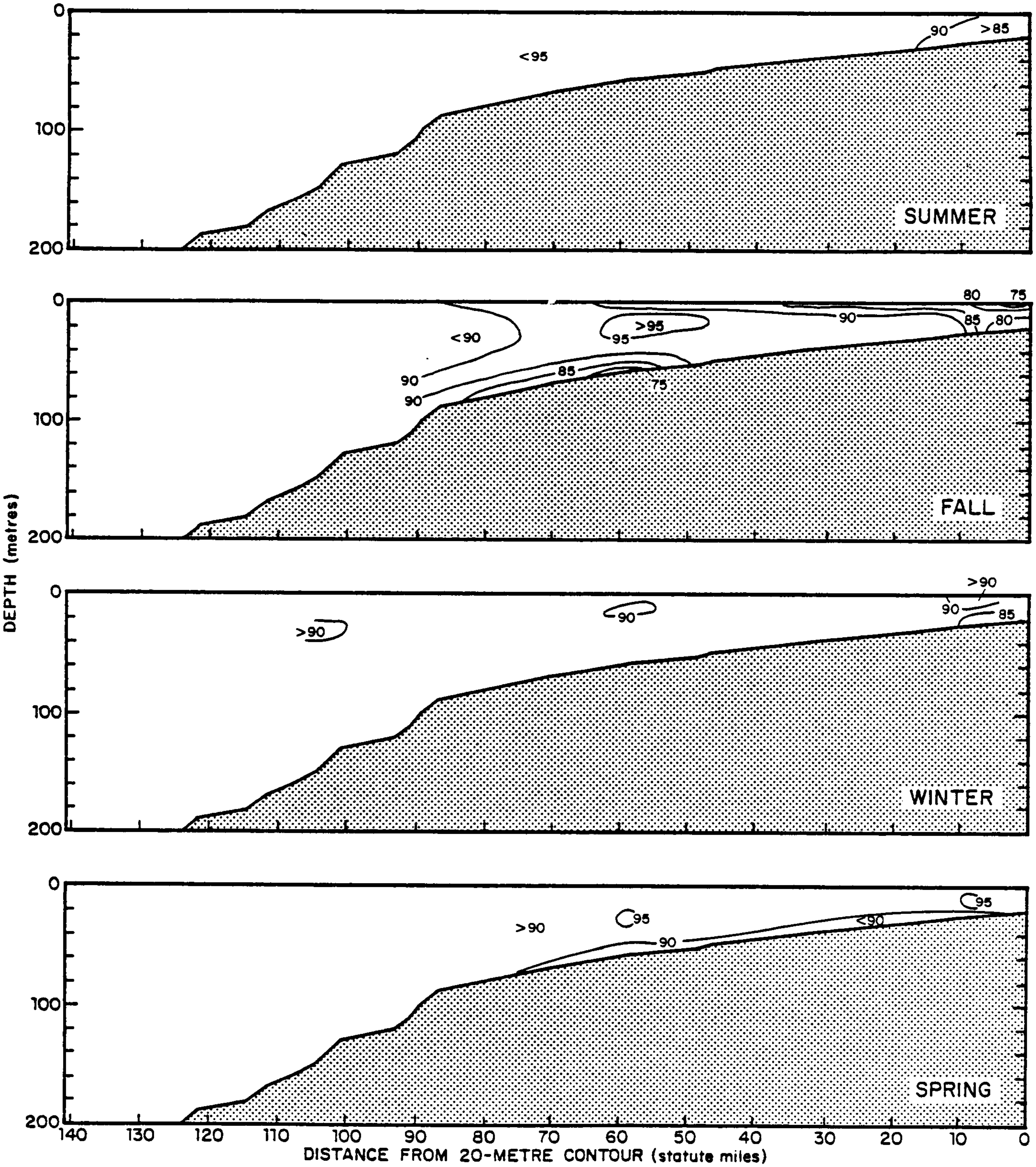

Figure 4-29. Seasonal transmissivity (%T) distributions on Transect A.

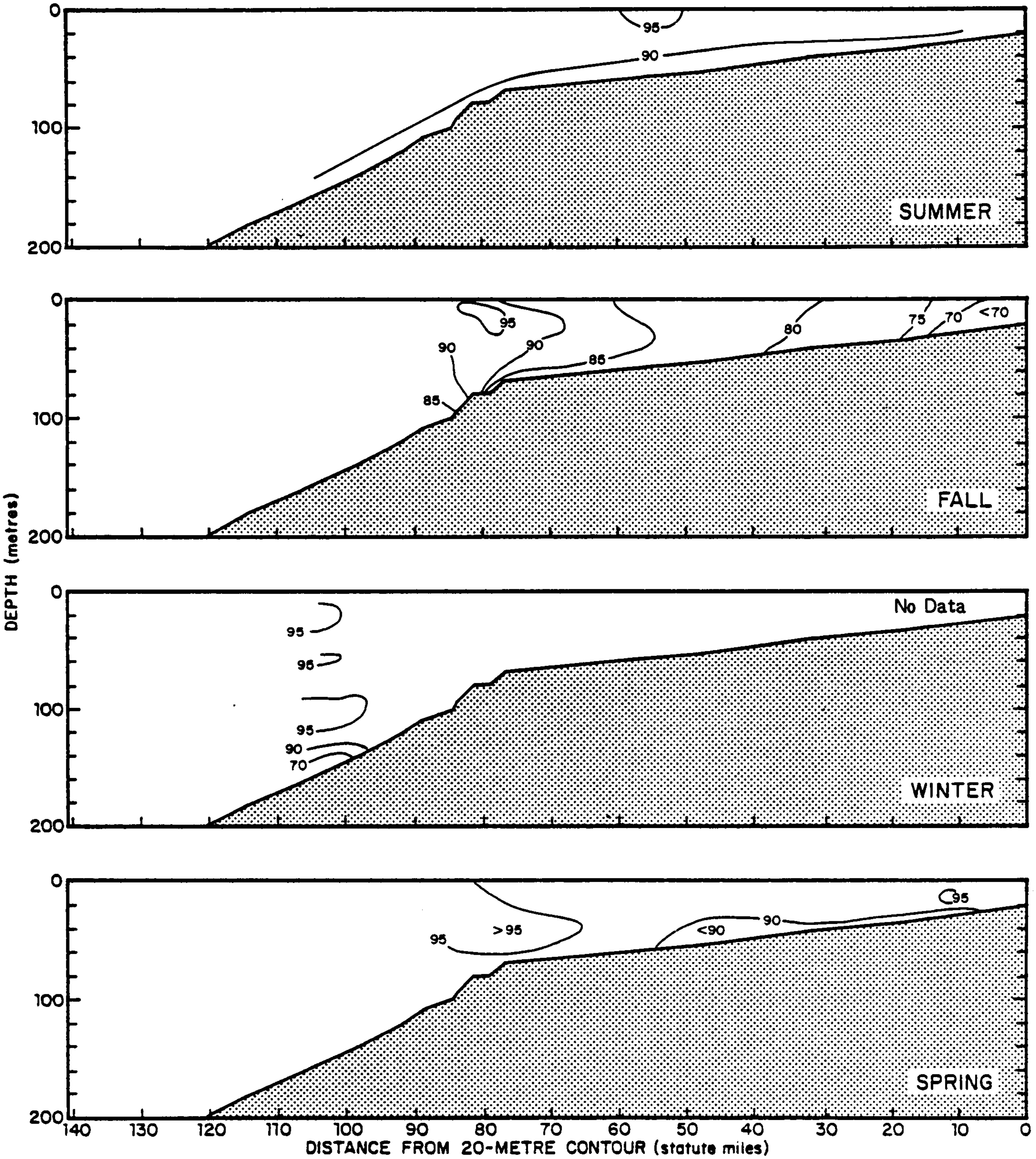

Figure 4-30. Seasonal transmissivity (%T) distributions on Transect B.

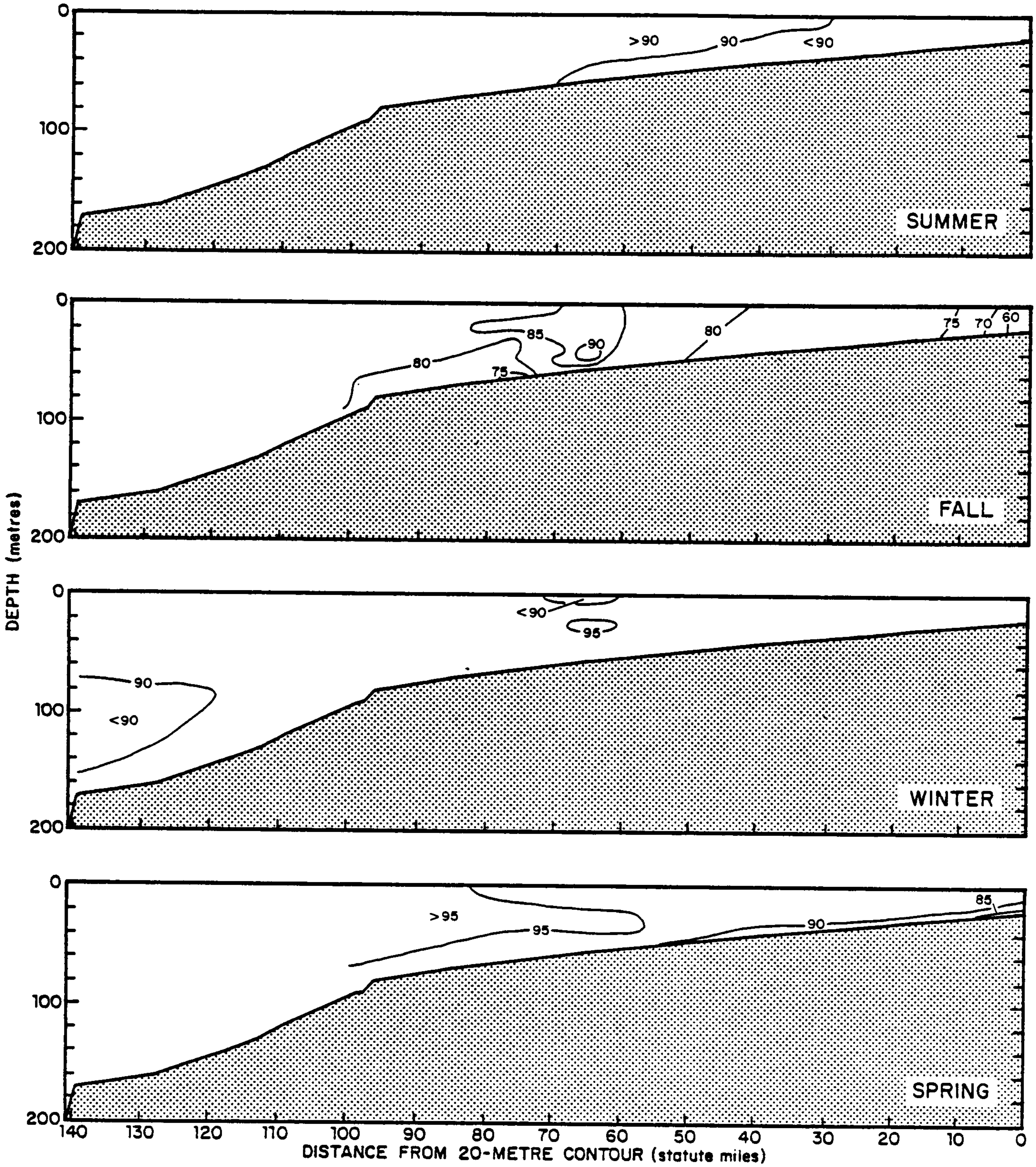

Figure 4-31. Seasonal transmissivity (%T) distributions on Transect C.

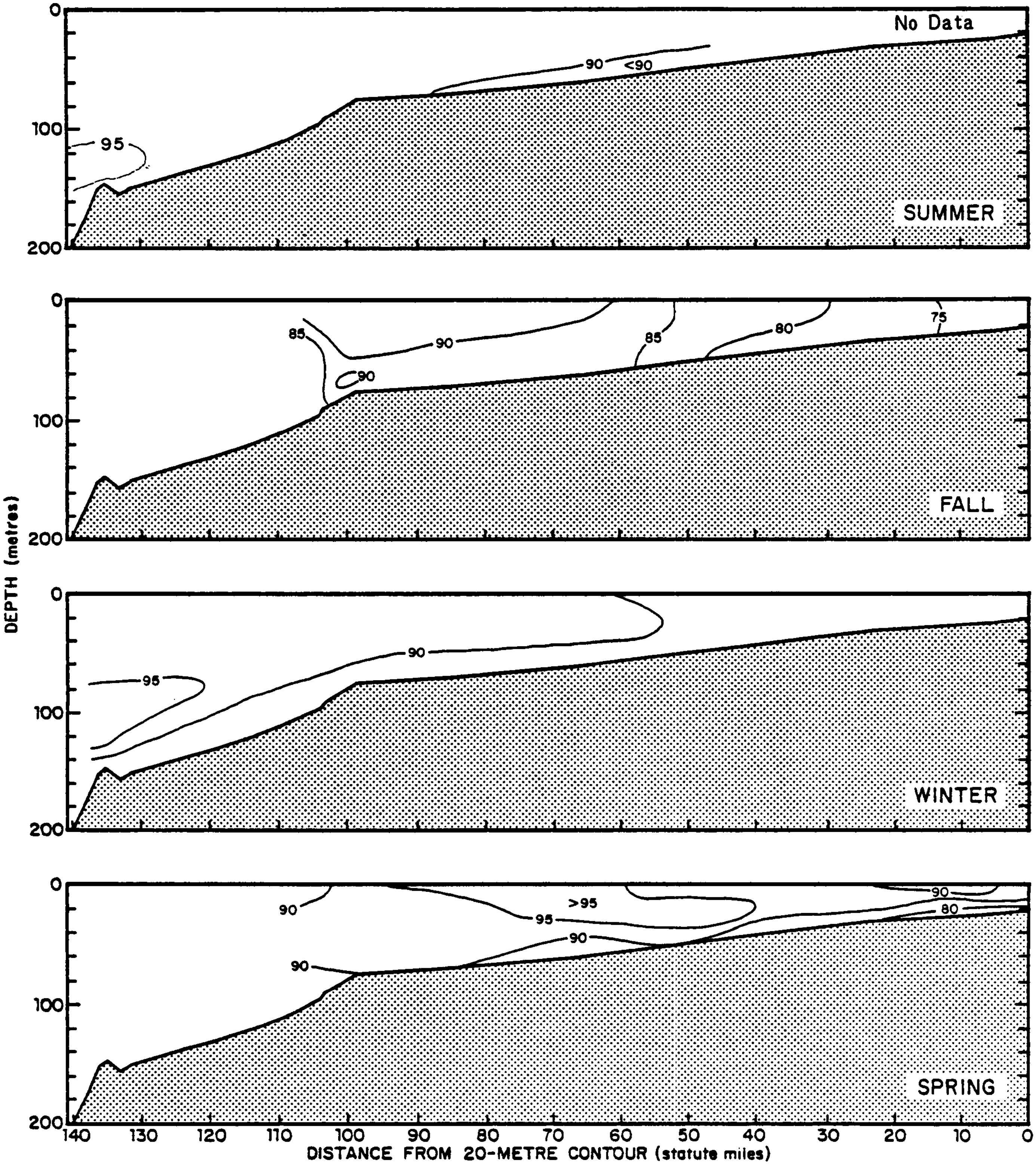

Figure 4-32. Seasonal transmissivity (%T) distributions on Transect D.

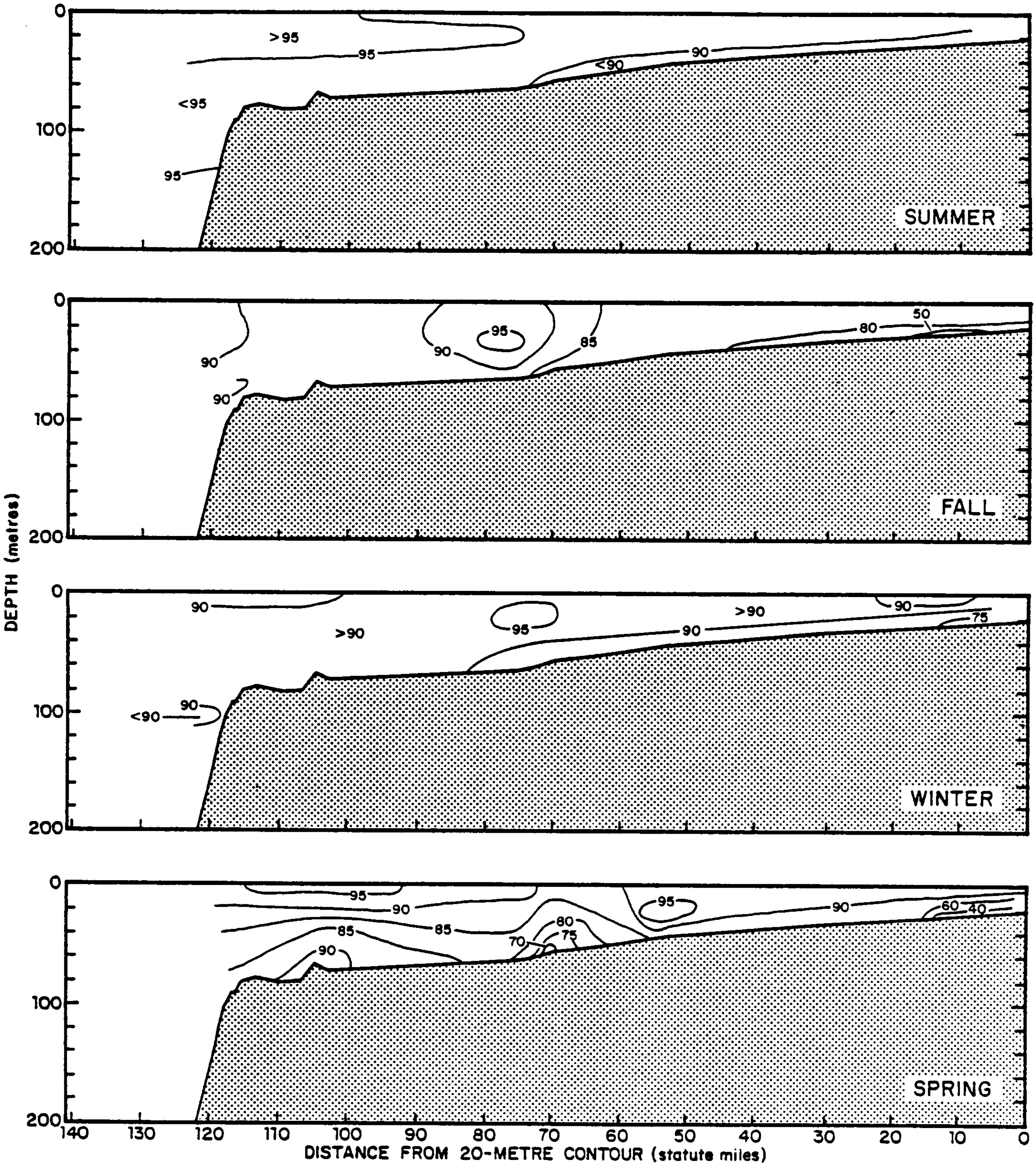

Figure 4-33. Seasonal transmissivity (%T) distributions on Transect E.

4.4.4.4 Dissolved Oxygen

Dissolved oxygen levels (Table 4-1) showed no clear seasonal patterns. The surface values ranged from 5.5 to 7.0 ml/l. The summer surface values were the lowest of the four cruises, averaging approximately 5.8 ml/l. The offshore near-bottom oxygen values were the lowest observed during the four cruises, generally being 4 to 5 ml/l. This was not the case for the Spring Cruise, where values did not fall below 5.78 ml/l. The bottom values corresponded to the temperature and salinity relationships, with the source of the lower oxygen water being from below the salinity maximum off the west Florida shelf.

4.4.4.5 Dissolved Nutrients

As with other parameters, nutrients did not exhibit any strong seasonal patterns. Three nutrients were measured: phosphate (PO_4-P, Figures 4-34 to 4-38), nitrite and nitrate (NO_2-NO_3-N, Figures 4-39 to 4-43), and silica (SiO_2, Figures 4-44 to 4-48). Nitrite was not interpretively distinguished because the nitrite concentrations were generally below the level of accuracy of detection. However, the data are available for more detailed anlaysis to those who are interested (Volume 5 - Appendix A.4).

With few exceptions the suface mixed layers had low concentrations of nutrients. However, concentrations increased below the pycnocline, occurring below the salinity maximum and with decreasing temperatures. The source of these nutrients lies in the open Gulf of Mexico waters, below 200m depths. The higher nutrient concentrations varied among transects and were most likely affected by local and mesoscale events.

PO_4-P concentrations ranged from <0.1μM in the mixed layers to >1.2μM below the pycnocline; they appeared to be a function of depth and the input of offshore waters (Figures 4-34 to 4-38).

Below the pycnocline NO_2-NO_3-N concentrations varied simultaneously with phosphate and temperature. It is likely that both PO_4-P and NO_2-NO_3-N were

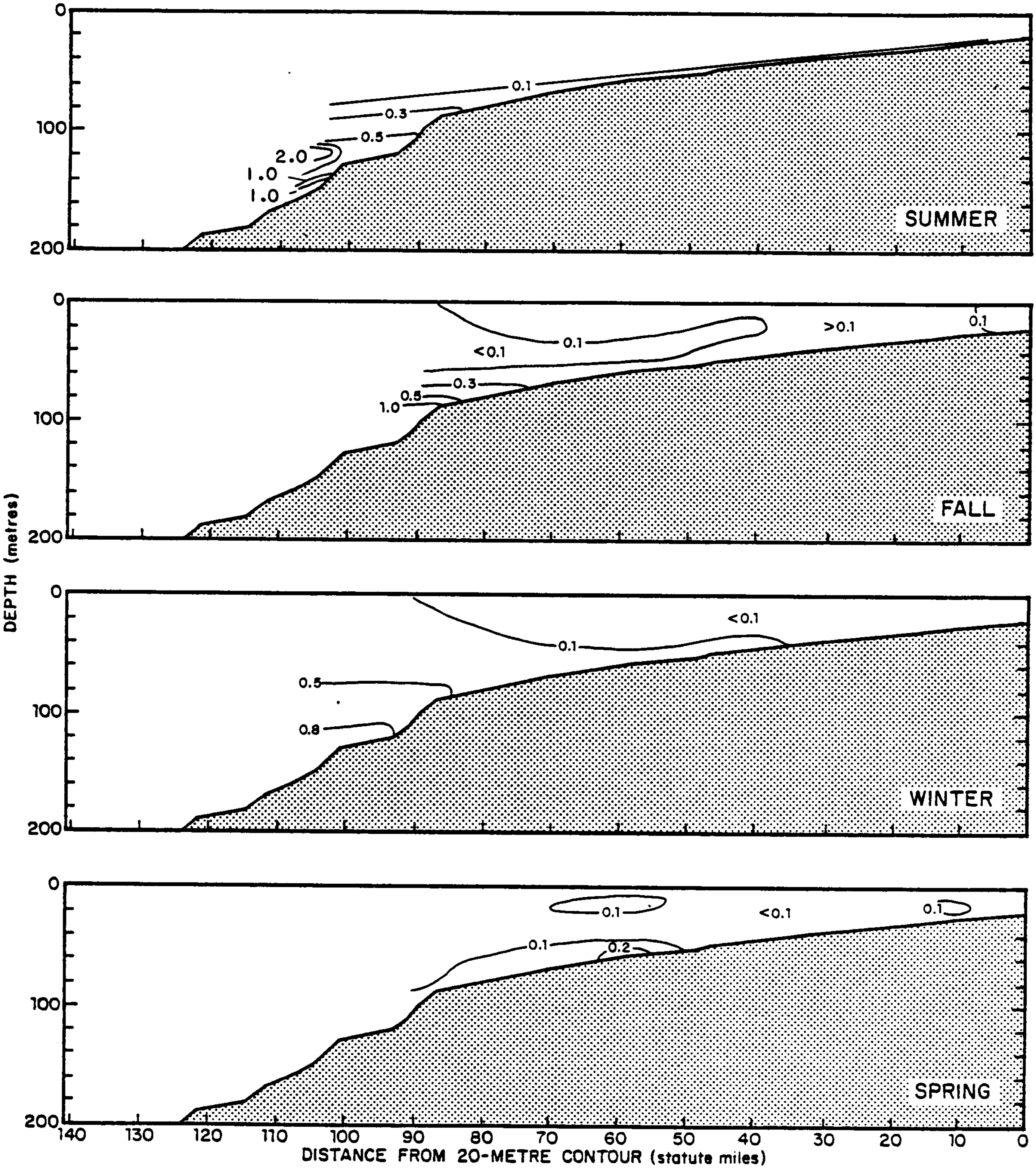

Figure 4-34. Seasonal phosphate (μM) distributions on Transect A

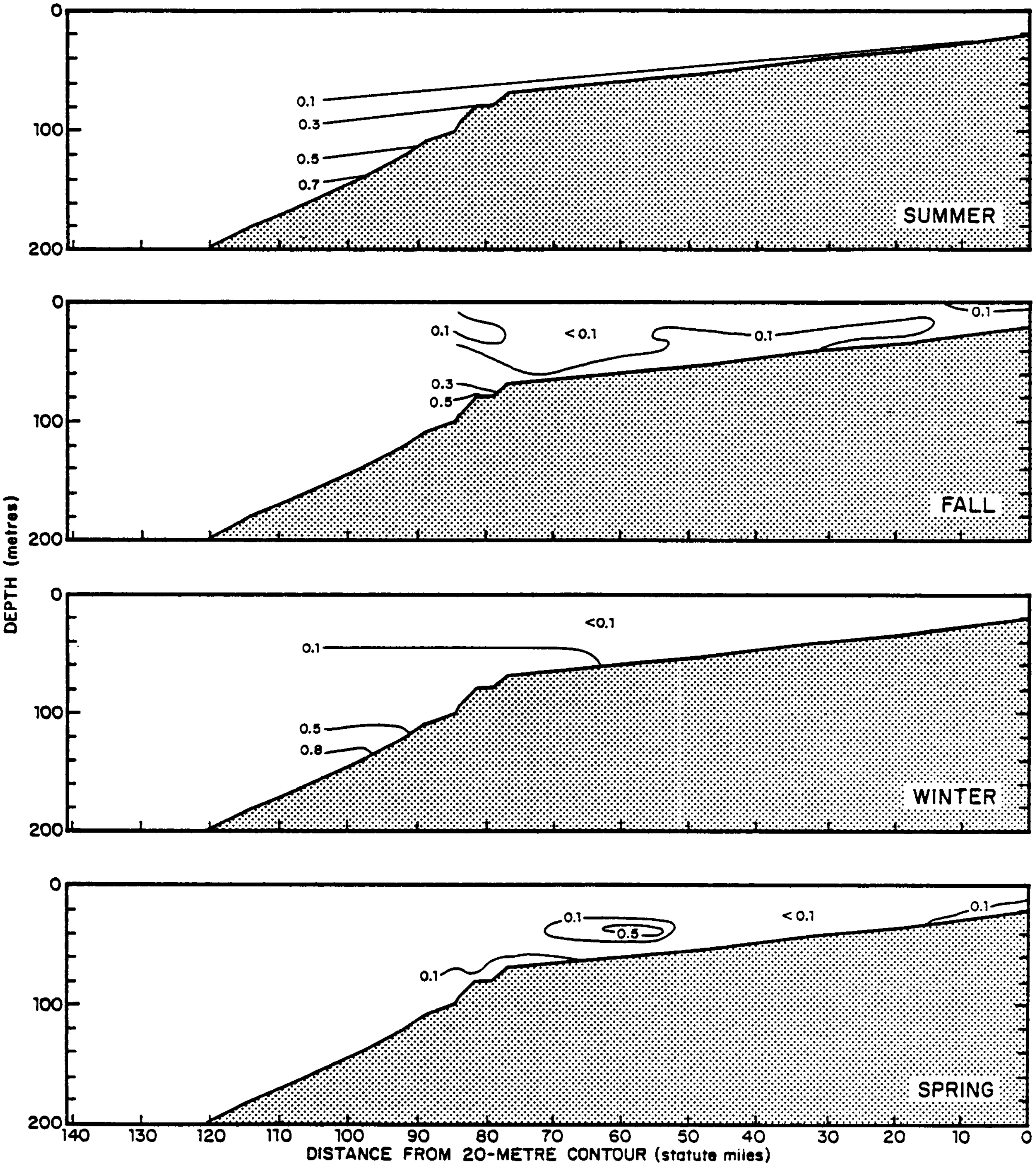

Figure 4-35. Seasonal phosphate (μM) distributions on Transect B

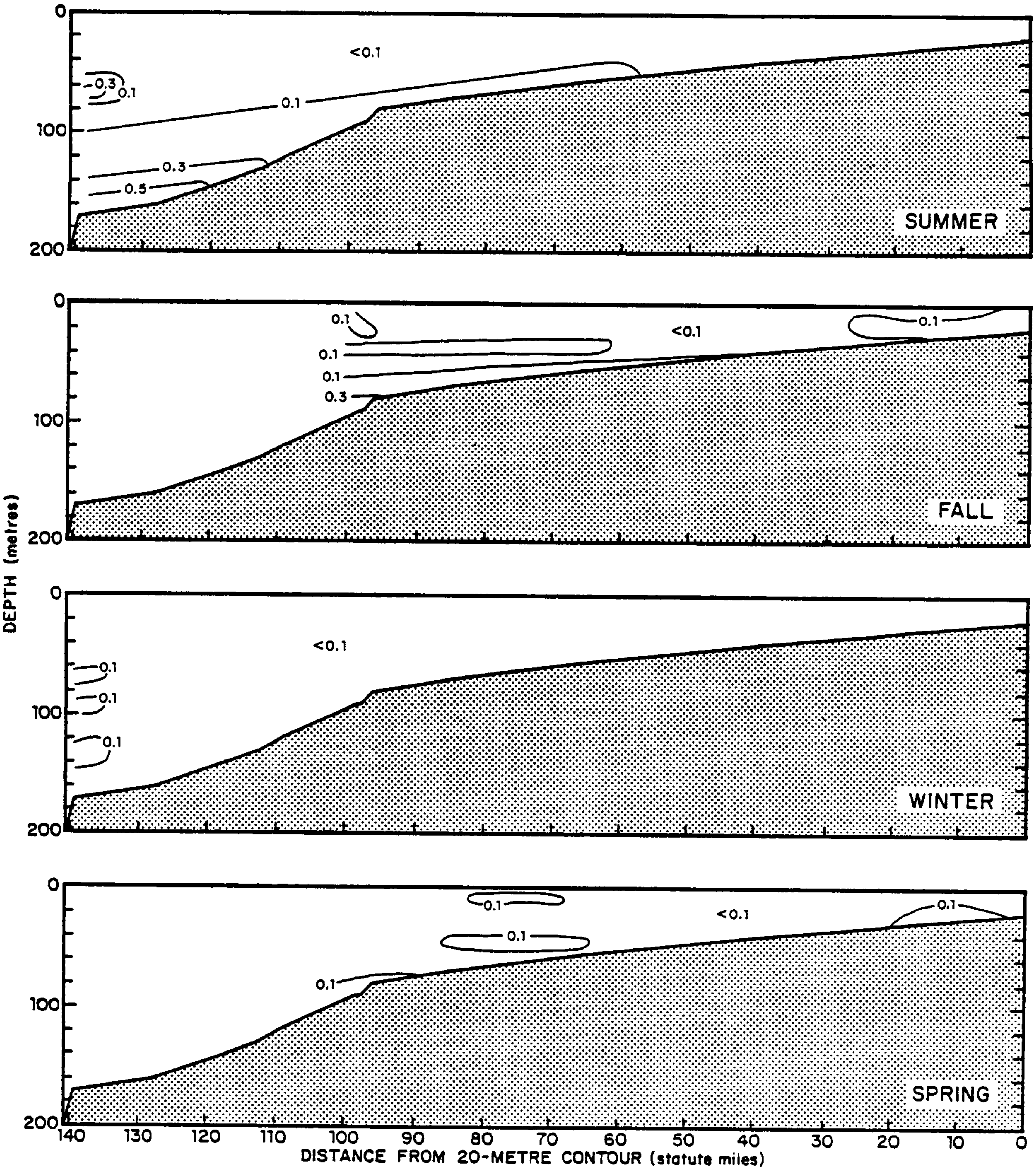

Figure 4-36. Seasonal phosphate (μM) distributions on Transect C

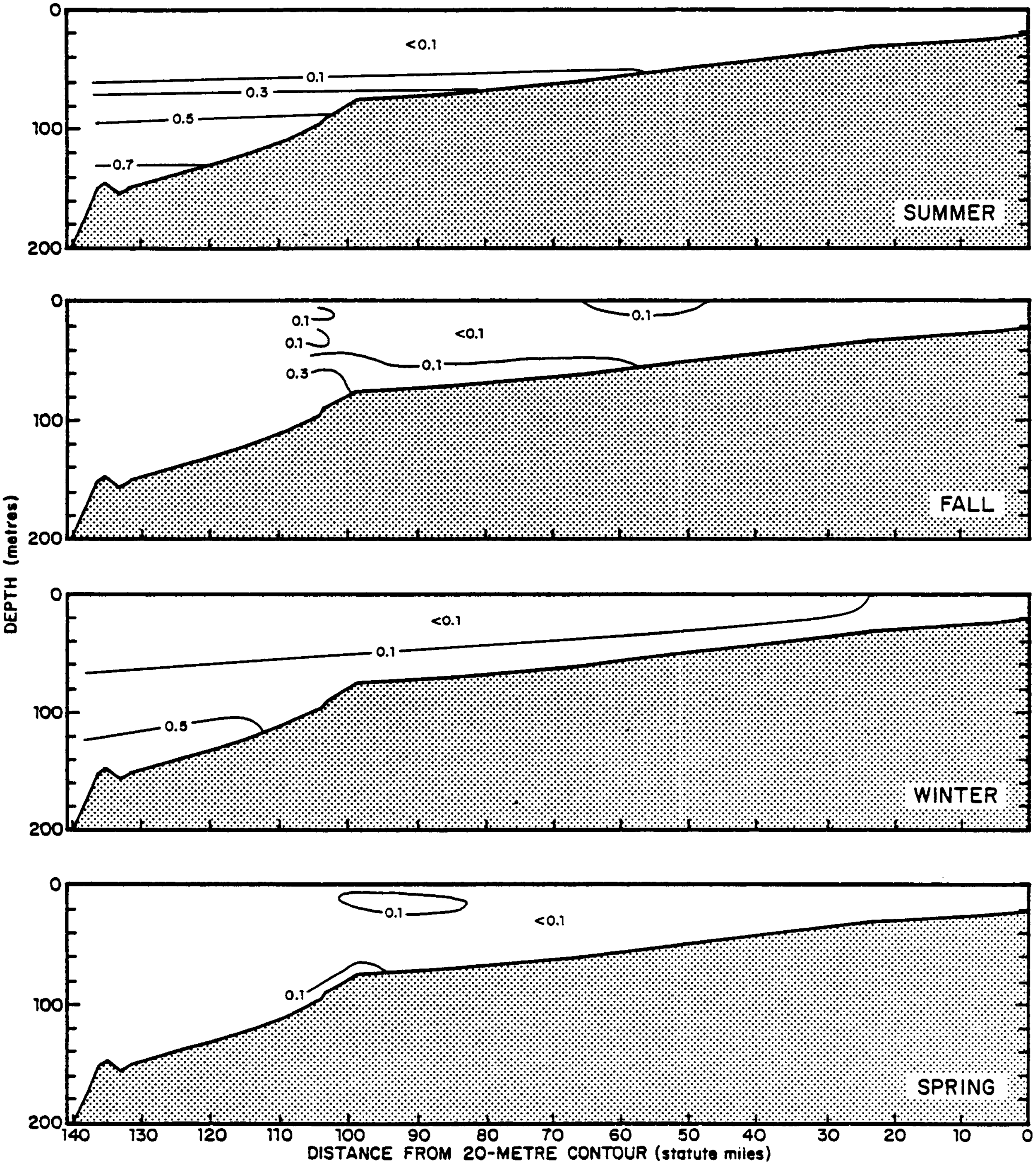

Figure 4-37. Seasonal phosphate (μM) distributions on Transect D

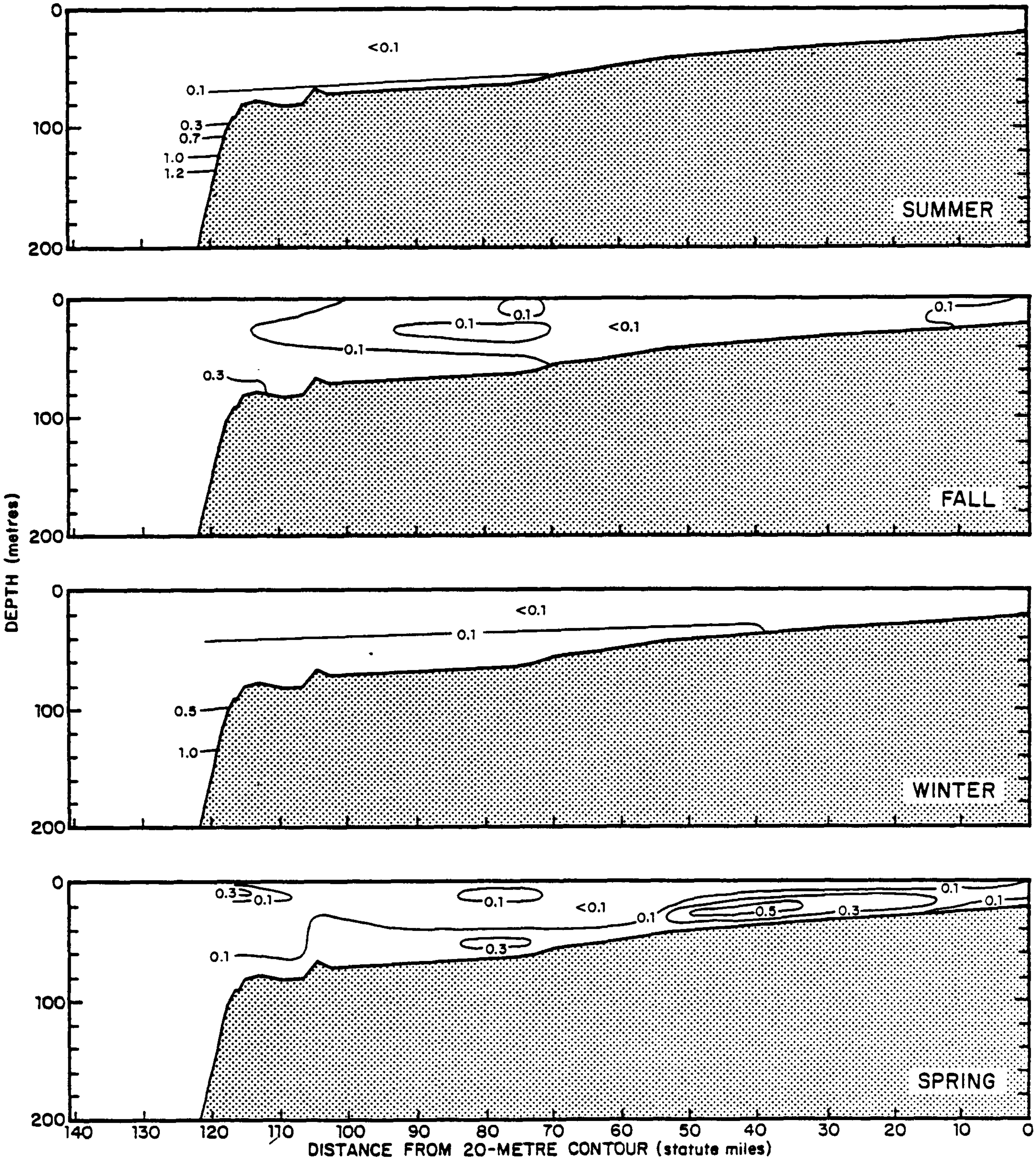

Figure 4-38. Seasonal phosphate (μM) distributions on Transect E

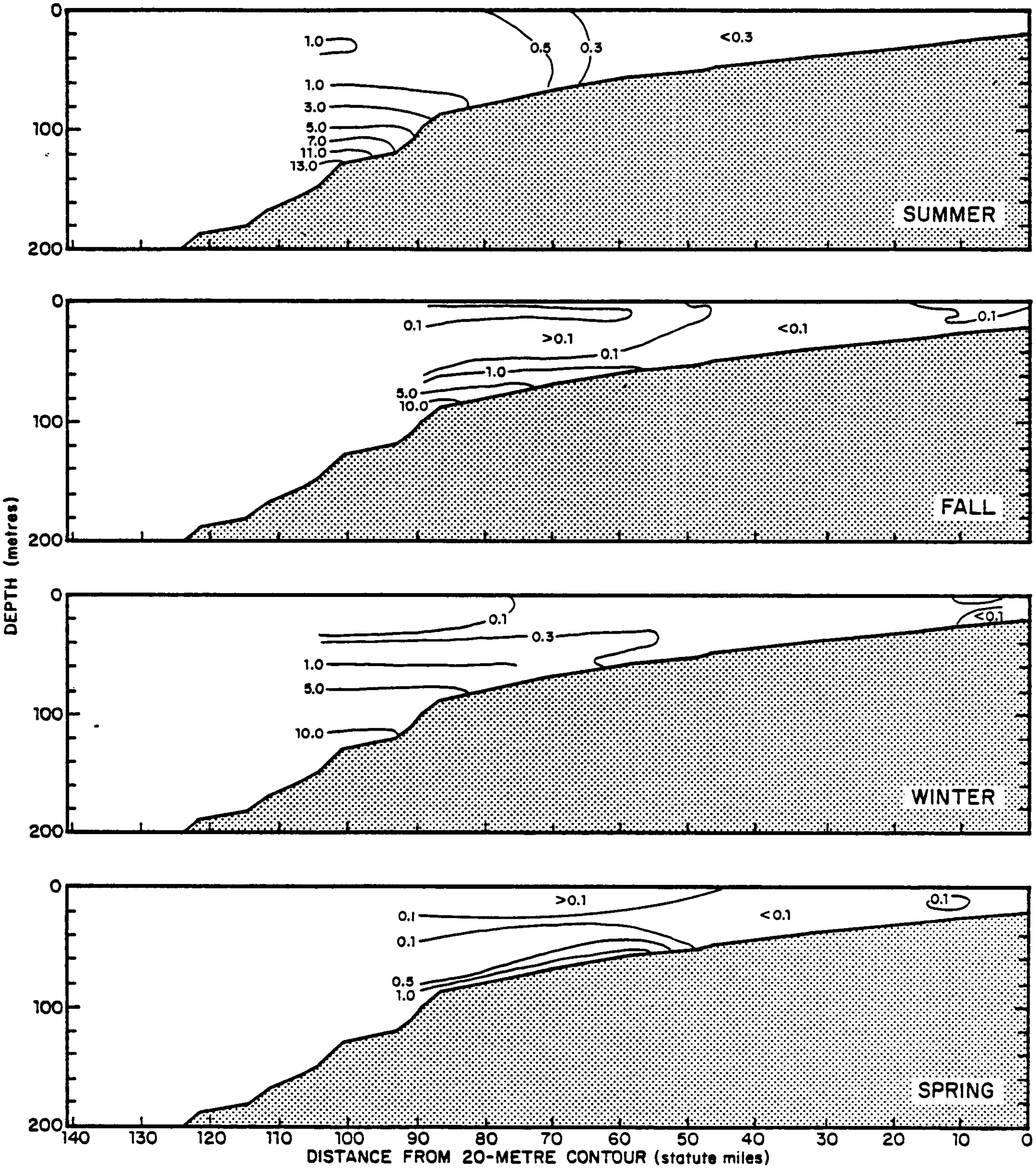

Figure 4-39. Seasonal nitrite + nitrate (µM) distributions on Transect A

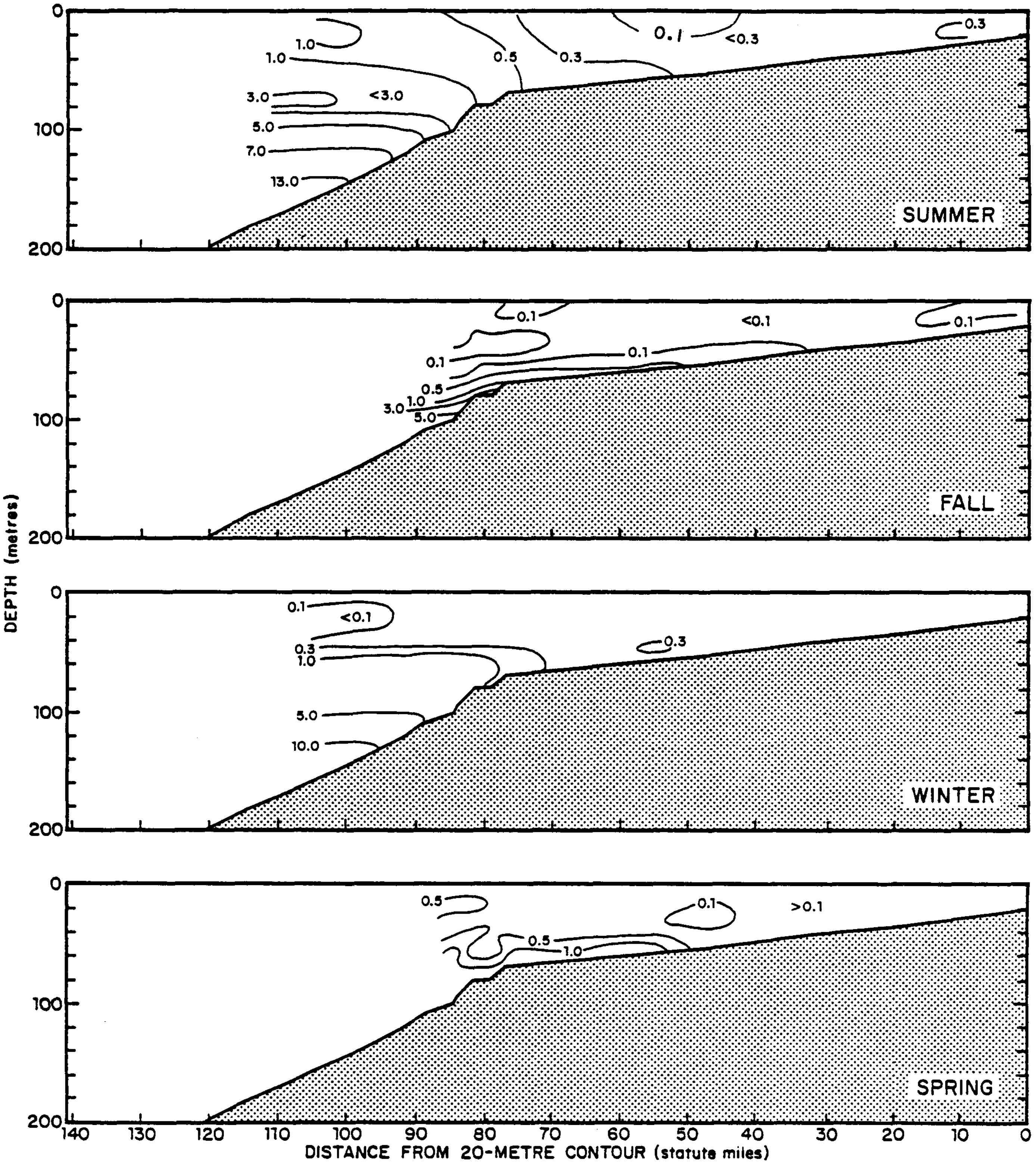

Figure 4-40. Seasonal nitrite + nitrate (μM) distributions on Transect B

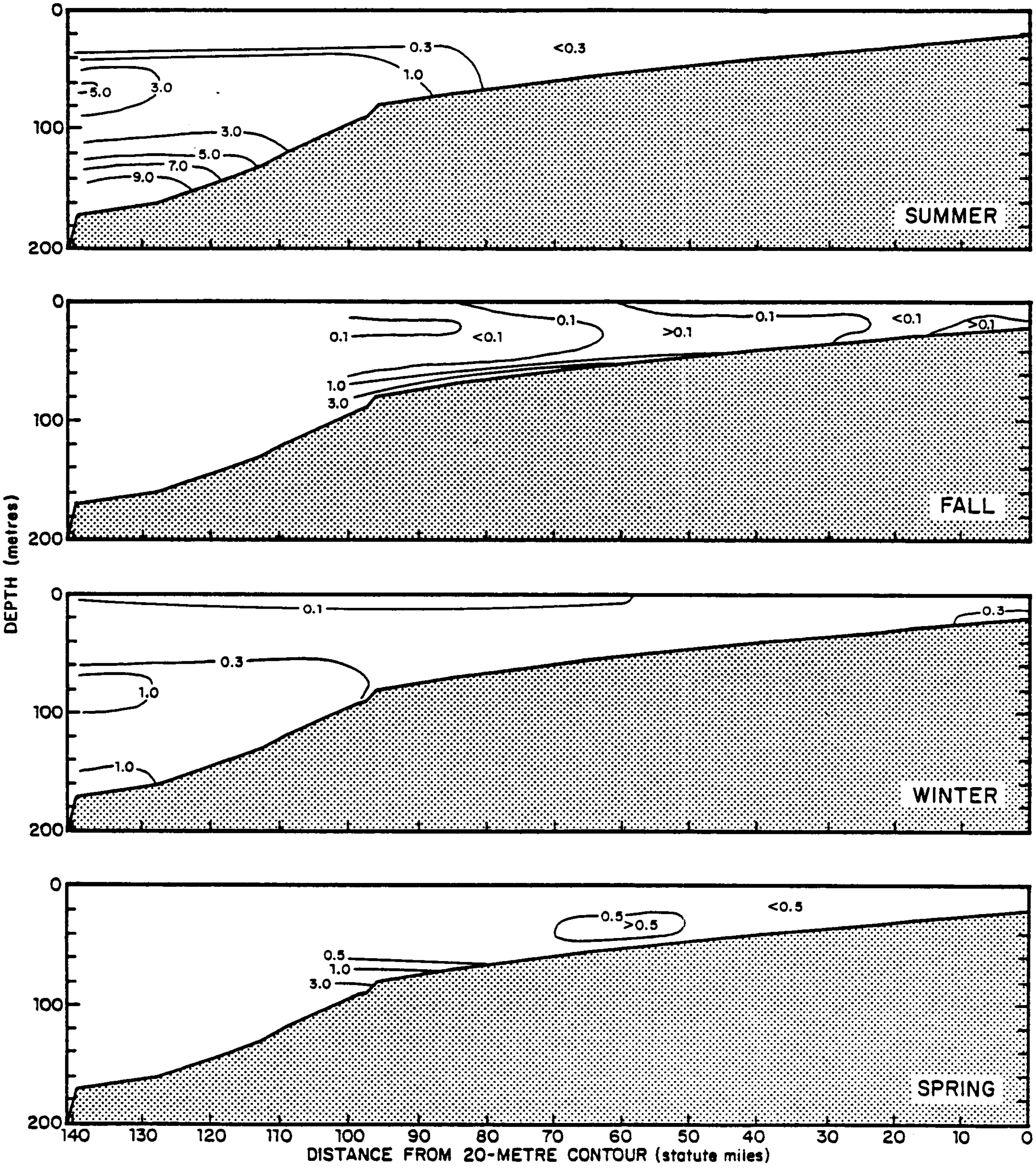

Figure 4-41. Seasonal nitrite + nitrate (μM) distributions on Transect C

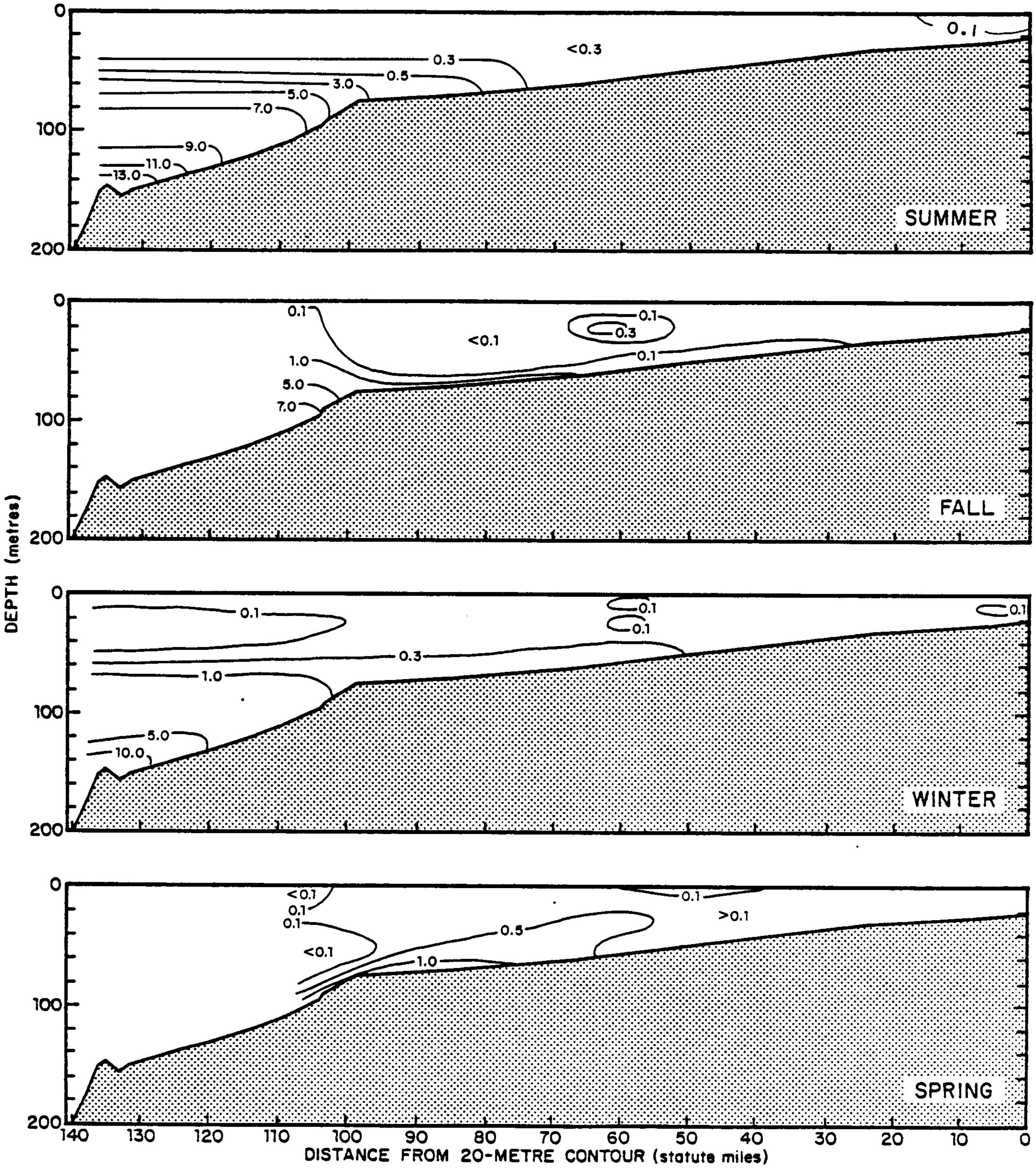

Figure 4-42. Seasonal nitrite + nitrate (μM) distributions on Transect D

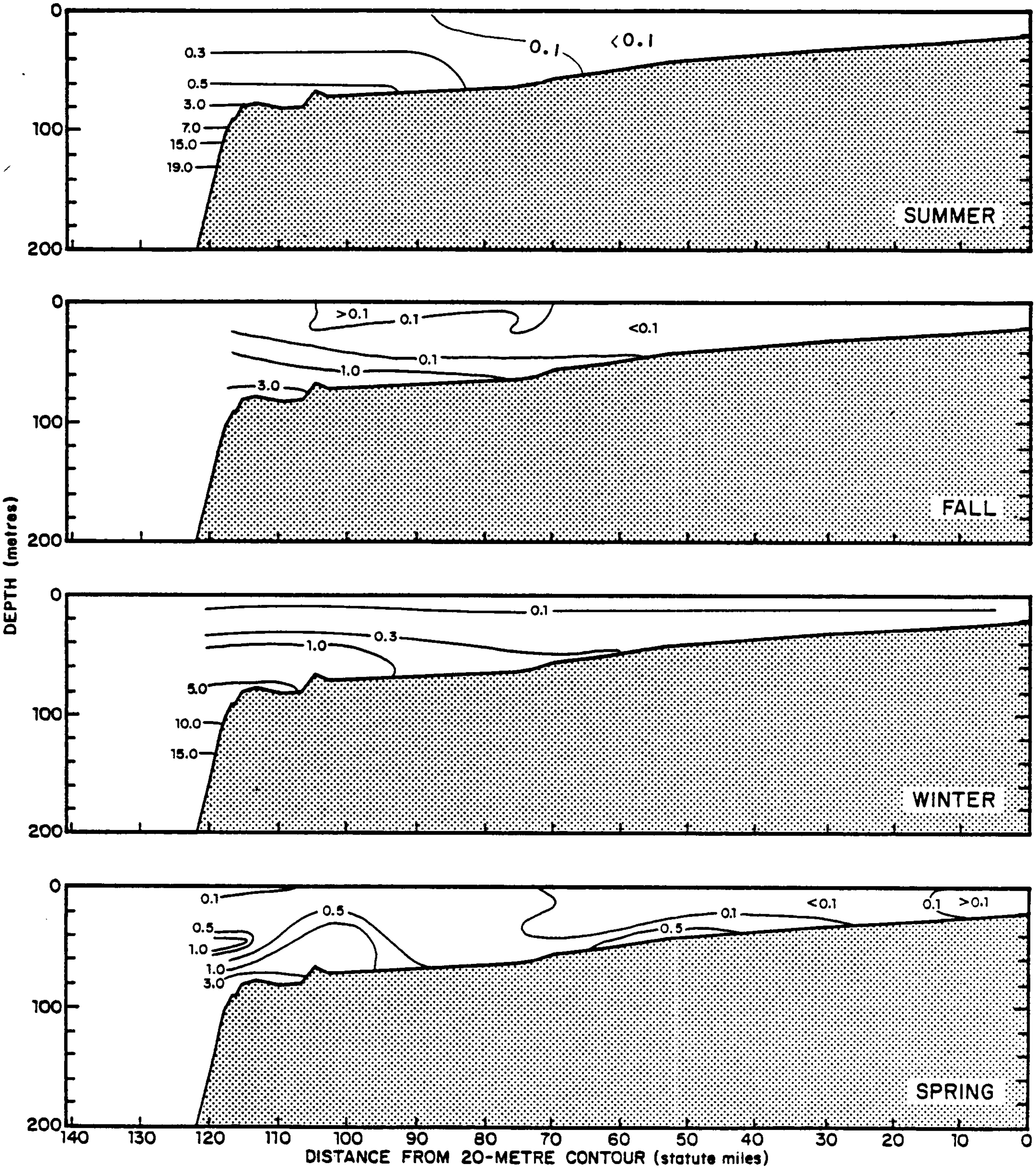

Figure 4-43. Seasonal nitrite + nitrate (µM) distributions on Transect E

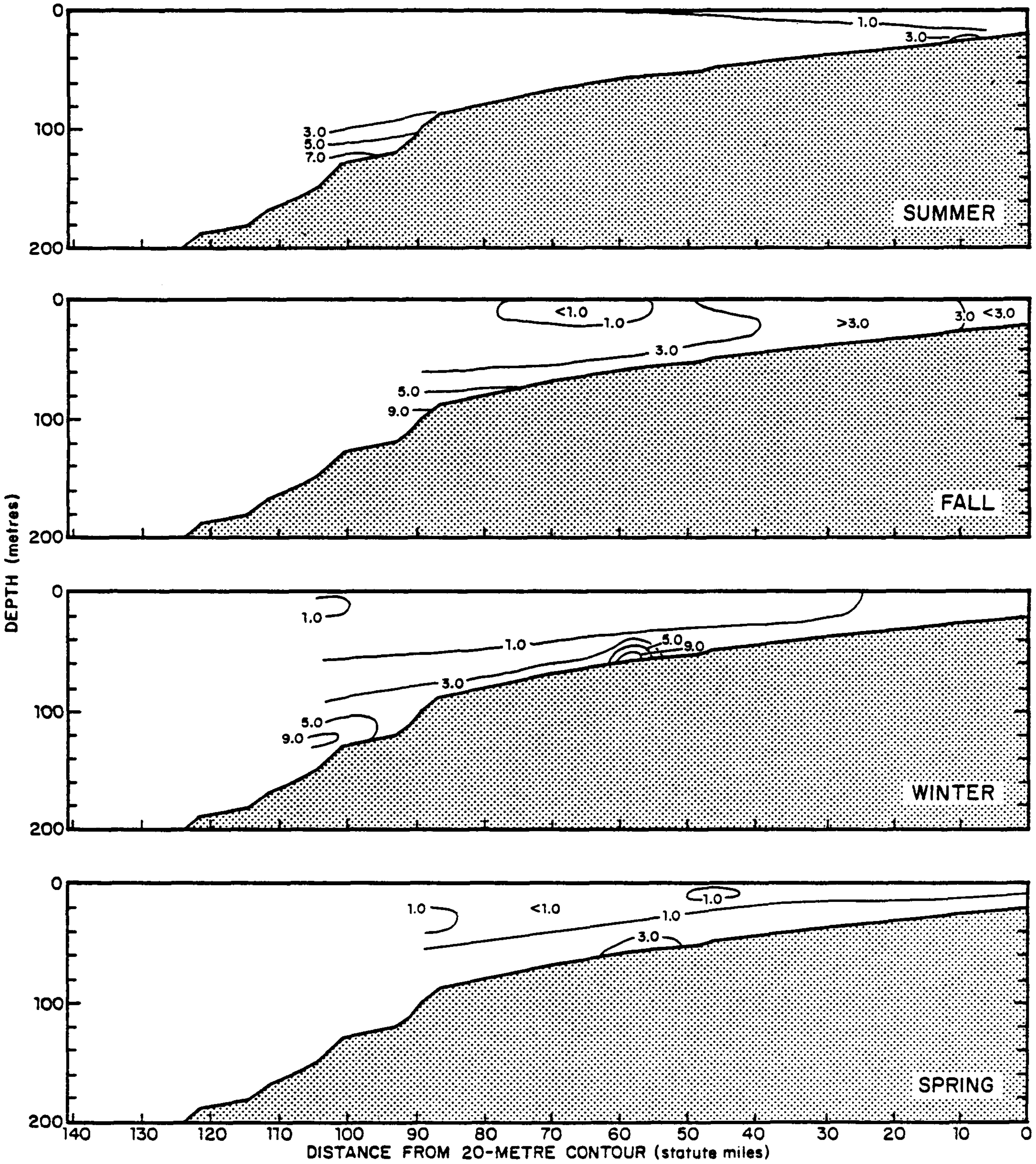

Figure 4-44. Seasonal silicate (μM) distributions on Transect A

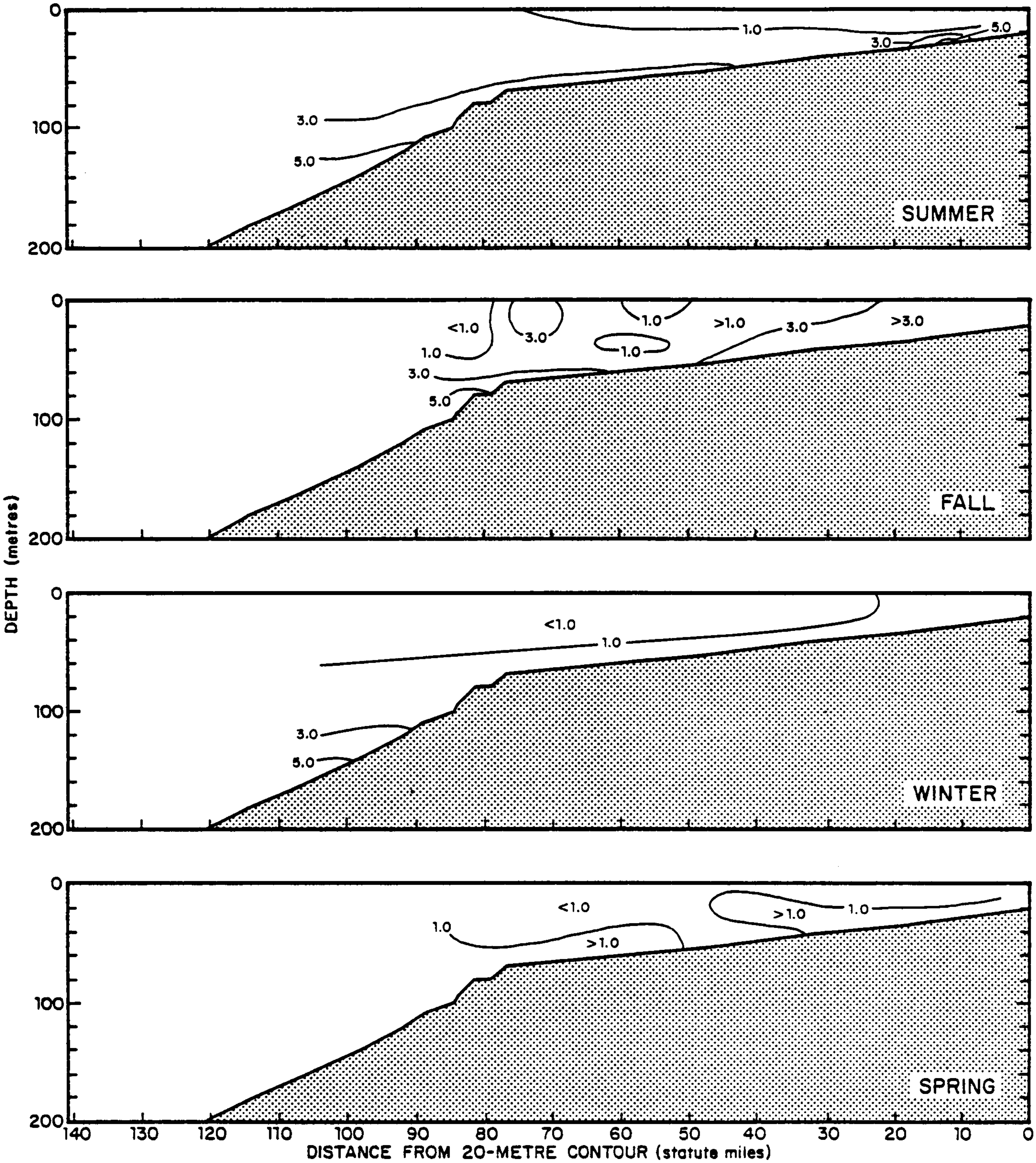

Figure 4-45. Seasonal silicate (µM) distributions on Transect B

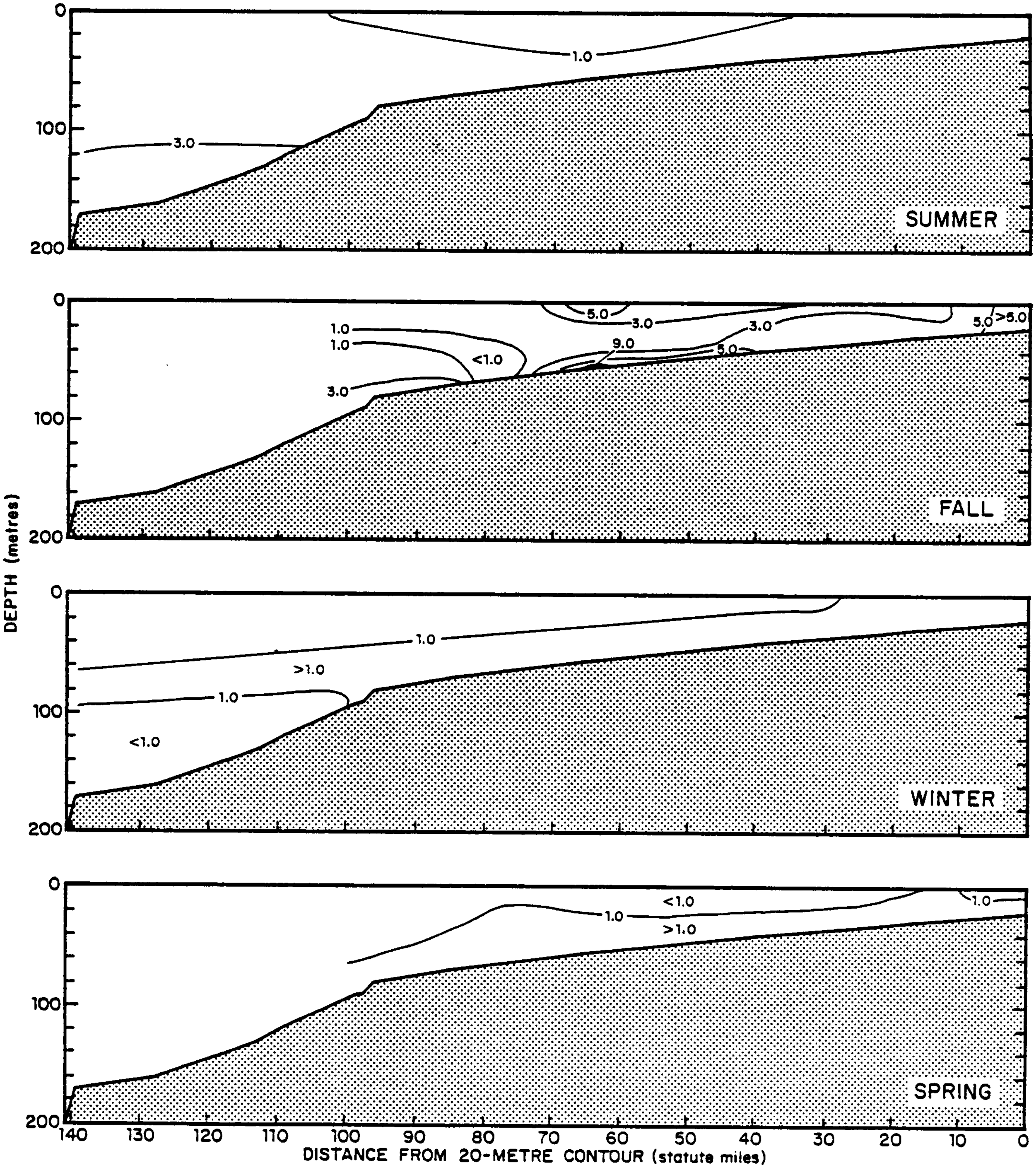

Figure 4-46. Seasonal silicate (µM) distributions on Transect C

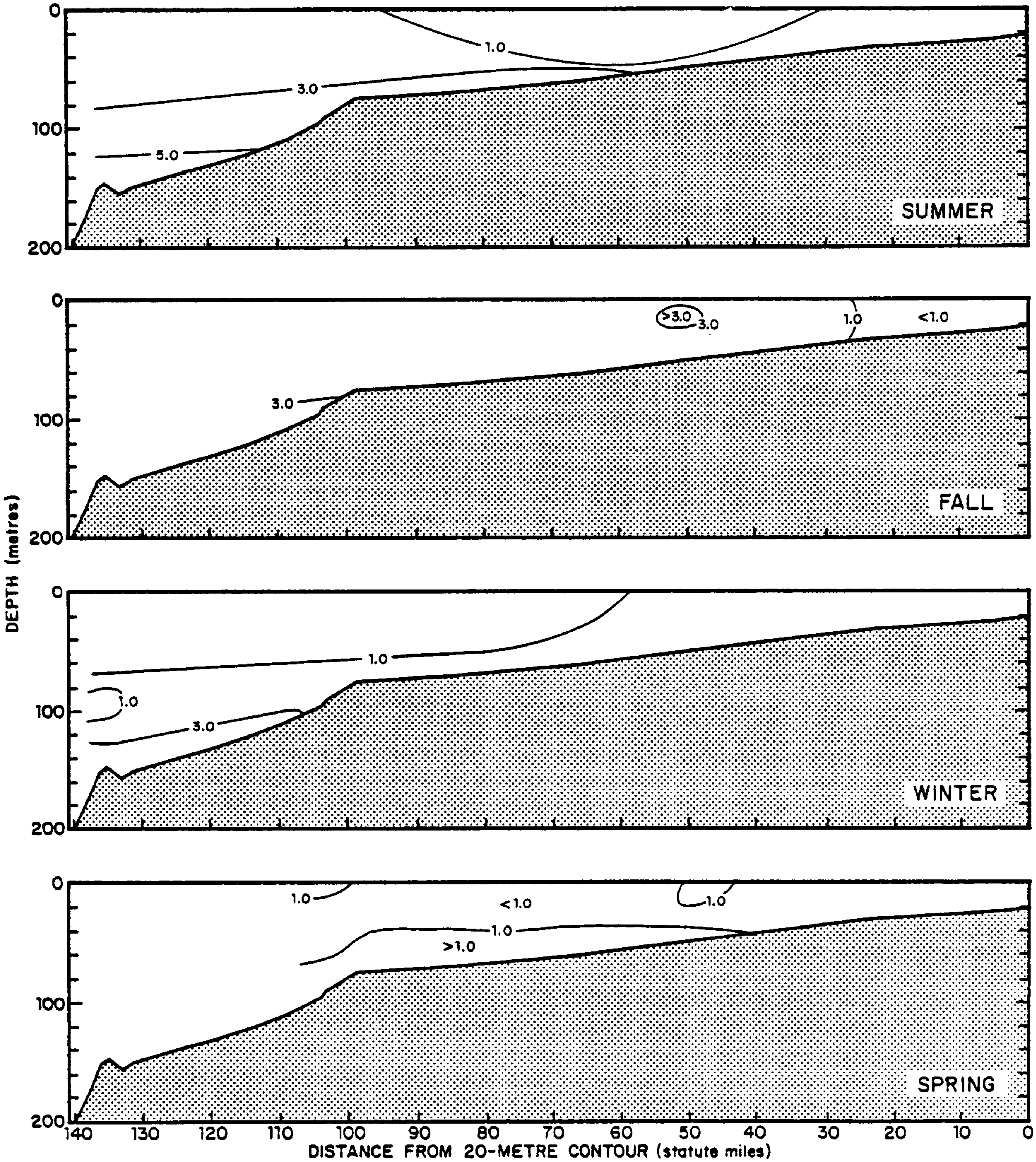

Figure 4-47. Seasonal silicate (μM) distributions on Transect D

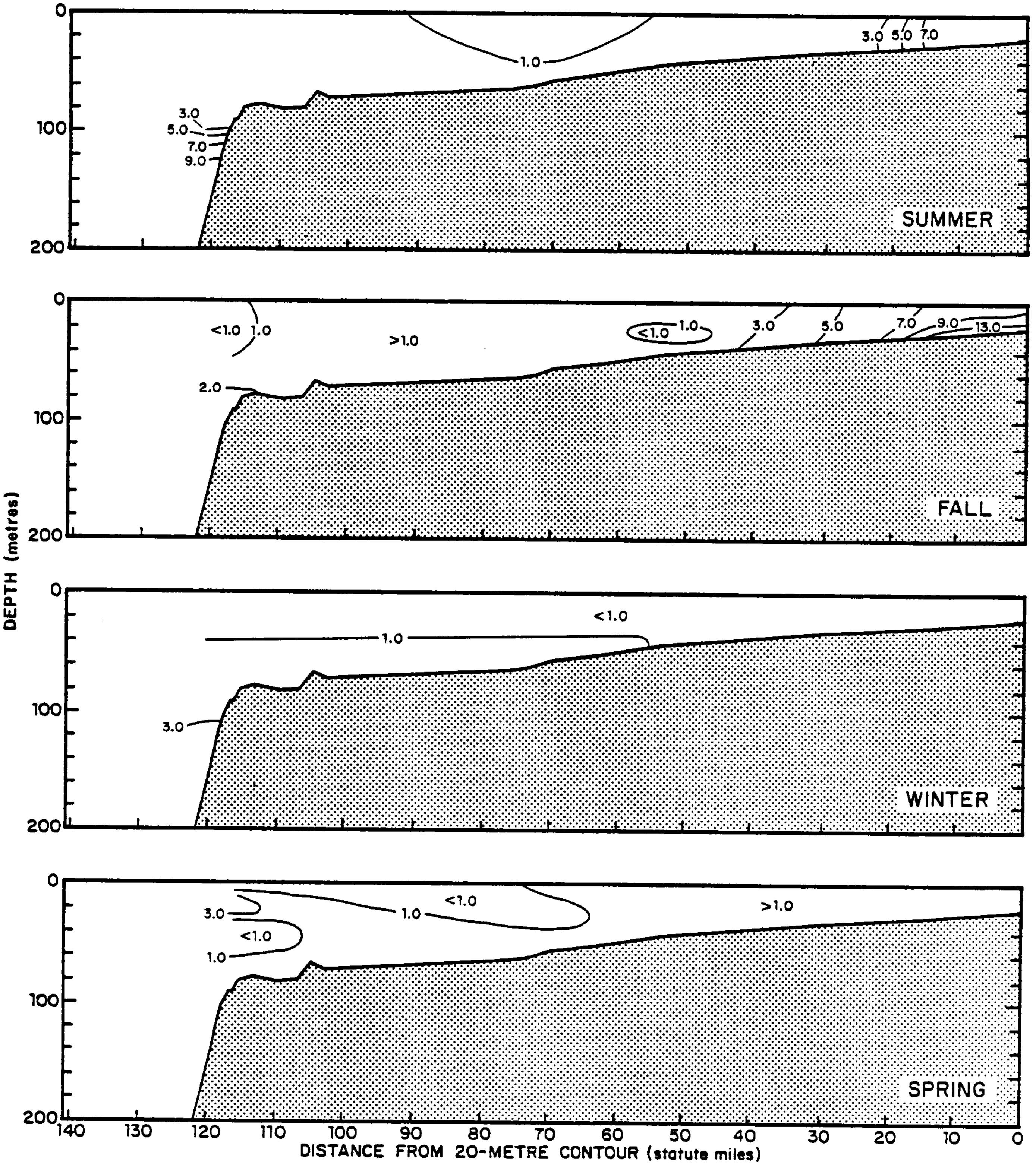

Figure 4-48. Seasonal silicate (μM) distributions on Transect E

directly related to the upwelling of offshore waters. Concentrations of NO_2-NO_3-N ranged from <0.1μM in the surface layers to >19.0μM below 130m. Again, seasonality was not obvious among the four cruises. NO_2-NO_3-N values showed the greatest variation from surface to depth than the other measured nutrients (Figures 4-39 to 4-43).

Silica (SiO_2) concentrations (Figures 4-44 to 4-48) generally ranged from <1.0 to >5.0μM in the mixed layer and from <1.0 to >5.0μM below the pycnocline. Offshore stations showed increasing concentrations with depth. The mid-shelf and inner shelf stations were quite variable, with concentrations as high as >13.0μM recorded. The greatest near-shore variability occurred at Station 25 on Transect E. The source of this anomaly is open for speculation but may reflect bottom resuspension.

4.4.4.6 Chlorophyll a

Chlorophyll a may be used as an indicator of phytoplankton standing crop or general phytoplankton biomass. As Chl a increases it can be expected that phytoplankton biomass will also increase. Although the relationship may not be a one-to-one function, it is certainly useful for trend analysis. Techniques for measuring Chl a concentrations are presently under scientific scrutiny and subject to change. Of particular current concern is the filtration process used for phytoplankton concentration. Standard filtration is through glass fiber filters that collect phytoplankton which are generally >1.0μM in size. This procedure permits smaller phytoplankton (picoplankton), to pass through the filters and be discarded with the filtrate. Thus it is very likely that Chl a concentrations generally reported in the literature underestimate the phytoplankton in the water column. It is probable that this underestimation is significant in what are generally termed "oligotrophic" (oxygenated, but nutrient poor) waters. During the present investigation standard techniques were employed in order to maintain a continuity for comparative purposes, but it is recognized that the resultant absolute values may be underestimated.

Chlorophyll a concentrations (Figures 4-49 to 4-53) ranged from <0.1mg/m^3 to <1.5mg/m^3. In temperate waters Chl a concentrations are generally highest in

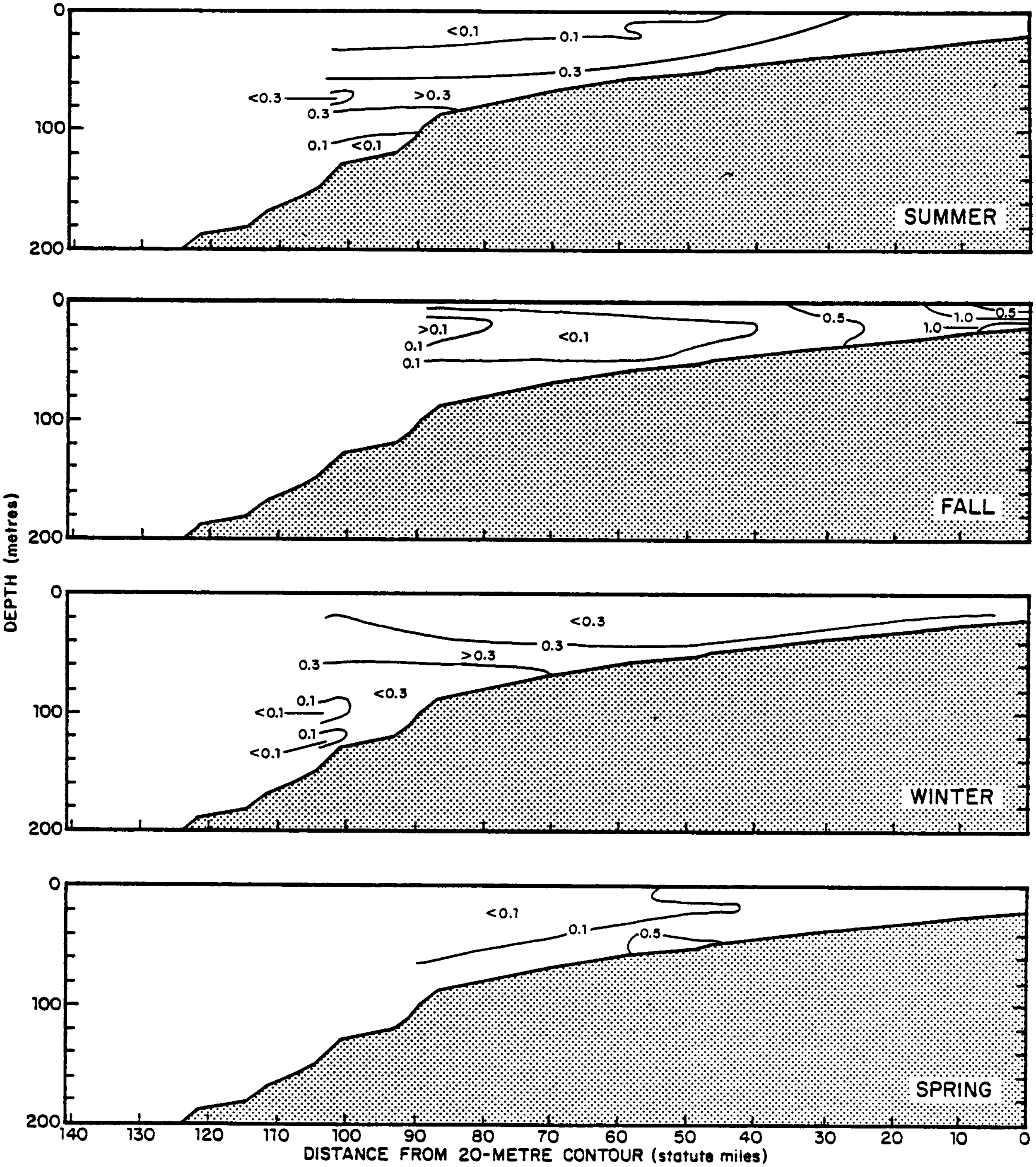

Figure 4-49. Seasonal chlorophyll a (mg/m^3) distributions on Transect A

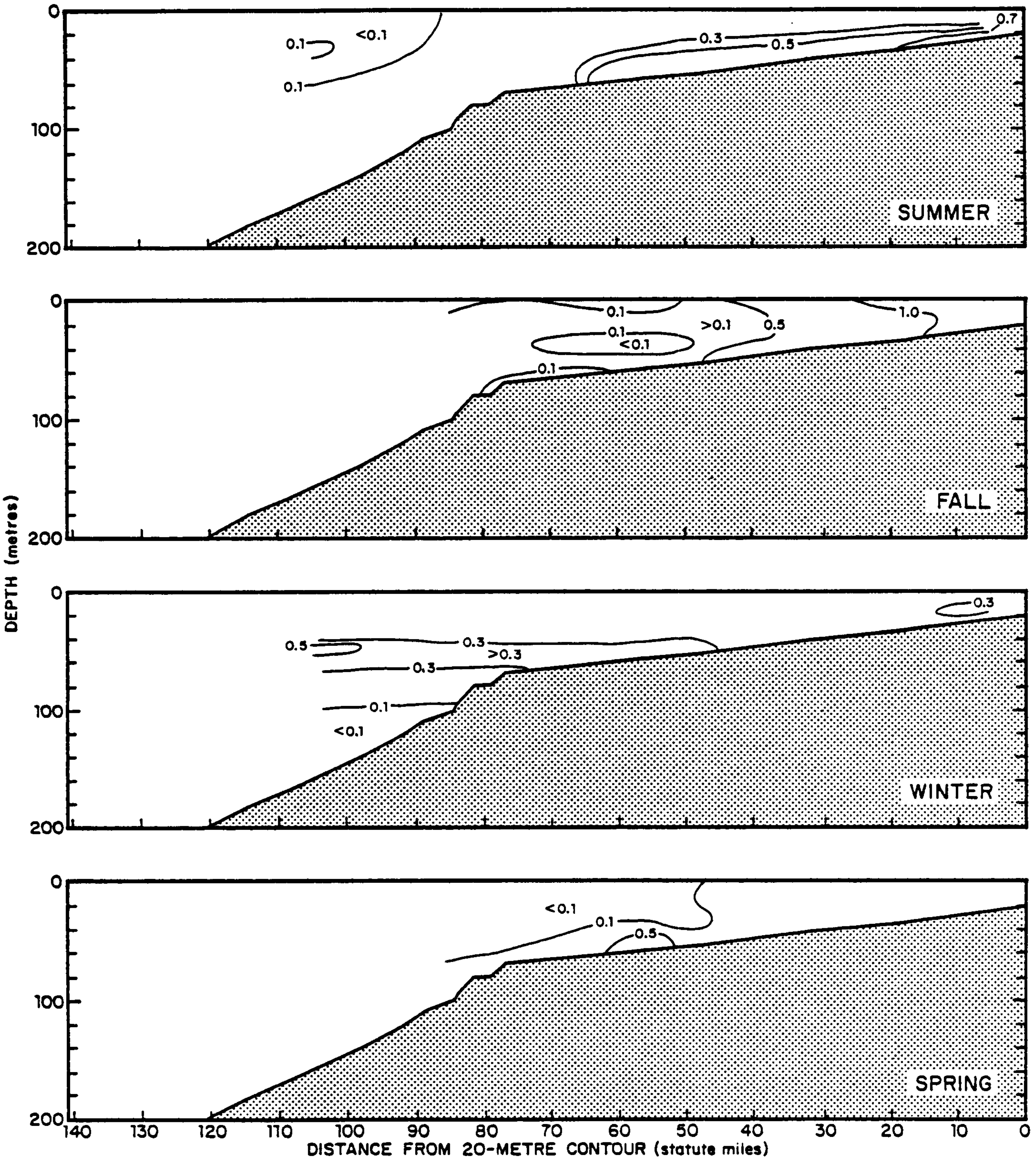

Figure 4-50. Seasonal chlorophyll a (mg/m^3) distributions on Transect B

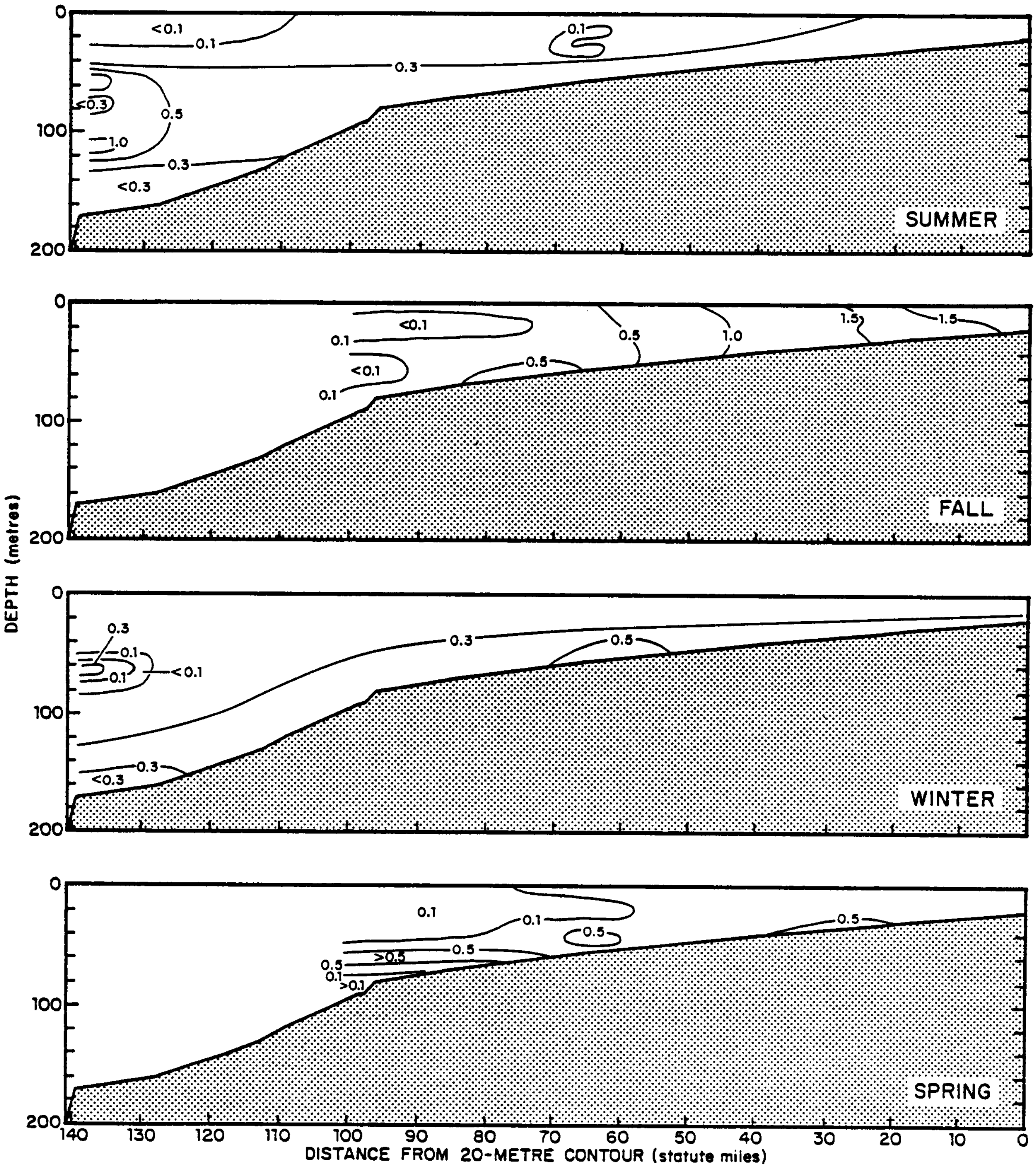

Figure 4-51. Seasonal chlorophyll a (mg/m^3) distributions on Transect C

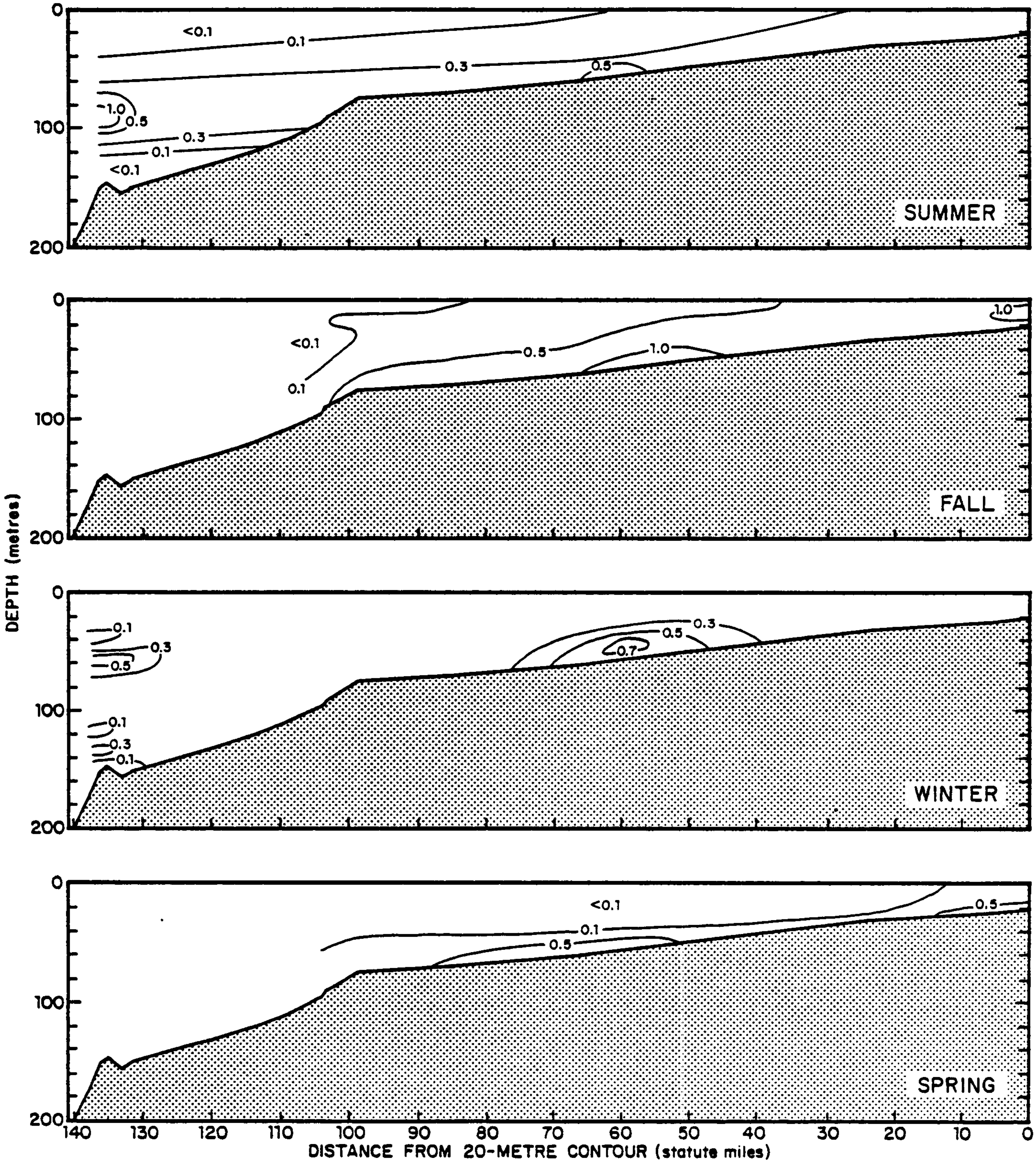

Figure 4-52. Seasonal chlorophyll a (mg/m^3) distributions on Transect D

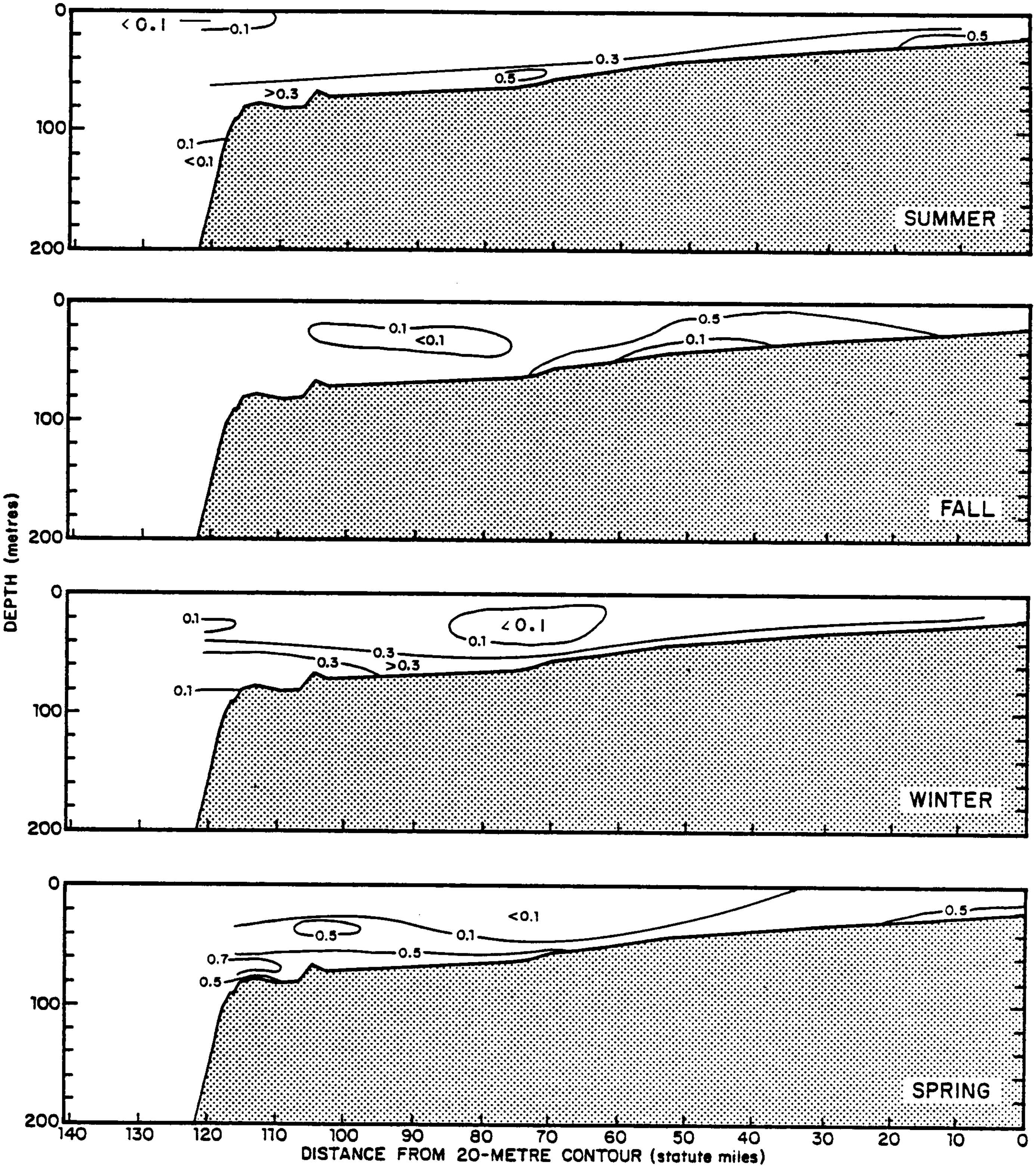

Figure 4-53. Seasonal chlorophyll a (mg/m^3) distributions on Transect E

the spring and fall, as waters warm and mix, respectively. In the subtropical-tropical waters of the southwest Florida shelf this was not evident. There was a fall near-shore increase in Chl a, but this may have been due to a toxic dinoflagellate bloom occurring at the time. Generally, the mixed layer had concentrations of <0.1 mg/m^3 and could be considered oligotrophic during all seasons. Near-shore Chl a increases were occassionally observed, suggesting a coastal contribution to the standing crop. The most significant and consistant higher levels of Chl a (0.3 to 1.0 mg/m^3) were found as subsurface maxima within the pycnocline (40 to 100m) during all four cruises. When comparing these depths to the light penetration data it is apparent that the phytoplankton standing crop was maximizing at or below the one-percent attenuation depth and at the top of the nutricline. Above these depths the sources of nutrients necessary for the photosynthetic process declined and a corresponding decrease in Chl a was observed.

5.0 SUBSTRATES

5.1 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 Year One (Fall and Spring Cruises) and Year Two (Summer and Winter Cruises) programs. Specific sampling locations and rationale were presented in Section 3.0. Data and samples were collected using a variety of methods. In the sections which follow, the physical characteristics (i.e., substrates) of the sea floor at each live bottom and soft bottom site are described. Overall spatial and seasonal trends are also discussed.

5.2 LIVE BOTTOM STATIONS

5.2.1 Methods

Underwater television videotapes and still camera photographs were used to characterize the bottom substrate at 20 live bottom stations. Ten locations were surveyed during both the Year One and Year Two programs, while remaining sites were examined only during Year One (i.e., fall and spring) or Year Two (i.e., summer and winter). For detailed accounts of sampling and analysis methodology, the reader is referred to Section 3.0 of the present document and

Section 5.0 of the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983).

All videotapes were analyzed to describe general substrate types at each station. Substrate types were classified according to the characterization scheme which was developed during the Year One ground truthing effort (see Section 2.3.1). While each videotape was reviewed, the bottom type was recorded on tow track navigation maps at 15-second intervals. Where present, sand waves were described and areas of bioturbation, noted. Following analysis, the tow track time intervals were converted to distances and the approximate percentage of each bottom type observed was calculated.

Still camera photographs were viewed in conjunction with the videotapes to further document bottom characteristics. Analyses provided a limited, small-scale view of the actual components of the bottom substrate at each station.

5.2.2 Shelfwide Distribution Patterns

5.2.2.1 General Substrate Types

Data from the underwater television videotapes indicated the occurrence of six major substrate types at live bottom stations (Table 5-1). These were 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, and Coarse Rubble (dead) with Attached Crinoids. The first five types, previously categorized during the Year One and Two ground-truthing cruises, were described in Section 2.3. The sixth category, however, was only observed during the Year Two biological sampling program at a single deep-water site (Station 38). All substrate types except Sand Bottom/Soft Bottom were indicative of live bottom areas. Estimated total coverages of live bottom and soft bottom substrates are presented in Table 5-2.

The general distributions of predominant substrate types at live bottom stations across the shelf are shown in Figure 5-1. The majority of sites were primarily composed of a mixture of Thin Sand over Hard Substrate and Sand

Table 5-1. Substrate types observed on videotape at live bottom sampling stations during the Year One and Year Two programs (values represent percent of the total station television transect).

Station	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	Coarse Rubble (dead) with Attached Crinoids	Season
1	A		27.2	72.8				Fall
		0.7	77.5	21.8				Spring
			41.9	58.1				Summer
			80.6	19.4				Winter
3	A		19.8	80.2				Fall
			16.5	83.5				Spring
			33.2	66.8				Summer
			64.7	35.3				Winter*
7	B		10.2	89.8				Fall
			33.4	66.6				Spring
		0.6	38.7	60.7				Summer
			34.4	65.6				Winter
9	B		45.3	54.7				Fall
			76.6	23.4				Spring
			100.0					Summer
			100.0					Winter
10	B			49.3	50.7			Fall
		3.2		41.4	55.4			Spring
11	B	0.8		57.1	42.1			Fall
		0.3		19.6	80.1			Spring
		0.6		61.5	37.9			Summer
		0.7		34.6	64.7			Winter
13	C		42.0	58.0				Fall
			46.8	53.2				Spring
			43.5	56.5				Summer
			37.4	62.6				Winter
15	C	3.3	47.5	49.2				Fall
			50.0	50.0				Spring
			68.5	31.5				Summer
			62.7	37.6				Winter

Table 5-1. (Continued)

Station	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	Coarse Rubble (dead) with Attached Crinoids	Season
17	C		20.6	79.4				Fall
			28.0	72.0				Spring
19	D		34.0	66.0				Fall
			35.7	64.3				Spring
21	D		71.4	28.6				Fall
			81.5	18.5				Spring
			82.8	17.2				Summer
			57.3	42.7				Winter
23	D				100.0			Fall
				3.8	96.2			Spring
					100.0			Summer
				7.0	93.0			Winter
27	E		14.2	85.8				Fall
			13.6	86.4				Spring
29	E					100.0		Fall
						100.0		Spring
						100.0		Summer
						100.0		Winter
30	E					100.0		Fall
						100.0		Spring
32	B		47.0	53.0				Summer
		0.4	50.9	48.7				Winter
35	C		80.2	19.8				Summer
		1.1	98.9					Winter*
36	D	0.3	23.6	76.1				Summer
		0.3	40.4	59.3				Winter
38	D						100.0	Summer
							100.0	Winter
39	E	100.0						Summer
		100.0						Winter

* "G-Pattern" was not run. Only a single line across the station block (<½ normal sample coverage) was examined.

Table 5-2. Estimates of actual live bottom and soft bottom areas at live bottom stations (values represent mean percent coverages, as estimated from videotape analysis).

Station	Transect	% Live Bottom	% Soft Bottom
1	A	57	43
3	A	34	66
7	B	29	71
9	B	80	20
10	B	55	45
11	B	57	43
13	C	42	58
15	C	58	42
17	C	24	76
19	D	35	65
21	D	74	26
23	D	97	3
27	E	14	86
29	E	100	0
30	E	100	0
32	B	49	51
35	C	90	10
36	D	32	68
38	D	100	0
39	E	100	0

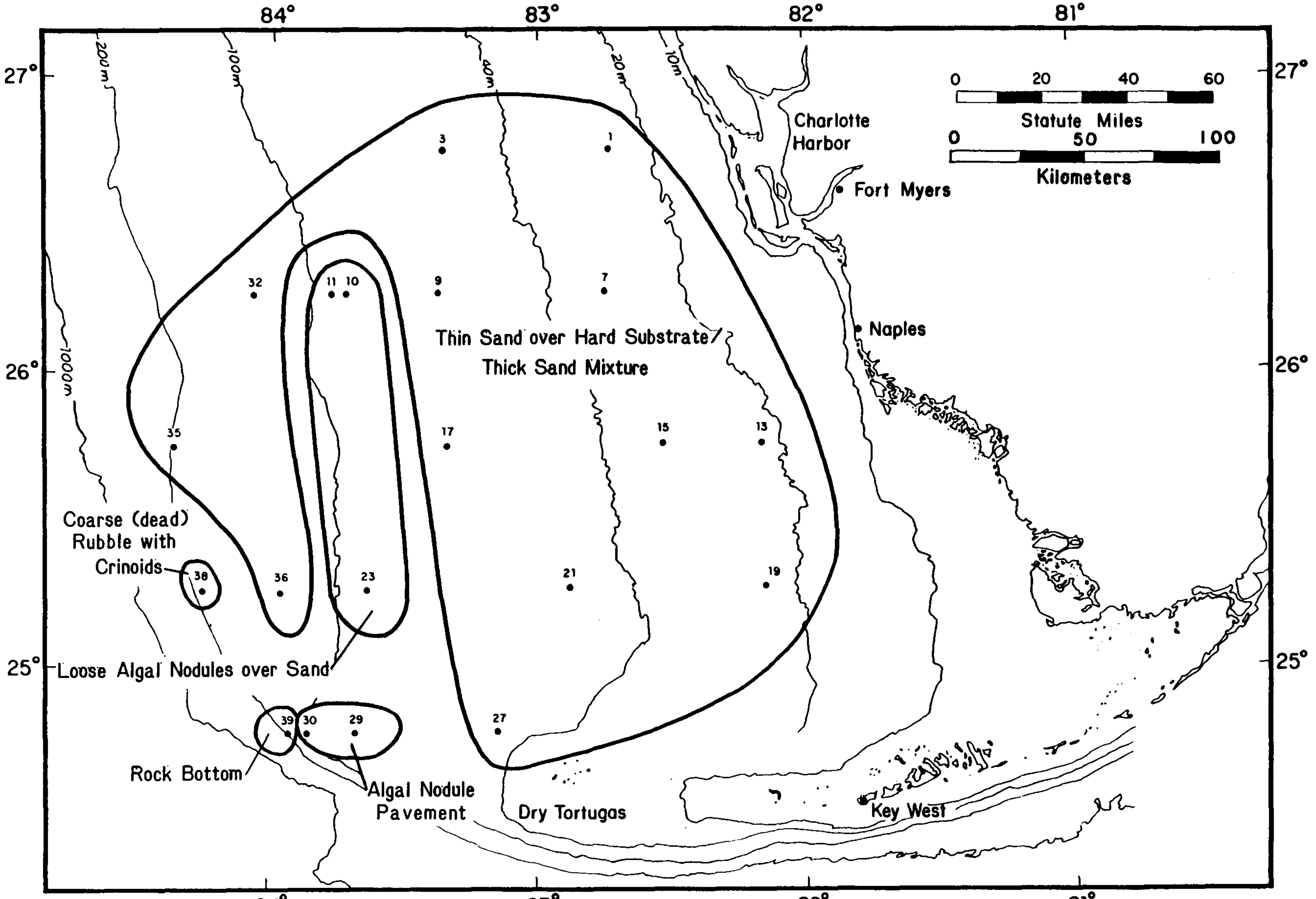

Figure 5-1. General distribution of predominant substrate types at live bottom stations, as determined from television videotape data.

Bottom/Soft Bottom substrates. All stations at water depths from 20 to 60m were of this group. Also included were three outer shelf stations (32, 35 and 36) on Transects B, C and D.

The coralline algal nodule substrate type predominated at three locations (Stations 10, 11 and 23) at 70 to 80m depths on Transects B and D,.

The southwestern portion of the study area, containing the remaining four stations, was anomalous in terms of hard bottom substrate types. At Stations 29 and 30 (62 and 76m depths, respectively), Algal Nodule Pavement with Agaricia Accumulations was the only substrate present. Station 39 (152m depth) appeared to be composed entirely of Rock Outcrops/Hard Bottom. An entirely "new" substrate type, which had not been observed prior to the Year Two biological cruises, was revealed at Station 38 (159m depth). Here, the entire station block was covered by a coarse, dead rubble substrate accompanied by large numbers of attached crinoids.

5.2.2.2 Substrate Components

Still camera data (Table 5-3) provided little information with regard to spatial variation in substrate composition. This is not entirely unexpected since their primary use was to examine epibiotal coverage. From the information that was available, little difference was seen in actual substrate components. At the majority of live bottom sites, substrates appeared to be composed of mixtures of sand and rock, shell or dead algal rubble. Stations 29 and 30 in the southwestern portion of the study area were exceptions. There, an algal nodule pavement was predominant.

In considering the data presented in Table 5-3 it is also important to emphasize the following:

- Those substrates reported were only those which were exposed and visible (i.e., not covered with epibiota).

- The still camera technique provides a much smaller scale view compared to the television camera videotape.

Table 5-3. Substrate components observed at live bottom stations during the Year One and Year Two programs. Values represent average percent cover, as determined from quantitative analysis of still camera slides.

		Exposed Bottom Surface Composition					
Station	Transect	Rock Outcrops	Sand	Rock, Shell, and Dead Algal Rubble	Algal Nodule Pavement	Epibiota	Season
1	A		68.0	16.5		15.5	Fall
			72.7	7.3		20.0	Spring
		0.1	60.2	12.8		26.9	Summer
			76.8	9.9		13.3	Winter
3	A	0.1	86.1	6.3		7.5	Fall
			66.6	16.8		16.6	Spring
			62.5	12.8		24.7	Summer
			73.7	13.2		13.1	Winter
7	B	7.5	58.8	18.8		14.9	Fall
		1.3	70.8	12.3		15.6	Spring
		0.3	69.9	12.1		17.7	Summer
			72.6	13.1		14.3	Winter
9	B		23.3	60.4		16.3	Fall
			66.8	18.6		14.6	Spring
			48.7	32.4		18.9	Summer
			67.4	19.4		13.2	Winter
10	B	4.6	16.1	68.0		11.3	Fall
		1.8	45.9	30.1		22.2	Spring
11	B	2.8	33.7	50.3		13.2	Fall
		0.5	45.7	46.7		7.1	Spring
			25.4	43.3		31.3	Summer
			59.9	24.9		15.2	Winter
13	C	1.8	70.8	8.7		18.7	Fall
			73.9	4.1		22.0	Spring
			37.8	1.9		60.3	Summer
			71.5	6.2		22.3	Winter
15	C	1.9	65.4	13.6		19.1	Fall
			67.6	12.6		19.8	Spring
			44.6	5.8		49.6	Summer
			55.0	15.5		29.5	Winter

Table 5-3. (Continued)

		Exposed Bottom Surface Composition					
Station	Transect	Rock Outcrops	Sand	Rock, Shell, and Dead Algal Rubble	Algal Nodule Pavement	Epibiota	Season
17	C		79.8	4.1		16.1	Fall
			82.0	9.5		8.5	Spring
19	D		74.8	5.8		19.4	Fall
			82.8	3.5		13.7	Spring
21	D		77.0	5.1		17.9	Fall
			74.7	5.4		19.9	Spring
		<0.1	38.8	3.8		57.4	Summer
			66.0	10.7		23.3	Winter
23	D		17.0	48.3		34.7	Fall
			26.1	36.8		37.1	Spring
		0.2	12.1	19.7		68.0	Summer
			25.3	48.8		25.9	Winter
27	E		90.5	2.0		7.5	Fall
			77.8	10.7		11.5	Spring
29	E			0.2	35.3	64.5	Fall
			0.7		19.7	79.6	Spring
			0.1	10.2		89.7	Summer
			0.9	24.3		74.8	Winter
30	E		10.2		42.0	47.8	Fall
			11.7		37.9	50.4	Spring
32	B		49.8	41.2		9.0	Summer
		2.3	84.0	5.5		8.2	Winter
35	C	1.1	21.5	56.0		21.4	Summer
			68.8	24.9		6.3	Winter
36	D		78.9	12.5		8.6	Summer
			73.2	13.0		13.8	Winter
38	D	0.4	41.4	42.7		15.5	Summer
			58.6	30.7		10.7	Winter
39	E		17.7	27.6		54.1	Summer
		3.4	30.8	48.7		17.1	Winter

- Slides analyzed were selected only from those in which there was at least 5% epibiotal coverage.

As such, the still camera data are of limited use. For the purpose of actual "substrate" comparisons, the television videotape information is more valid and useful.

5.2.3 Seasonal Changes

5.2.3.1 General Substrate Types

Although substrate types present at a given live bottom station generally did not change from season to season, the actual percent coverage by each type often showed considerable fluctuation (Table 5-1). Taking into account that each television tow observed only about 0.4% of the total area that comprised a station (per cruise tow), this is not surprising. Figure 5-2 shows an example of total station coverage examined by sled tows during each of the four seasonal cruises. In actual fact the "camera view" along each track line would be only 5 to 10% of the thickness of each drawn line. Thus, only a very small portion of each sample block was actually viewed. Most of the variation in substrate noted from cruise to cruise at a single station was probably an artifact of sampling rather than an actual seasonal change in bottom type. In any case, the data collected are clearly insufficient for objective examination of temporal variations.

5.2.3.2 Substrate Components

Substrate components determined from still camera slides exhibited similar variations from season to season as noted above for the video tape data. While the general categories remained relatively unchanged, the actual percent coverage of each sometimes varied widely. These changes are also probably an artifact of sampling. Slight changes in camera sled tow path from season to season could easily account for the observed variations. Since substrates were only measured in exposed areas not "hidden" by epibiota, seasonal fluctuations in epibiotal coverage could also greatly affect the data.

STATION II TELEVISION/STILL CAMERA TOW TRACKS

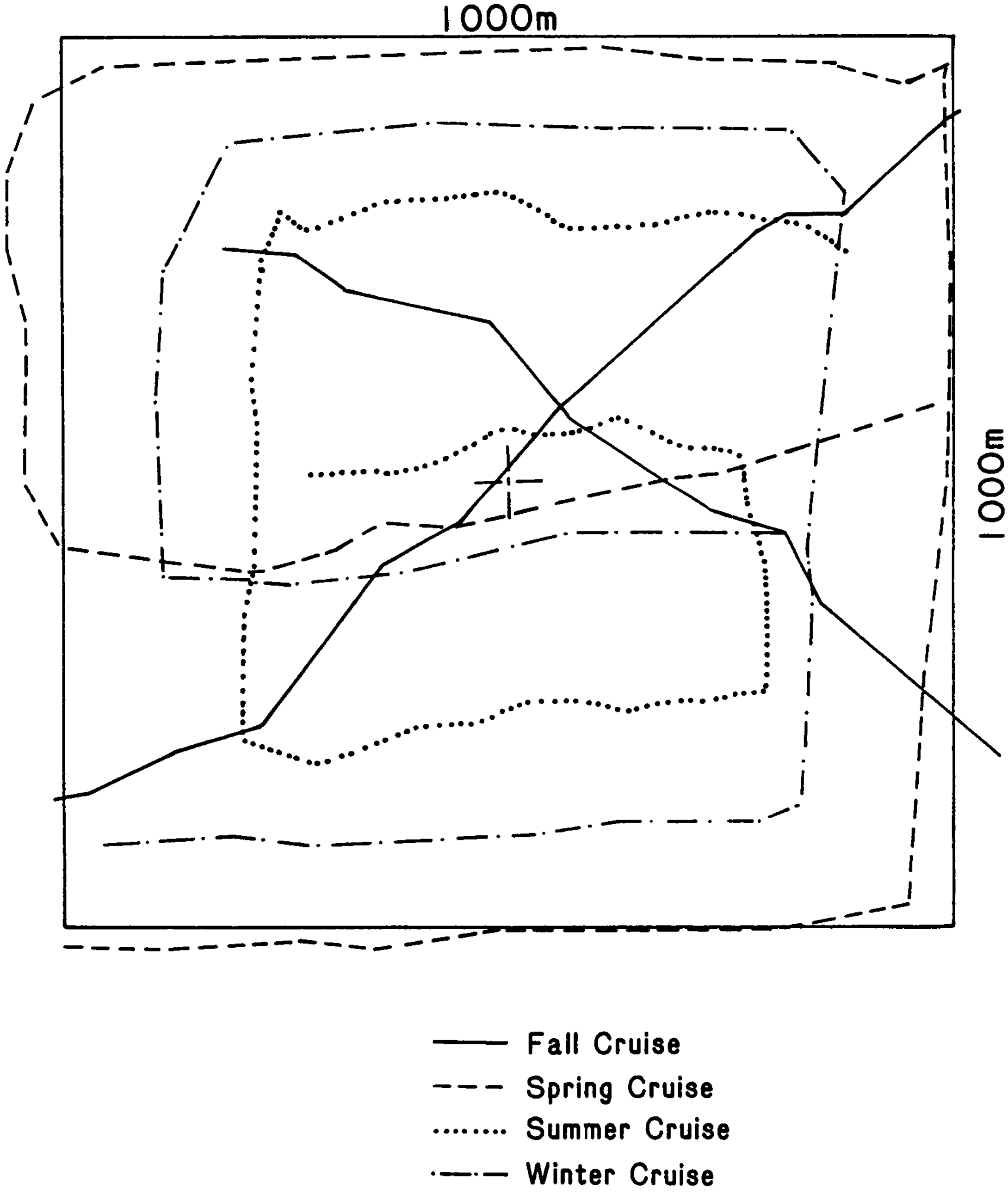

Figure 5-2. Example of total station area examined by underwater television/still camera sled tows during the combined Year One and Year Two programs.

5.2.4 Station Descriptions

Summary descriptions of the substrates and physical characteristics of each live bottom sampling station are presented below. The information has been compiled from bathymetry, underwater television, and underwater still camera data. In considering the descriptions it is important to note the following:

- General Substrate Type - Percent cover values listed were obtained from underwater television tow data (Table 5-1).

- Substrate Composition - Percentages listed for each component were obtained from quantitative analysis of still photographs (Table 5-3) and must be interpreted with care (see Section 5.2.2.2). The values shown represent average percent coverages of total area viewed by the photographic slides. Epibiotal coverage, which obscures viewing of the bottom substrate on the slides, represents the remaining percent composition. Thus, the values presented must be viewed as minimum values only -- and only strictly applicable to live bottom "patches" within the station sample block.

- Sedimentary Structures - Percent occurrence values shown for bioturbation actually represent the percentages of fix-mark intervals in which bioturbation occurred along the station camera tow tracks.

5.2.4.1 Station 1

Location -- 26°45.77'N, 82°43.11'W; 41.0km (25.5mi) from shore.

Depth & Relief -- Depth at station center: 24m; depth range across station: 24 to 25m; general slope: little apparent slope; physical features: occasional rock outcrops with up to 0.6m relief.

General Substrate Type -- From the videotape data it would appear that the substrate at this station is a mixture of thick, Sand Bottom/Soft Bottom and Thin Sand over Hard Bottom types. Relative amounts of each varied considerably between the four sampling cruises. Sand Bottom/Soft Bottom ranged from 19 to 73% of total bottom viewed. Thin Sand over Hard Substrate occupied from 27 to 81% of the station tow tracks.

Substrate Composition -- Quantitative slide analysis (QSA) data indicate that the substrate of live bottom patches at this site was primarily composed of sand (60 to 77%) with rock, shell and dead algal rubble (7 to 16%). A few rock outcrops were also observed (during Summer Cruise). A photographic example of a live bottom substrate at Station 1 is presented in Figure 5-3.

Sedimentary Structures -- Sand ripples were noted during the spring and summer, covering 12 and 5% of the station tow tracks, respectively. Ripple marks were smaller than those generally observed at other stations. Heights ranged from 5 to 10cm; wavelengths, from 20 to 36cm. Axes were oriented in a north-south direction (as were all ripple marks at all locations). Bioturbation was observed, but only during the Spring Cruise (Year I), when it occurred along 11% of the tow track.

5.2.4.2 Station 3

Location -- 26°45.86'N, 83°21.44'W; 96.5km (60mi) from shore.

Depth & Relief -- Depth at station center: 50.5m; depth range across station: 49 to 50m; general slope: downward from WNW to ESE; physical features: none significant.

General Substrate Type -- Bottom is composed of Sand Bottom/Soft Bottom (35 to 84% coverage) with generally lesser amounts of Thin Sand over Hard Substrate (16 to 65% coverage).

Substrate Composition -- Substrate in live bottom patches at this station was composed of mostly sand (63-83%), with lesser amounts of rock, shell and dead algal rubble (6-17%). A few outcrops were observed during the Fall Cruise (Table 5-2).

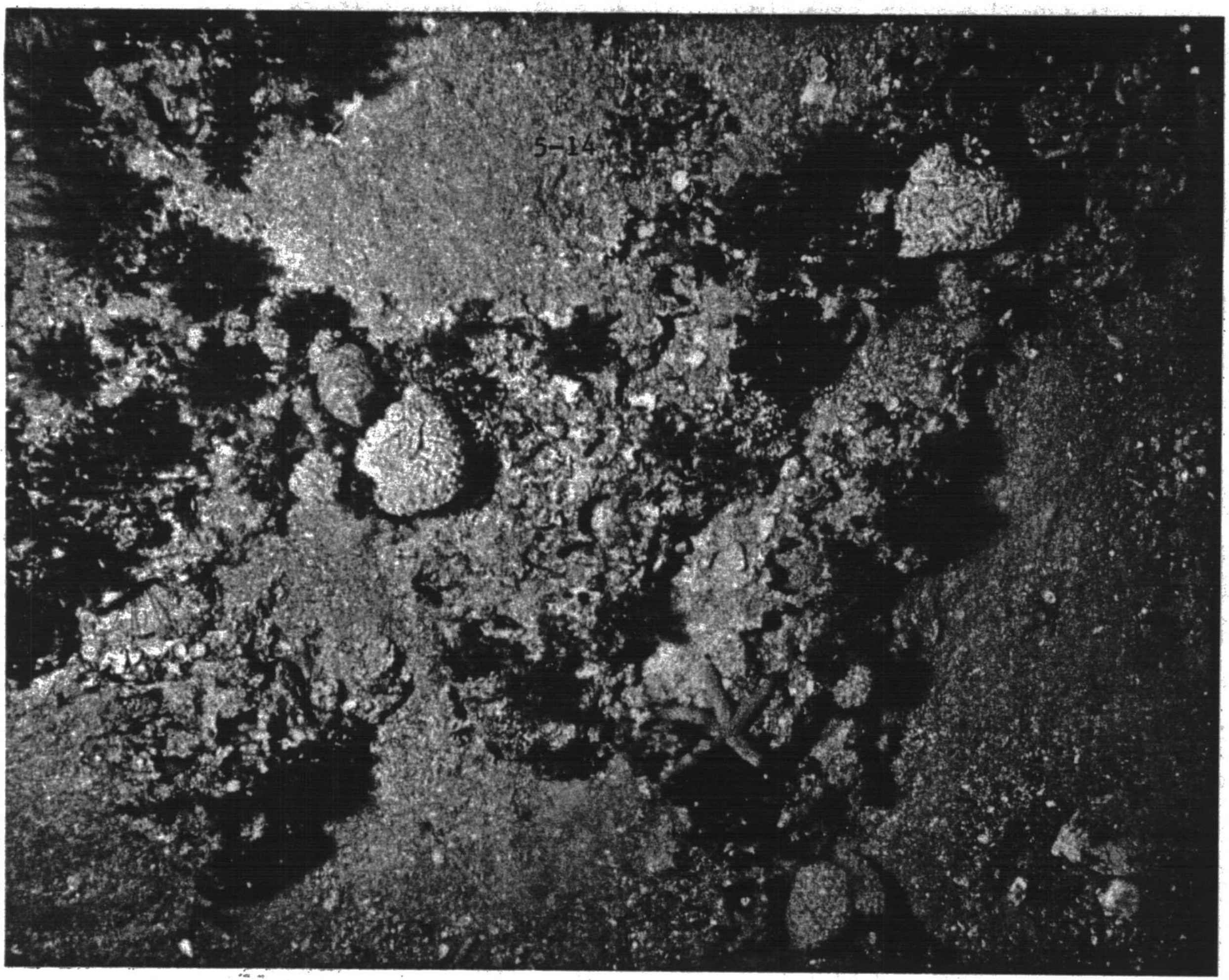

Figure 5-3. Photographic example of live bottom substrate at Station 1. Shown here is a low-relief rock outcrop. Associated biota includes the ascidian Echinoclinum verrilli (center, upper right, lower right), the asteroid Echinaster spinulosus (lower right) and unidentified red alga.

Sedimentary Structures -- No sand ripple marks were observed at this site. However, extensive bioturbation was observed during the fall and spring (along 81 and 85% of the tow track, respectively).

5.2.4.3 Station 7

Location -- 26°16.82'N, 82°44.02'W; 70.0km (43.5mi) from shore.

Depth & Relief -- Depth at station center: 30.5m; depth range across station: 30 to 31m; general slope: little apparent slope; physical features: none significant.

General Substrate Type -- Videotape data show the substrate to be mostly Sand Bottom/Soft Bottom (61-90%), accompanied by lesser coverage of Thin Sand over Hard Substrate (10-39%). A few rock outcrops were also noted during the Summer Cruise (Year II). A photographic example of a live bottom substrate at Station 7 is presented in Figure 5-4.

Substrate Composition -- QSA data indicate that sand was the primary component of bottom substrate (59-73%) within live bottom patches at this station. Rock, shell and dead algal rubble were secondary, comprising from 12 to 19% of the substrate. Rock outcrops were also observed in slides from the Fall, Spring and Summer Cruises (8, 1, and 0.3% average coverages, respectively).

Sedimentary Structures -- Sand ripple marks were seen during all seasons but fall. Coverage ranged from 9 to 28% (Winter and Spring Cruises, respectively) along tow tracks. Sizes fluctuated somewhat, with the smallest ripples observed during spring. Ripple axes were oriented in a north-south direction. Bioturbation was evident during each cruise, except summer. Percent occurrence (i.e., percent of fix-mark intervals in which it was observed) ranged from 25 to 91% (spring and fall, respectively) at those times.

5.2.4.4 Station 9

Location -- 26°16.83'N, 83°23.81'W; 125.5km (78mi) from shore.

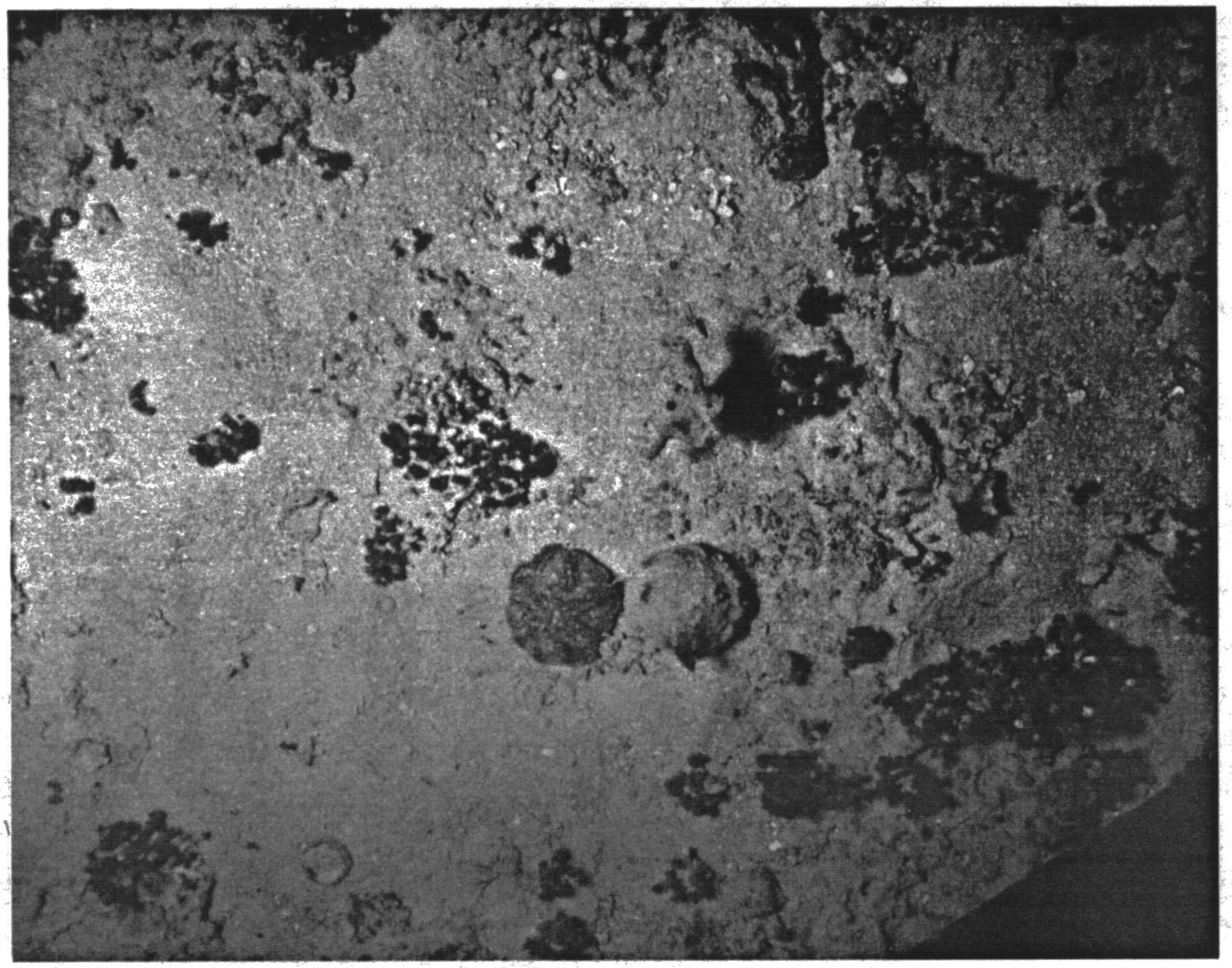

Figure 5-4. Photographic example of live bottom substrate at Station 7. Shown here is a thin sand layer covering a hard bottom. Associated biota include the sponges Homaxinella waltonsmithi (right center), Cinachyra alloclada (right center) and Placospongia melobesioides (upper right); and the hard corals Isophyllia sp. (center) and Cladocora arbuscula (throughout).

Depth & Relief -- Depth at station center: 56m; depth range across station: 55.5 to 56.5m; general slope: slight downward slope from east to west; physical features: none significant.

General Substrate Type -- Videotape data show the Thin Sand over Hard Substrate to be the predominant substrate type (45-100% coverage). Sand Bottom/ Soft Bottom accounted for the remaining substrate (0-55%).

Substrate Composition -- QSA data show the substrate to be composed of a varying mixture of sand (23-67%) and rock, shell and dead algal rubble (19-60%). A few rock outcrops were seen in slides taken during the Fall Cruise.

Sedimentary Structures -- Sand ripple marks were observed only during the winter, when they covered approximately 29% of the station tow track. Ripple marks were average in height, but somewhat shorter than average (10 to 30cm wavelength). Wave axes ran NNE to SSW. Bioturbation was noted during the fall (53% occurrence), spring (18% occurrence) and winter (56% occurrence).

5.2.4.5 Station 10

Location -- 26°16.73'N, 83°42.81'W; 154.5km (96mi) from shore.

Depth & Relief -- Depth at station center: 71.5m; depth range across station: 70.5 to 75.5m; general slope: downward from east to west; physical features: gradual slope from east to west occurs along about two-thirds of the eastern portion of the station block (70.5 to 71.5m). An abrupt drop (from 71.5 to 75.5m) is evident in the western portion.

General Substrate Type -- Videotape data show the bottom to be a near even mixture of Sand Bottom/Soft Bottom (41-49%) and Coralline Algal Nodule Layer over Sand (51-55%) substrate types. Rock Outcrops/Hard Bottom substrate was also observed in spring, comprising only 3% of total coverage.

Substrate Composition -- QSA data indicate that the substrate in live bottom patches was a mixture of sand (16-46%) and rock, shell and dead algal rubble

(30-68%). Minor amounts of exposed rock outcrops also contributed to substrate composition during the fall and spring, comprising 2 and 5%, respectively. A photographic example of a live bottom substrate at Station 10 is presented in Figure 5-5.

Sedimentary Structures -- No sand ripple marks were observed at this location. Bioturbation was widespread during each cruise (45-51% occurrence along fix-mark intervals).

5.2.4.6 Station 11

Location -- 26°16.72'N, 83°46.82'W; 159.3km (99mi) from shore.

Depth & Relief -- Depth at station center: 77m; depth range across station: 77 to 84.5m; general slope: downward from east to west; physical features: eastern three-fourths of block with gradual slope, and a sharp drop-off (reef edge or face) about 250m east of the west edge of the station. Rough rock outcrops were prominent along the break, which runs north-south.

General Substrate Type -- Videotape data show the substrate to be a varying mixture of Sand Bottom/Soft Bottom (20-62%) and Coralline Algal Nodule Layer over Sand (38-80%), with small areas of Rock Outcrop/Hard Bottom (0.3-0.8%).

Substrate Composition -- QSA data show the surface substrate in live bottom patches to be a mixture of sand (25-60%); rock, shell and dead algal rubble (22-50%); and exposed rock outcrops (0-3%).

Sedimentary Structures -- No sand ripple marks were observed at this station. Bioturbation, however, was noted during all cruises, varying from 3 to 87% occurrence (fall and winter, respectively) along tow tracks.

5.2.4.7 Station 13

Location -- 25°45.93'N, 82°09.35'W; 50.7km (31.5mi) from shore.

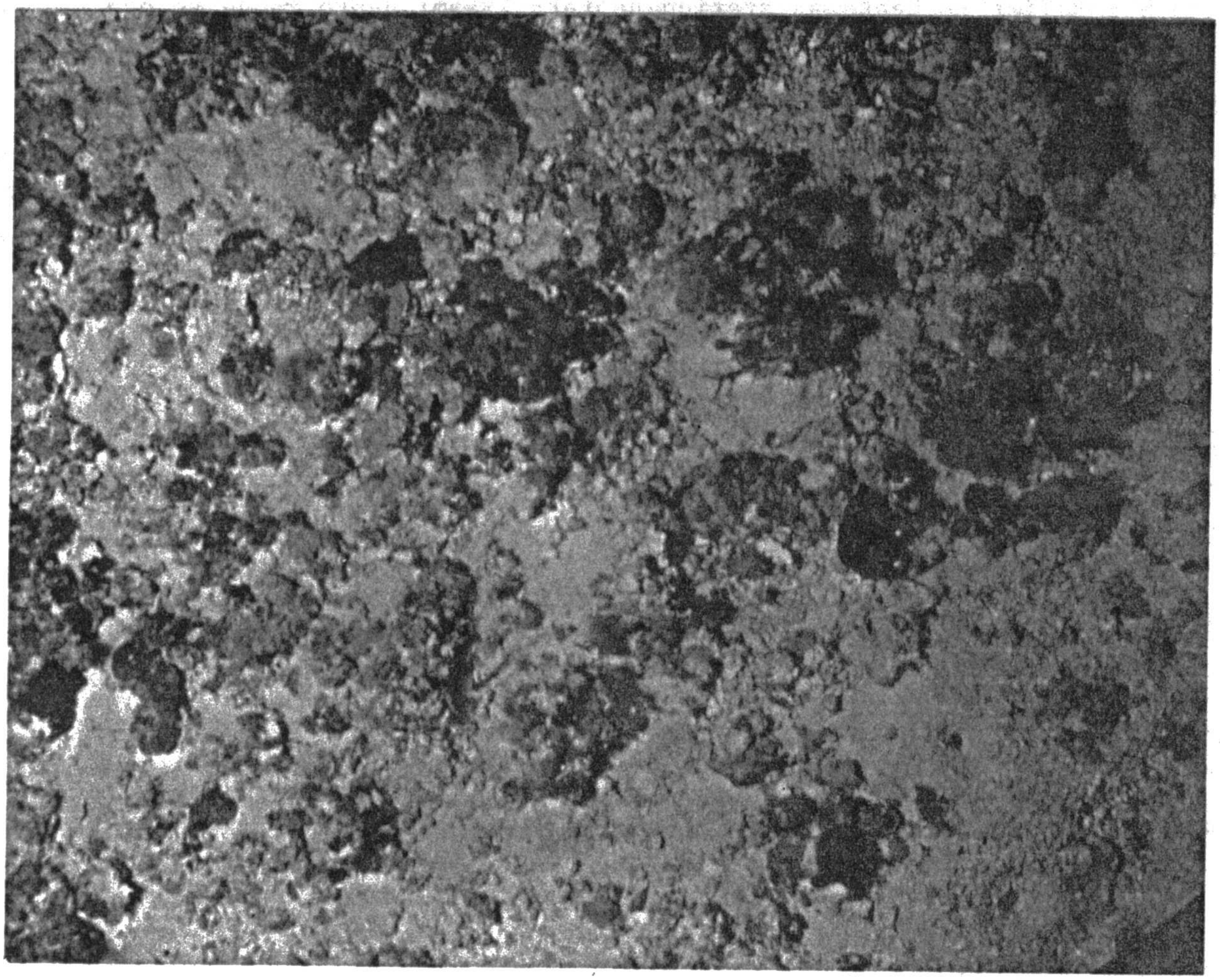

Figure 5-5. Photographic example of live bottom substrate at Station 10. Shown here is a coarse sand/shell rubble/coralline nodule substrate. Small sponges, numerous living and dead algal nodules and calcareous algae (<u>Peyssonnelia</u> <u>simulans</u> and <u>P. rubra</u>) predominate.

Depth & Relief -- Depth at station center: 19.5m; depth range across station: 19.5 to 20m; general slope: slight downward slope from ENE to WSW; physical features: slight bathymetric variation, with occasional 0.3m depressions.

General Substrate Type -- Videotape data show the substrate to be a mixture of Sand Bottom/Soft Bottom (53-63%) and Thin Sand over Hard Substrate (37-47%). A photographic example of a live bottom substrate at Station 13 is presented in Figure 5-6.

Substrate Composition -- Substrate in live bottom patches was composed of mostly sand (38-74%), with lesser amounts of rock and shell rubble (2-9%). Rock outcrops were also noted during the Fall Cruise (2% coverage).

Sedimentary Structures -- Sand ripple marks were recorded during the Spring and Winter Cruises, when their coverages were 16 and 22%, respectively. Ripple marks were of average size and oriented in a north-south direction (axes). Bioturbation was observed during all cruises except summer. Percent occurrence ranged from 32 (Fall Cruise) to 100% (Winter Cruise) along station tow tracks.

5.2.4.8 Station 15

Location -- 25°45.89'N, 82°31.62'W; 82.1km (51mi) from shore.

Depth & Relief -- Depth at station center: 31m; depth range across station: 31 to 32m; general slope: none indicated; physical features: slight bathymetric variation, with occasional 0.3m depressions.

General Substrate Type -- Videotape data indicate the substrate to be a mixture of the Thin Sand over Hard Substrate (48-68%) and Sand Bottom/Soft Bottom (32-50%) types. Rock outcrops were also observed during the Fall Cruise, comprising only 3% of the tow track coverage. A photographic example of a live bottom substrate at Station 15 is presented in Figure 5-7.

Figure 5-6. Photographic example of live bottom substrate at Station 13. Shown here is a thin sand layer overlying a hard substrate. Associated biota include the sponges Xestospongia muta (large sponge, center right), Aiolochroia crassa (lower right) and Aplysina fistularis (far right) and the gorgonian Pseudopterogorgia ? acerosa (upper center and upper right).

Figure 5-7. Photographic example of live bottom substrate at Station 15. Shown here is a thin sand layer covering a hard substrate. Associated biota shown include numerous sponges (*Homaxinella waltonsmithi*, *Cinachyra alloclada*, *Phacospongia melobesioides*, *Aplysina fistularis*, and ? *Cribrochalina sp.*) and a hard coral (*Scolymia lacera*).

Substrate Composition -- Surface substrates within live bottom patches were composed of mixtures of sand (55-68%) and rock and shell rubble (6-16%). Exposed rock outcrops (1.9%) were also noted during the Fall Cruise.

Sedimentary Structures -- Sand ripple marks were observed during all seasons except fall. Coverages were consistent at those times (spring: 15%, summer: 15%, winter: 16%). Smaller ripple marks were observed during the winter than in other seasons. All axes were oriented in a north-south direction. Bioturbation was noted during all cruises and ranged in occurrence (within successive fix-mark intervals) from 13 to 45%.

5.2.4.9 Station 17

Location -- 25°45.58'N, 83°20.24'W; 149.6km (93mi) from shore.

Depth & Relief -- Depth at station center: 59m; depth range across station: 58.5 to 59.5m; general slope: slight downward slope from east to west; physical features: irregular 0.3 to 0.6m variation in bathymetry.

General Substrate Type -- Videotapes show the bottom substrate to be composed primarily of Sand Bottom/Soft Bottom (72-79%), with lesser coverages of Thin Sand over Hard Substrate (21-28%). No rock outcrops were observed at this station.

Substrate Composition -- QSA data show the surface substrate in live bottom patches to be composed mainly of sand (80-82%), with minor amounts of dead algal rubble (4-10%).

Sedimentary Structures -- No ripple marks were observed at this location. Bioturbation was seen during both sampling cruises on which the station was examined (Fall and Spring Cruises). Percent occurrence along tow tracks ranged from 64 to 84%.

5.2.4.10 Station 19

Location -- 25°17.36'N, 82°09.00'W; 84.5km (52.5mi) from shore.

Depth & Relief -- Depth at station center: 22.5m; depth range across station: 22 to 23m; general slope: none indicated; physical features: none significant.

General Substrate Type -- Videotapes indicate that the bottom substrate is primarily Sand Bottom/Soft Bottom (64-66%), accompanied by lesser coverages of Thin Sand over Hard Substrate (34-36%).

Substrate Composition -- QSA data show the surface substrate in live bottom patches to be composed of mostly sand (75-83%) with patches of shell rubble (4-6%).

Sedimentary Structures -- Ripple marks were only observed during the Spring Cruise, where they covered 31% of the station tow track. Axes were oriented in a north-south direction. Bioturbation was noted during both sampling cruises at this site (Fall and Spring Cruises). Percent occurrence was unchanged between cruises; bioturbation occurred within 54% of the fix mark intervals along the tow track.

5.2.4.11 Station 21

Location -- 25°17.26'N, 82°52.16'W; 140.0km (87mi) from shore.

Depth & Relief -- Depth at station center: 45m; depth range across station: 44.5 to 45.5m; general slope: slight downward slope from east to west; physical features: none significant.

General Substrate Type -- Videotapes show the substrate to be primarily Thin Sand over Hard Substrate (57-83%) and lesser coverages of Sand Bottom/Soft Bottom (14-43%). A photographic example of a live bottom substrate at Station 21 is presented in Figure 5-8.

Substrate Composition -- From the benthic still photos (QSA data) the surface substrates within live bottom patches appear to be composed of sand (39-77%) and rubble (4-11%). A few small rock outcrops were also noted during the Spring Cruise.

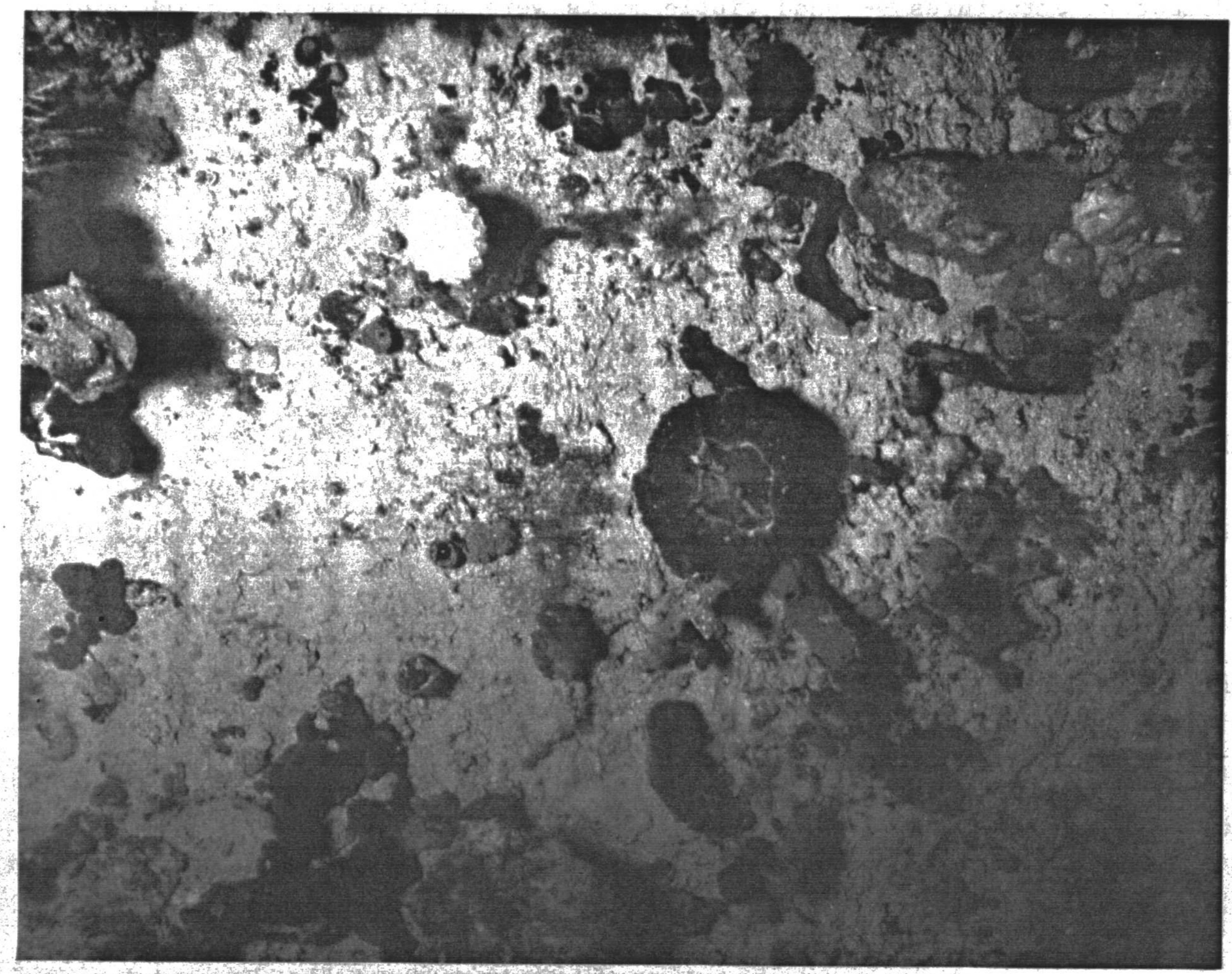

Figure 5-8. Photographic example of live bottom substrate at Station 21. Shown here is a thin sand layer covering a hard substrate. Associated biota shown include various sponges (*Placospongia melobesioides*, *Aiolochroia crassa* and *Neofibularia nolitangere*), hard coral (*Scolymia lacera*), and an ascidian (*Clavelina sp.*)

Sedimentary Structures -- Sand ripple marks were only observed during winter, and then with only minor coverage (3%). Bioturbation was recorded during all but the Summer Cruise. Percent occurrences along tow tracks ranged from 33 to 53%.

5.2.4.12 Station 23

Location -- 25°16.89'N, 83°37.79'W; 207.6km (129mi) from shore.

Depth & Relief -- Depth at station center: 70m; depth range across station: 69.5 to 73m; general slope: variable slope, upward from station center to the east and west; physical features: elevations and depressions extending along the NNE - SSW axis.

General Substrate Type -- Videotape data show the substrate to be almost entirely Coralline Algal Nodule Layer over Sand (93-100%). Sand Bottom/Soft Bottom was sometimes present in minor amounts (0-7%). A photographic example of a live bottom substrate at Station 23 is presented in Figure 5-9.

Substrate Composition -- Bottom substrates within live bottom patches appear to be composed of dead algal and rock rubble (20-49%), with lesser coverages of sand (12-26%). Exposed rock outcrops were also noted during the Summer Cruise (0.2%).

Sedimentary Structures -- No ripple marks were observed at this location. Bioturbation was seen during the Winter Cruise only, and then with only minor frequency (6% occurrence along tow track).

5.2.4.13 Station 27

Location -- 24°47.76'N, 83°08.01'W; 207.6km (129mi) from shore.

Depth & Relief -- Depth at station center: 53.5m; depth range across station: 52.5 to 54m; general slope: slight downward slope from east to west; physical features: little bathymetric variation.

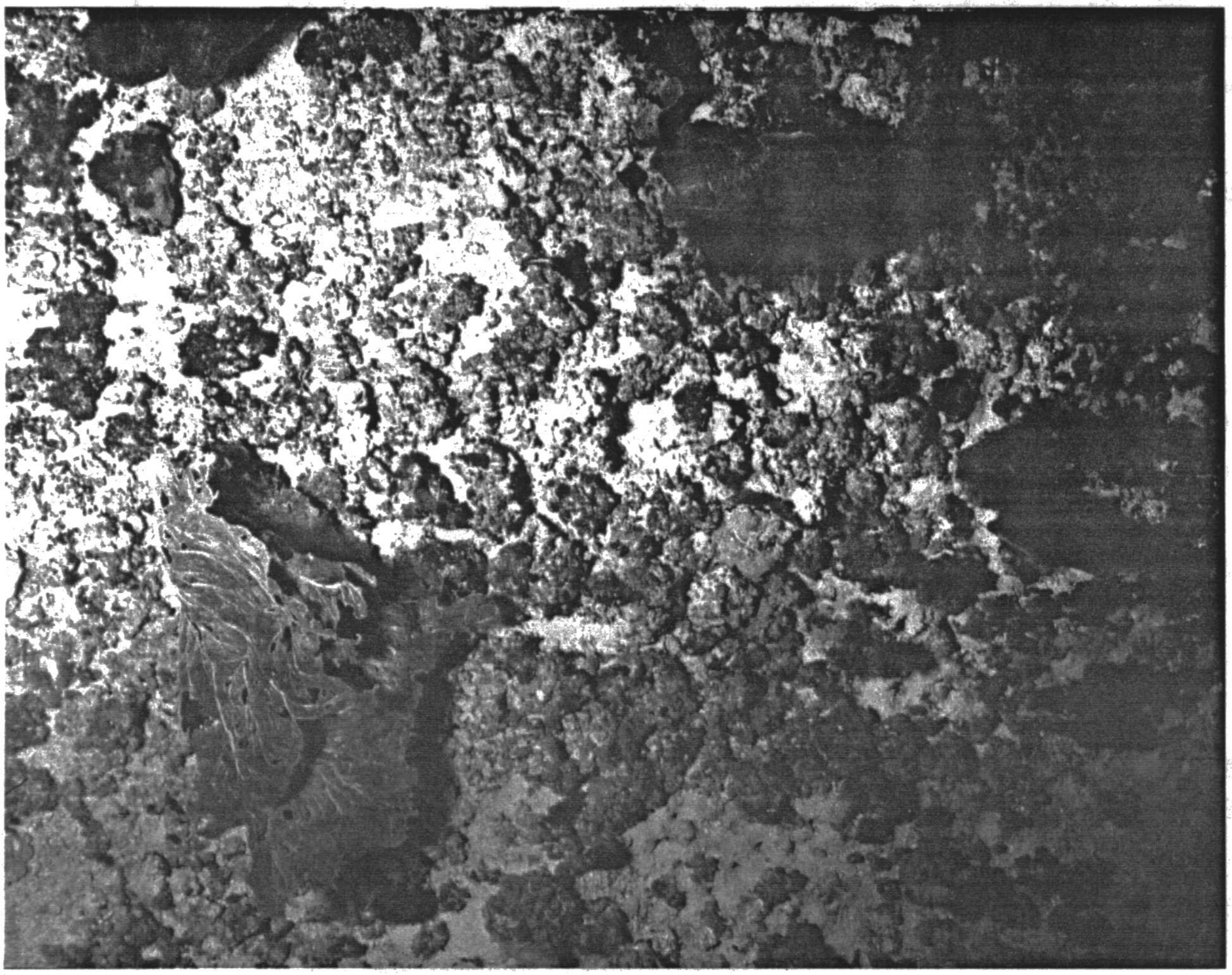

Figure 5-9. Photographic example of live bottom substrate at Station 23. Shown here is a fairly thick covering of coralline algal nodules overlying sand. Associated biota shown include the green alga Anadyomene menziesii (lower left) and the red alga Peyssonnelia rubra (upper left).

General Substrate Type -- From the videotape data it would appear that the substrate at this site is mostly Sand Bottom/Soft Bottom (86%). Thin Sand over Hard Substrate represented approximately 14% of the total substrate.

Substrate Composition -- QSA data show the surface substrate within live bottom patches to be primarily composed of sand (78-90%). Rubble made up a much smaller part of the substrate (2-11%).

Sedimentary Structures -- Sand ripple marks were not observed at this station. Bioturbation was found to be abundant during each cruise. Percent occurrences along station tow tracks ranged from 81 to 90%.

5.2.4.14 Station 29

Location -- 24°47.51'N, 83°41.19'W; 241.4km (150mi) from shore.

Depth & Relief -- Depth at station center: 59.5m; depth range across station: 59.5 to 64.5m; general slope: none indicated; physical features: bottom covered with elevations and depressions, primarily hard substrate with ledges up to 1.2m relief.

General Substrate Type -- Videotape data indicate that the substrate at this site was entirely Algal Nodule Pavement with *Agaricia* Accumulations. A photographic example of a live bottom substrate at Station 29 is presented in Figure 5-10.

Substrate Composition -- QSA data show the substrates within live bottom patches to be composed of algal nodule pavement (0-35%), algal and rock rubble (0.2-24%), and minor amounts of sand (<1%).

Sedimentary Structures -- No sand ripple marks or bioturbation were observed at this station.

5.2.4.15 Station 30

Location -- 24°47.41'N, 83°51.15'W; 255.8km (159mi) from shore.

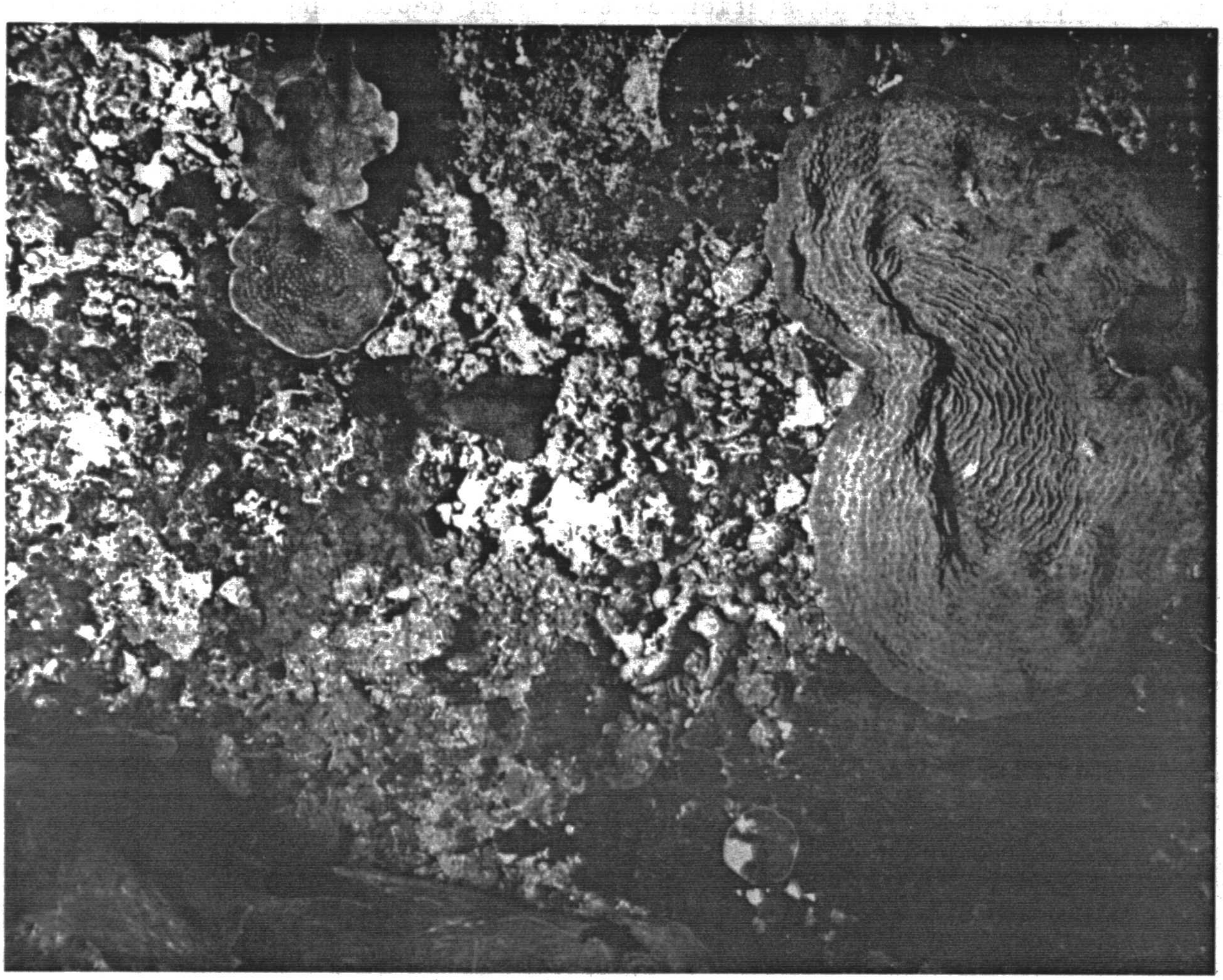

Figure 5-10. Photographic example of live bottom substrate at Station 29. Shown here is a consolidated coralline algal pavement with attached hard corals *Agaricia agaricites purpurea* (right), *A. fragilis* (upper right) and *Madracis decactis* (upper center). The algae *Anadyomene menziesii* (lower left) and *Peyssonnelia rubra* (lower right) are also present.

Depth & Relief -- Depth at station center: 76m; depth range across station: 75.5 to 77m; general slope: none indicated; physical features: occasional 0.6m rises and depressions.

General Substrate Type -- Algal Nodule Pavement with *Agaricia* Accumulations was the exclusive substrate type at this station. Unlike Station 29, however, at this station *Agaricia* was only a minor component of the substrate.

Substrate Composition -- QSA data show the surface substrate to be composed primarily of algal nodule pavement (38-42% exposed bottom). Sand only comprised 10 to 12% of the surface.

Sedimentary Structures -- None observed.

5.2.4.16 Station 32

Location -- 26°16.67'N, 84°04.08'W; 183.4km (114mi) from shore.

Depth & Relief -- Depth at station center: 137m; depth range across stations: 137 to 140m; general slope: slopes upward from the station center out in all directions; physical features: entire station appears to be a slight depression.

General Substrate Type -- Videotape data show the substrate to be a nearly even mixture of Sand Bottom/Soft Bottom (49-53%) and Thin Sand over Hard Substrate (47-51%) bottom types. Occasional rock outcrops were observed during the Winter Cruise.

Substrate Composition -- Surface substrate in live bottom patches was composed of sand (50-84%) and rubble (6-41%). Rock outcrops were noted in slides taken during the Winter Cruise. A photographic example of a live bottom substrate at Station 32 is presented in Figure 5-11.

Sedimentary Structures -- None observed.

Figure 5-11. Photographic example of live bottom substrate at Station 32. Shown here is a sand/rubble covered bottom with crinoids and several unidentified hexactinellid sponges.

5.2.4.17 Station 35

Location -- 25°44.84'N, 84°21.03'W; 238.9km (148.5mi) from shore.

Depth & Relief -- Depth at station center: 159m; depth range across station: 157.5 to 164m; general slope: downward from ESE to WNW; physical features: none significant.

General Substrate Type -- Videotape data indicate that the bottom is mostly of Thin Sand over Hard Substrate (80-99%), with lesser amounts of Sand Bottom/ Soft Bottom (0-20%) and Rock Outcrops/Hard Bottom (0-1%). A photographic example of a live bottom substrate at Station 35 is presented in Figure 5-12.

Substrate Composition -- Surface substrates within live bottom patches appear to be composed of sand (22-69%) and rubble (25-56%). Rock outcrops were also sometimes observed in slides (0-1%).

Sedimentary Structures -- None observed.

5.2.4.18 Station 36

Location -- 25°16.83'N, 83°57.35'W; 236.5km (147mi) from shore.

Depth & Relief -- Depth at station center: 127m; depth range across station: 124 to 127m; general slope: downward from east to west; physical features: none significant.

General Substrate Type -- Videotape data show the predominant substrate type to be Sand Bottom/Soft Bottom (59-76%), with lesser coverages of Thin Sand over Hard Substrate (24-40%). A few rock outcrops were observed at this station during each cruise (<1%).

Substrate Composition -- Surface substrates in live bottom patches were primarily composed of sand (73-79%) and rubble (12-13%). A photographic example of a live bottom substrate at Station 36 is presented in Figure 5-13.

Figure 5-12. Photographic example of live bottom substrate at Station 35. Shown here is a low-relief rock outcrop. Associated biota shown include numerous sea fans (Nicella sp.), antipatharian coral (Antipathes sp.), a squirrelfish (Holocentrus sp. below) and a vermilion snapper (Rhomboplites aurorubens, above).

Figure 5-13. Photographic example of live bottom substrate at Station 36. Shown here is a sand and coralline rubble bottom covered with small unidentified sponges, a crinoid, and predominantly dead algal nodules.

Sedimentary Structures -- No sand ripples were reported at this location. Only a minor amount of bioturbation (~2% occurrence) was observed, and then only during the Summer Cruise.

5.2.4.19 Station 38

Location -- 25°16.50'N, 84°14.77'W; 265.5km (165mi) from shore.

Depth & relief -- Depth at station center: 159m; depth range across station: 155.5 to 161m; general slope: downward from east to west; physical features: none significant.

General Substrate Type -- Videotape data indicate that the bottom substrate at this station was entirely Coarse Rubble (dead) with Attached Crinoids. This is the only site which had this substrate type.

Substrate Composition -- Surface substrate within live bottom patches was composed of sand (41-59%) and rubble (31-43%). A few rock outcrops were observed during the Summer Cruise (<1%). A photographic example of a live bottom substrate at Station 38 is presented in Figure 5-14.

Sedimentary Structures -- No sand ripple marks or bioturbation was observed at this location.

5.2.4.20 Station 39

Location -- 24°47.16'N, 83°55.36'W; 260.7km (162mi) from shore.

Depth & Relief -- Depth at station center: 151.5m; depth range across station: 138 to 165m; general slope: downward NE to SW; physical features: hard bottom area with rock outcrops and ledges up to 6m in height, rock outcrops more rounded than observed at other locations.

General Substrate Type -- Videotape data indicate that the bottom substrate is entirely of the Rock Outcrops/Hard Bottom type. A photographic example of a live bottom substrate at Station 39 is presented in Figure 5-15.

Figure 5-14. Photographic example of live bottom substrate at Station 38. Shown here is a hard bottom area covered with rock rubble and a thin sand layer. Numerous sea fans and antipatharians are seen in this photo, including Nicella sp., Antipathes sp. and Aphanipathes sp.

Figure 5-15. Photographic example of live bottom substrate at Station 39. Shown here is a typical rock outcrop with encrusting biota. Visible in the center is a unidentified squirrelfish (Holocentrus sp.).

Substrate Composition -- QSA data show the surface substrate to be composed of rubble (28-49%), sand (18-31%) and rock outcrops (0.1-3%).

Sedimentary Structures -- No ripple marks or bioturbation were observed at this station.

5.3 SOFT BOTTOM STATIONS

5.3.1 Methods

Surficial sediment samples, underwater television videotapes, and still camera photographs were used to characterize the bottom substrate at 19 soft bottom stations (Section 3.0). Eleven sites were sampled during both the Year One and Year Two programs; while the remaining eight stations were either sampled during Year One or Year Two (Table 3-1).

Videotapes were collected and analyzed using the same methodologies utilized for live bottom sites (Section 5.2.1). Detailed descriptions of these were presented in the Year One Final Report and are not repeated here (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983). Videotape data provided general information on the type and coverage of different substrates and sedimentary structures present at each sampling location.

Still camera slides taken at each station were used to further document substrate characteristics. While the data were collected in the same manner as at live bottom stations, analysis methodology differed substantially. Due to the scarcity of epibiota at soft bottom sites, detailed quantitative analysis of the slides was not performed; instead the slides were examined to closely view surficial sediment type and structure.

The majority of substrate information at the soft bottom sites was provided by surficial sediment samples. These were collected by box core and analyzed for grain size, carbonates, hydrocarbons, and trace metals. Detailed accounts of sampling and analysis procedures have been discussed previously (Section 3.0) and will not be repeated here. Sediment type, grain size distribution and carbonate content are discussed below. Surficial sediment hydrocarbon and trace metal data are summarized separately in Sections 5.4 and 5.5, respectively.

5.3.2 Shelfwide Distribution Patterns of Soft Bottom Substrates

5.3.2.1 Television Videotape Data

Underwater television videotapes showed the Sand Bottom/Soft Bottom substrate type (see Section 2.3 for description) to predominate at all soft bottom sites. Only three stations (12, 28 and 33) exhibited any measurable coverages by live bottom substrate. Rock Outcrops/Hard Bottom was observed over less than 1% of the total area videotaped at each of these locations.

5.3.2.2 Still Camera Photograph Data

Significant visual changes in sediment characteristics were apparent at most soft bottom stations. Figures 5-16 through 5-18 summarize the variations of sediment types at each station as recorded by still photographs during the Fall, Summer and Winter Cruises (Spring Cruise photos were not analyzed during the Year One program). Sand, sand/shell and sand/rubble substrates are recorded.

5.3.2.3 Surficial Sediment Samples

Following grain size analysis of surficial sediment samples, the percentages of sand, silt, and clay at each site were plotted on a textural triangle diagram (Shepard, 1954). Figures 5-19 through 5-22 present the plots for samples collected during the Fall, Spring, Summer, and Winter Cruises, respectively. All but two stations yielded grain sizes classified as sand. At Stations 25 and 26, located in the southeastern portion of the study area, sandy silt sediments predominated.

Distributions of mean grain sizes (i.e., averaged over all cruises) across the shelf showed a similar pattern (Figure 5-23). With the exception of Stations 25 and 26 where silt/clay was indicated, sand covered the bottom at all sites. However, sand grain sizes were variable across the shelf and ranged from very

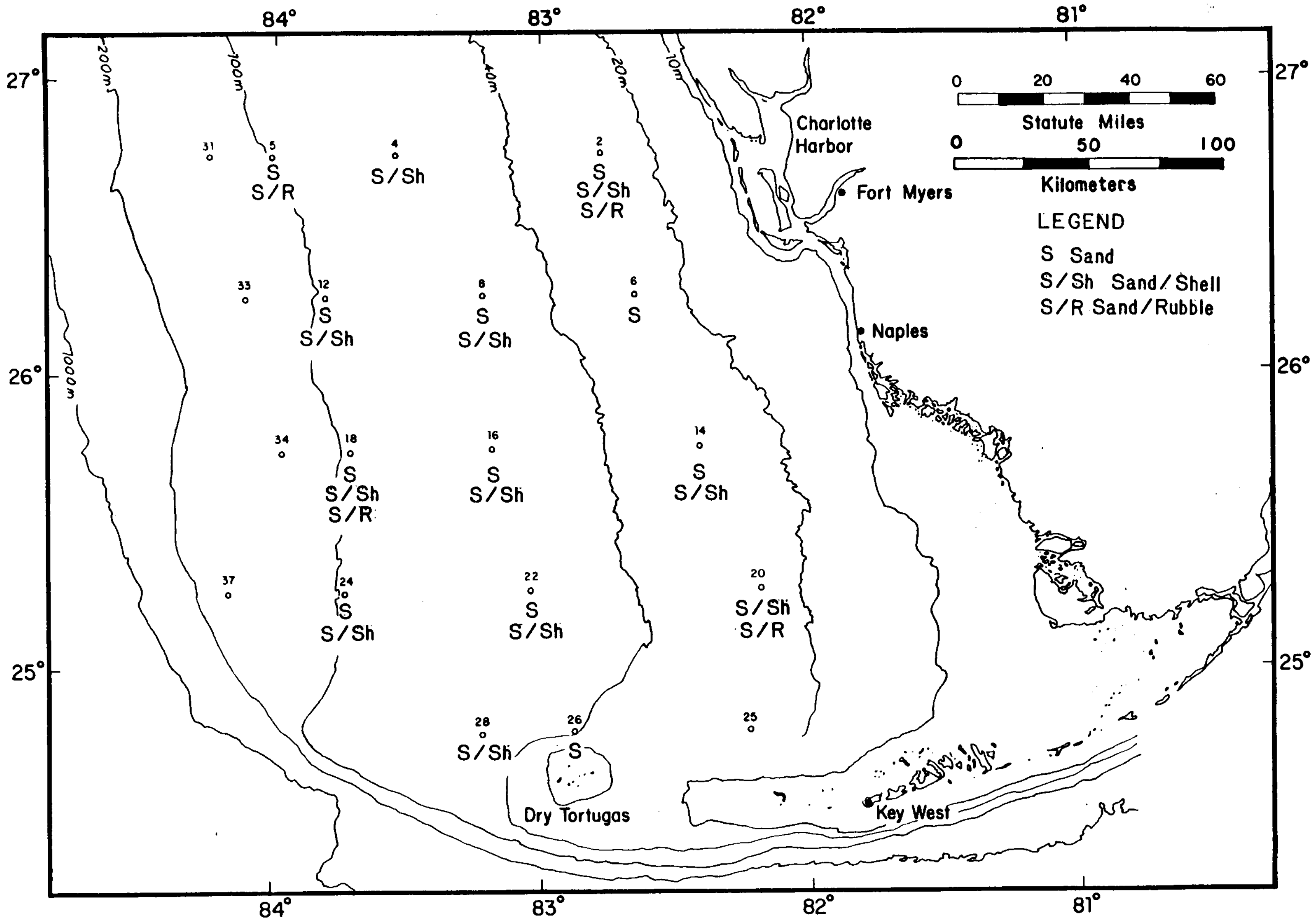

Figure 5-16. Sediment types recorded from still photographs during the Fall Cruise, 1980.

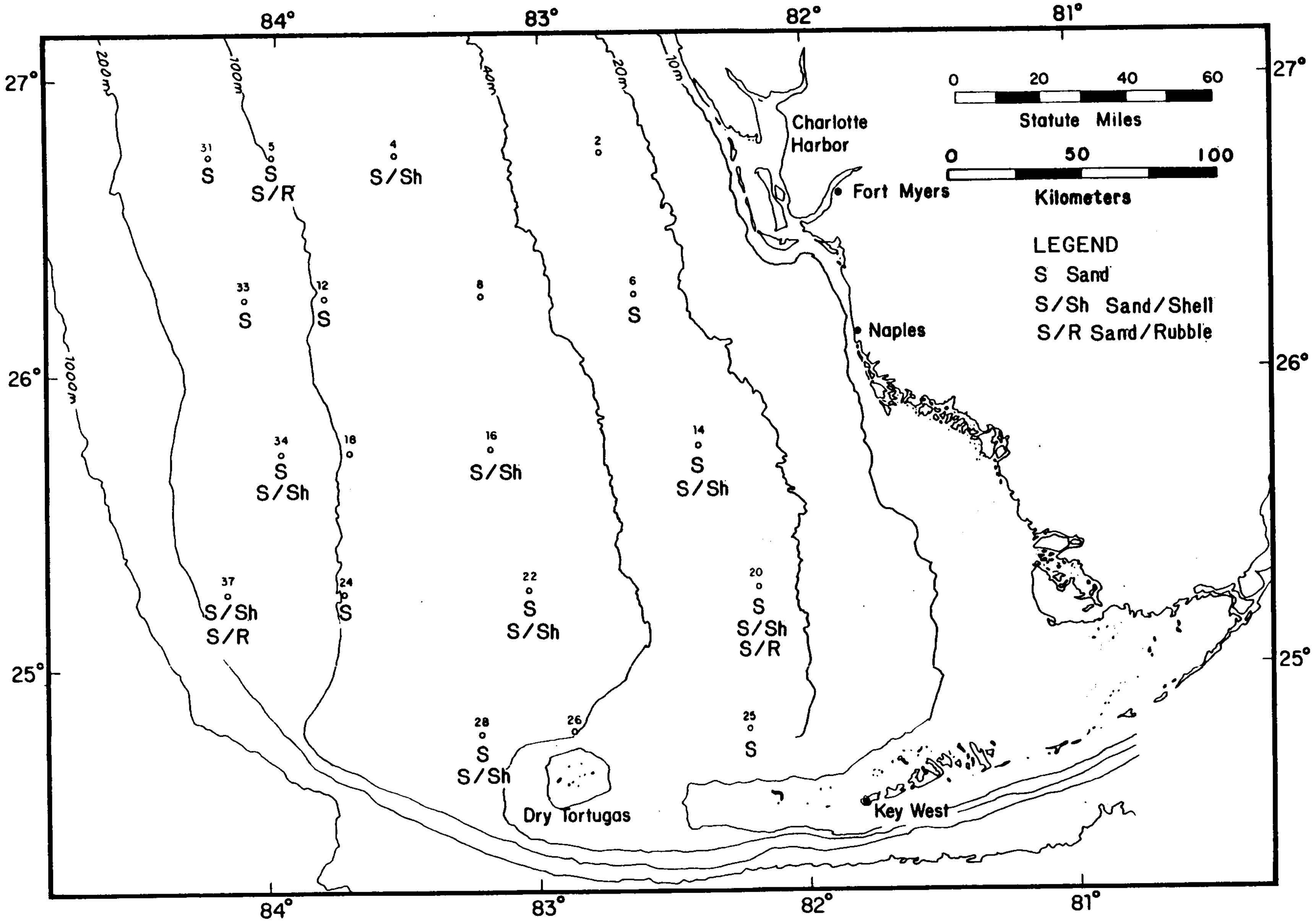

Figure 5-17. Sediment types recorded from still photographs during the Summer Cruise, 1981.

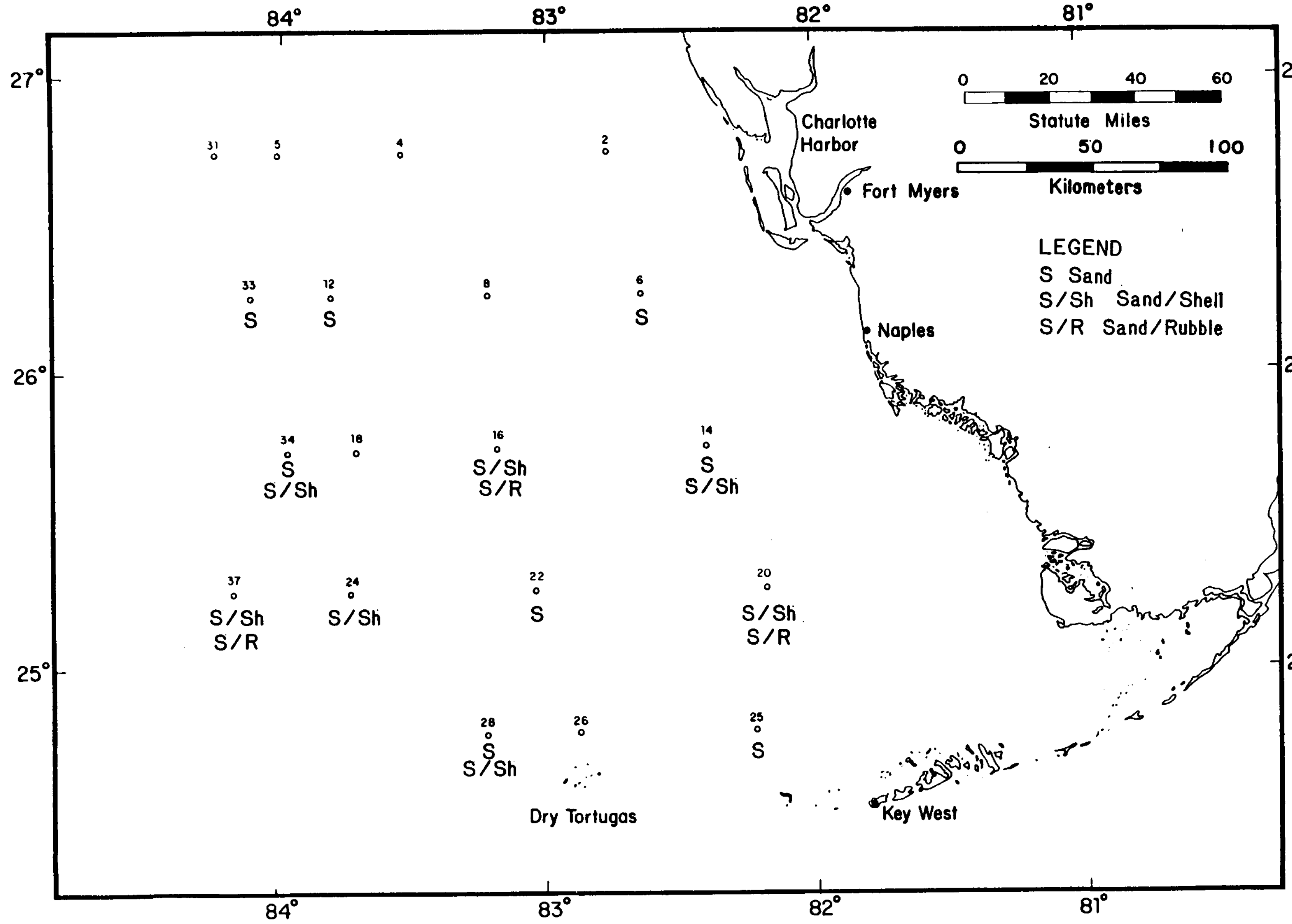

Figure 5-18. Sediment types recorded from still photographs during the Winter Cruise, 1982.

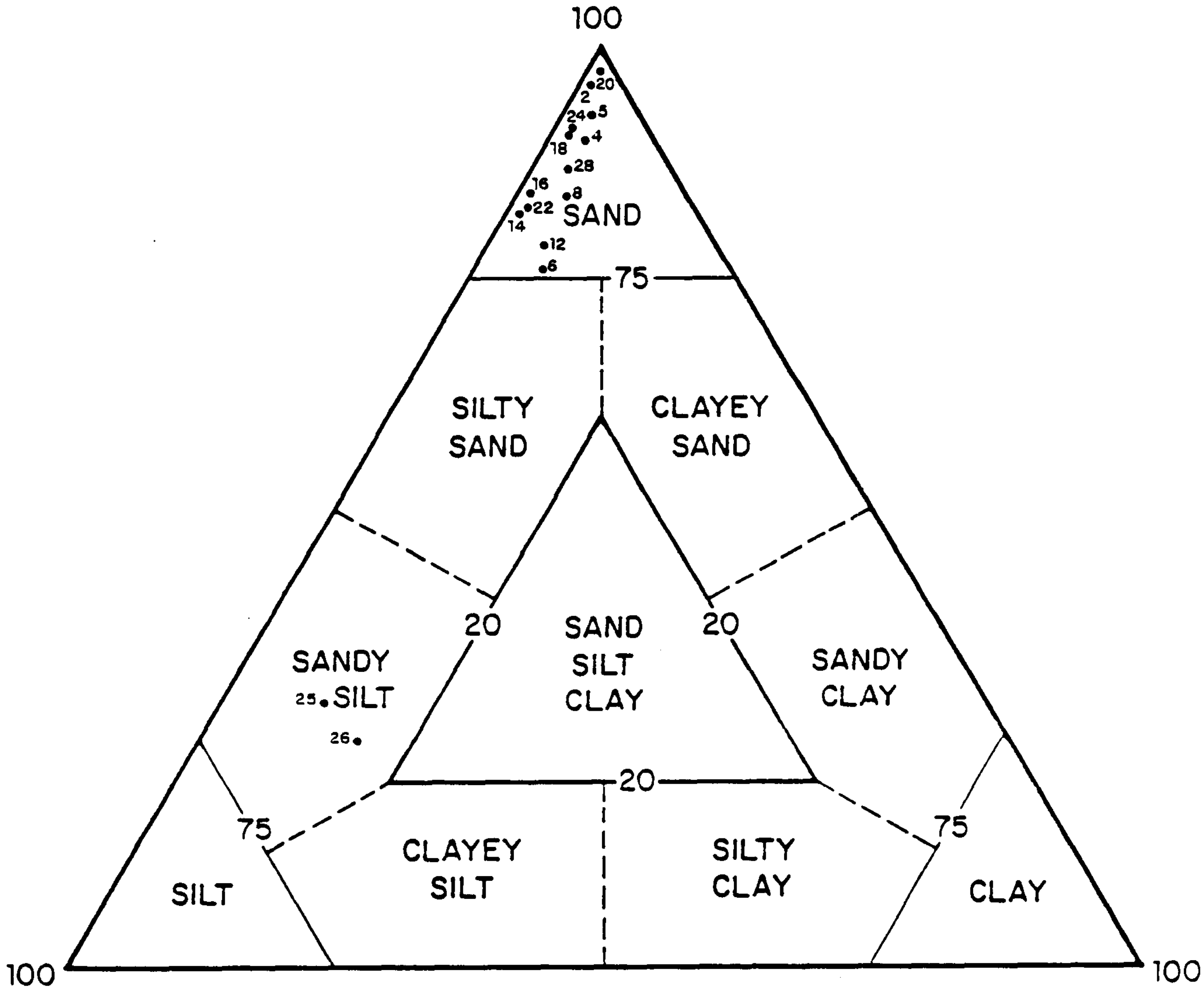

Figure 5-19. Textural triangle diagram for Fall Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpendicular distances from the respective apexes. Small numbers represent sampling stations.

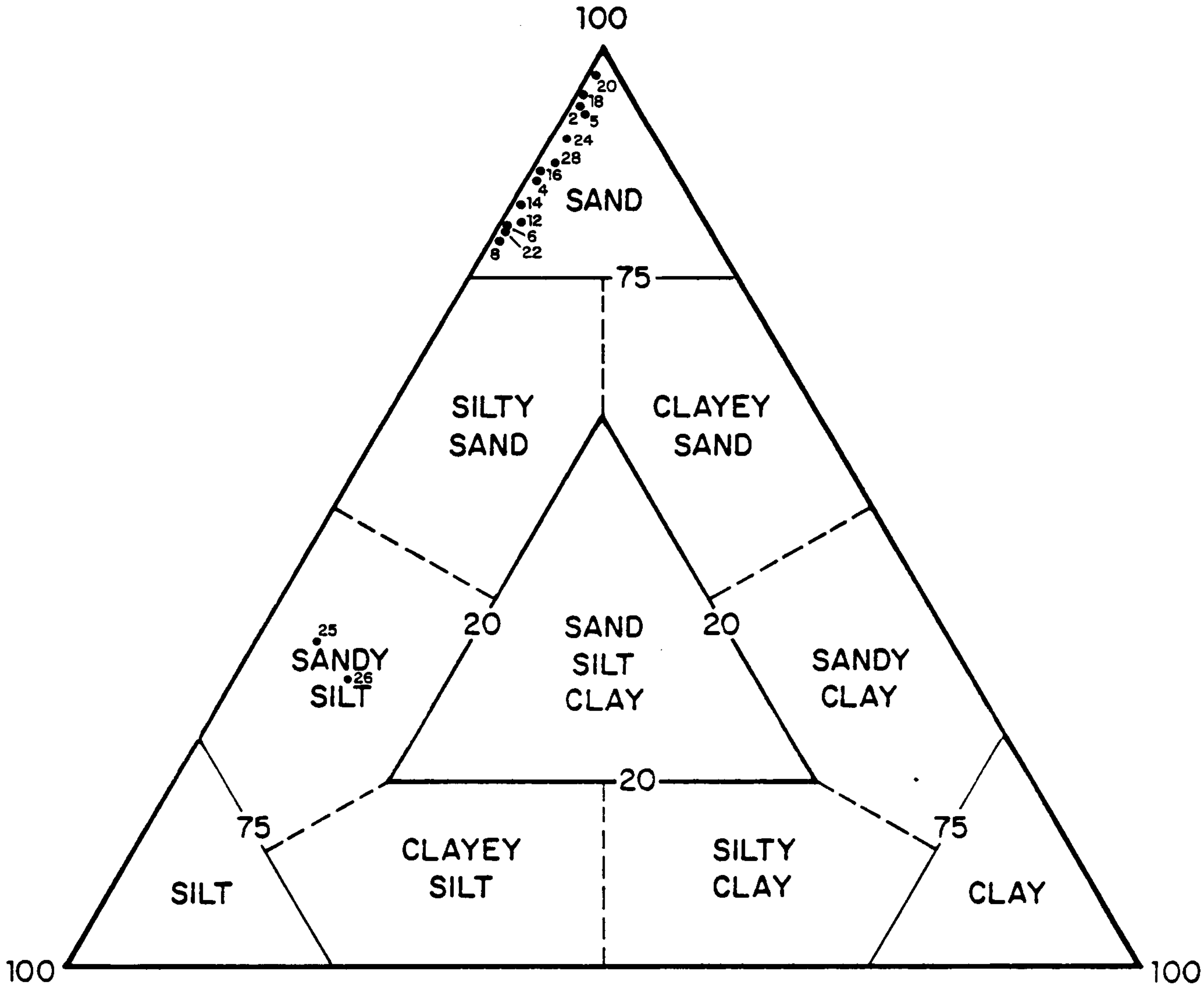

Figure 5-20. **Textural triangle diagram for Spring Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpendicular distances from the respective apexes. Small numbers represent sampling stations.**

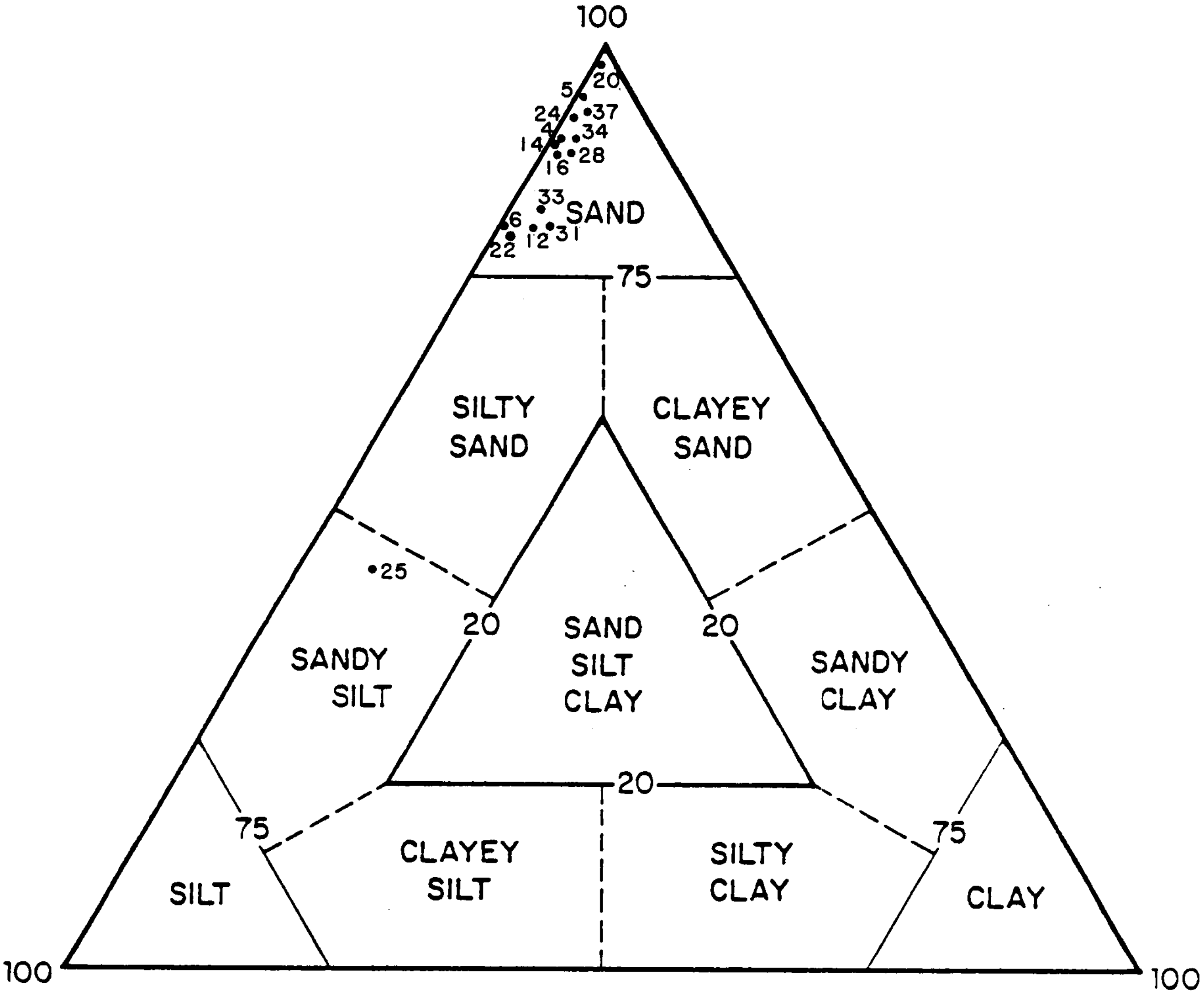

Figure 5-21. Textural triangle diagram for Summer Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpenducular distances from the respective apexes. Small numbers represent sampling stations.

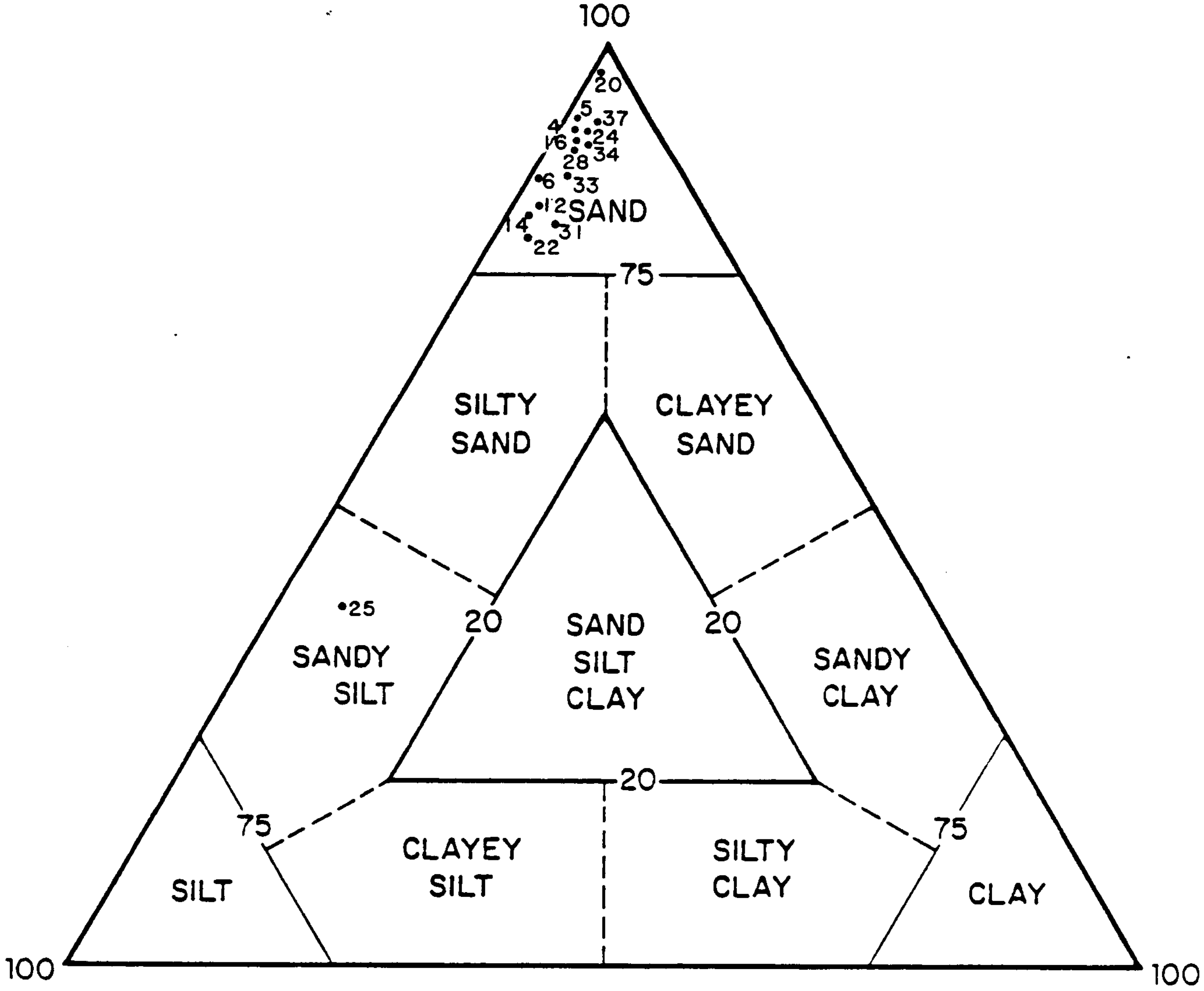

Figure 5-22. Textural diagram for Winter Cruise sediment samples. Large numbers represent reference marks on the scales for relative percent compositions of sand, silt, and clay. Scale measurements are based on perpendicular distances from the respective apexes. Small numbers represent sampling stations.

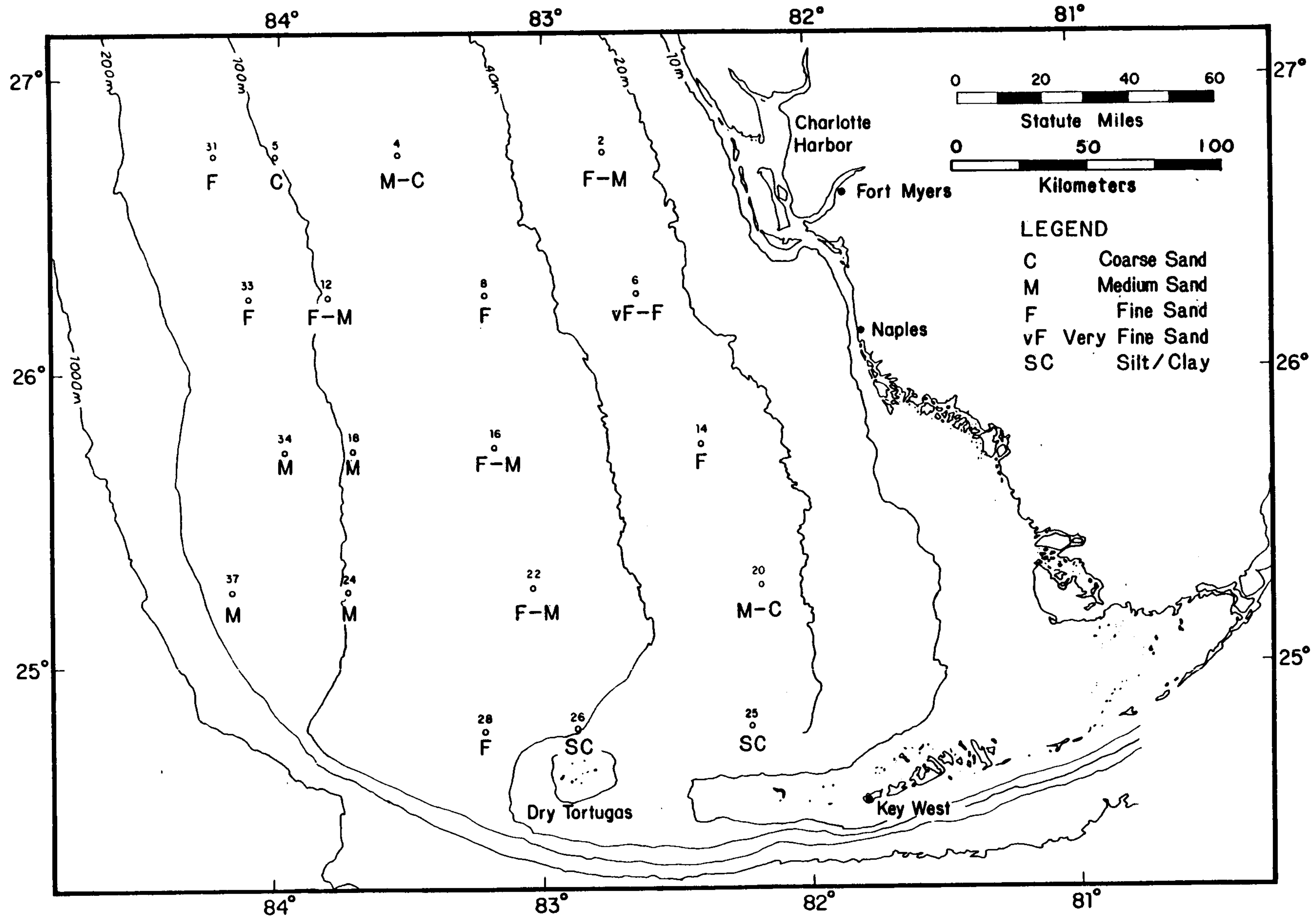

Figure 5-23. Distribution of mean sediment grain sizes across the southwest Florida shelf. (Ranges are shown where sediment variations were observed).

fine to coarse at different locations. More detailed spatial patterns were not readily discernible.

The distribution of the sediment silt/clay fractions (<63 µM grain size) is shown in Figure 5-24. Data presented are ranges of mean percentages of silt/clay in sediments collected during the Year One and Year Two programs. Results suggest a major accumulation of fine-grained sediments at Stations 25 and 26. A moderate buildup of silt/clays is also seen at Stations 6, 8, 12, 14, 16, 22, 31, and 33.

In general, the grain size analyses indicated a poor sorting of sediments throughout the southwest Florida shelf (Figure 5-25). Surficial sediments at inshore sites (Stations 2, 14, 20 and 25) appeared to be the best sorted, ranging from poor to moderately well sorted.

The distribution of percent calcium carbonate in surficial sediments at soft bottom stations is shown in Figure 5-26. Data indicated a predominant carbonate facies at sites across the shelf. Station 2 (and to some extent Station 6) showed a reduced carbonate content, indicating a greater abundance of insoluble quartz clastics. This increase in quartz clastics may reflect the proximity to the coast and/or sediment transport from the Caloosahatchee River and Charlotte Harbor.

Detailed listings of all Year One and Year Two sediment data are presented in Volume 5-Appendix A-5.

5.3.3 Seasonal Changes in Soft Bottom Substrates

5.3.3.1 Television Videotape Data

No seasonal changes in general substrate type were evident from the underwater television videotapes taken at the various soft bottom sampling stations.

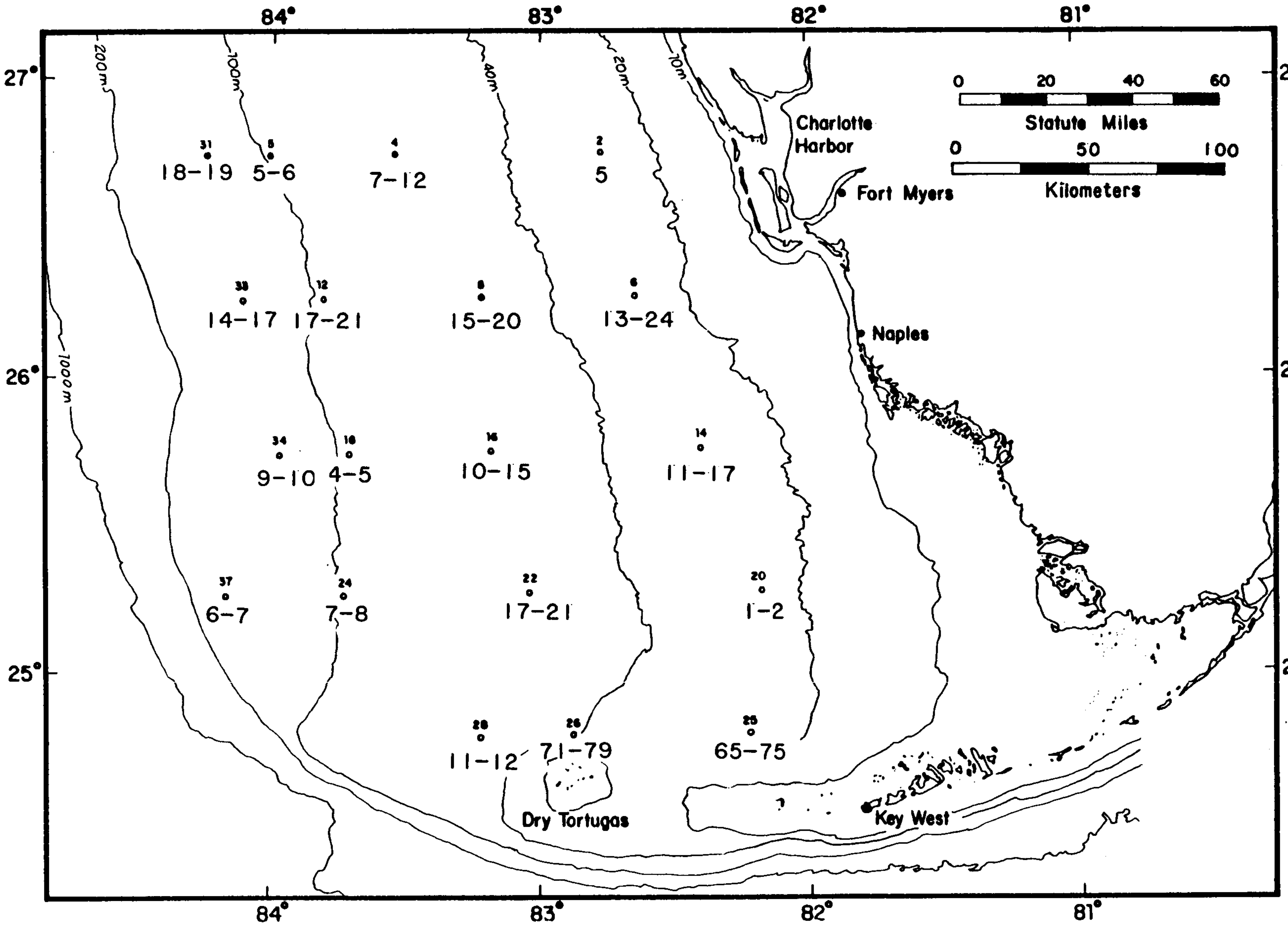

Figure 5-24. Ranges of mean percentages of silt/clay (< 63 μm) fraction in soft bottom surficial sediment samples collected during the Year One and Year Two programs.

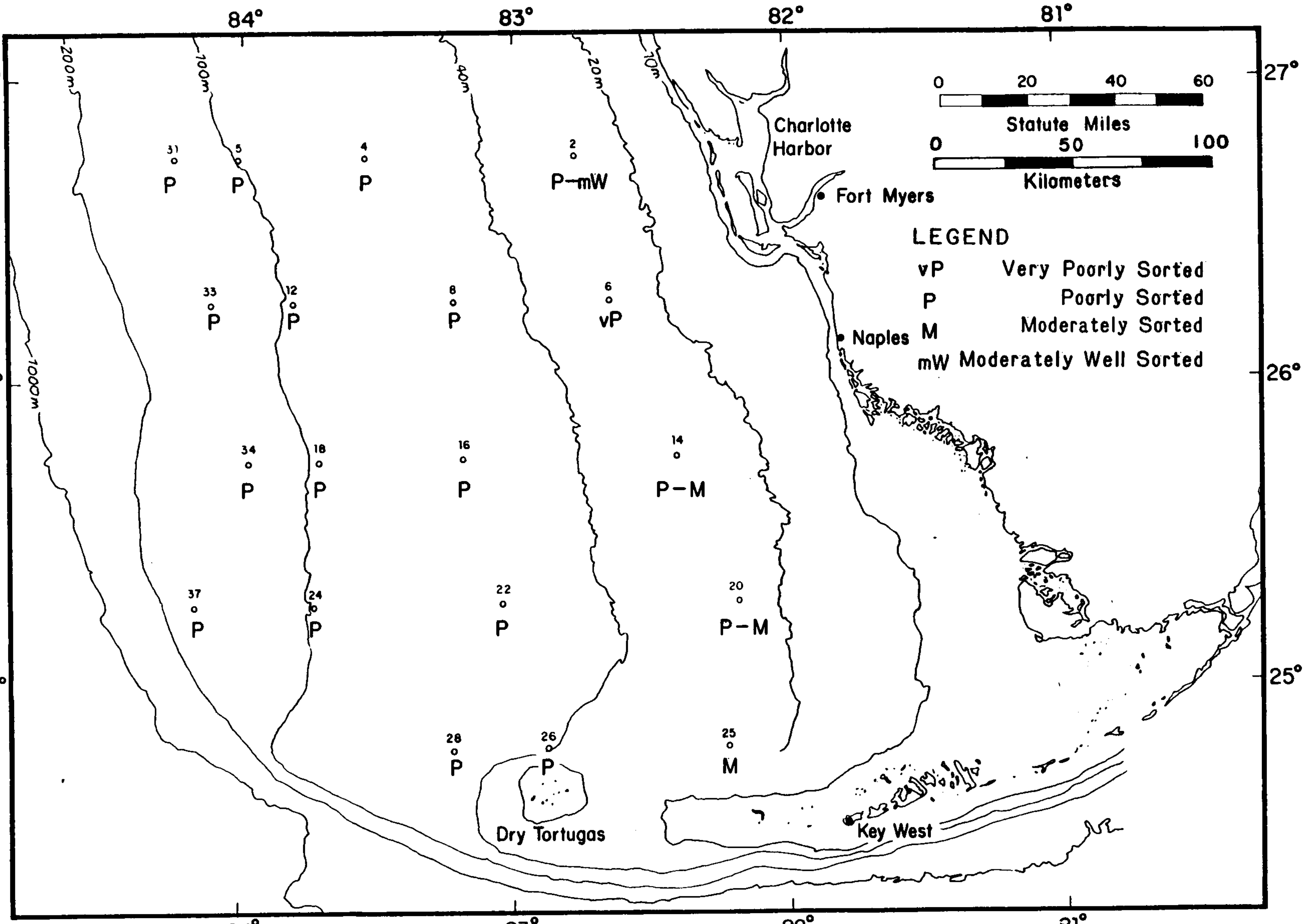

Figure 5-25. Degree of sorting (based upon inclusive graphic standard deviation) of sediments across the southwest Florida shelf. (Ranges are shown where seasonal variations were observed).

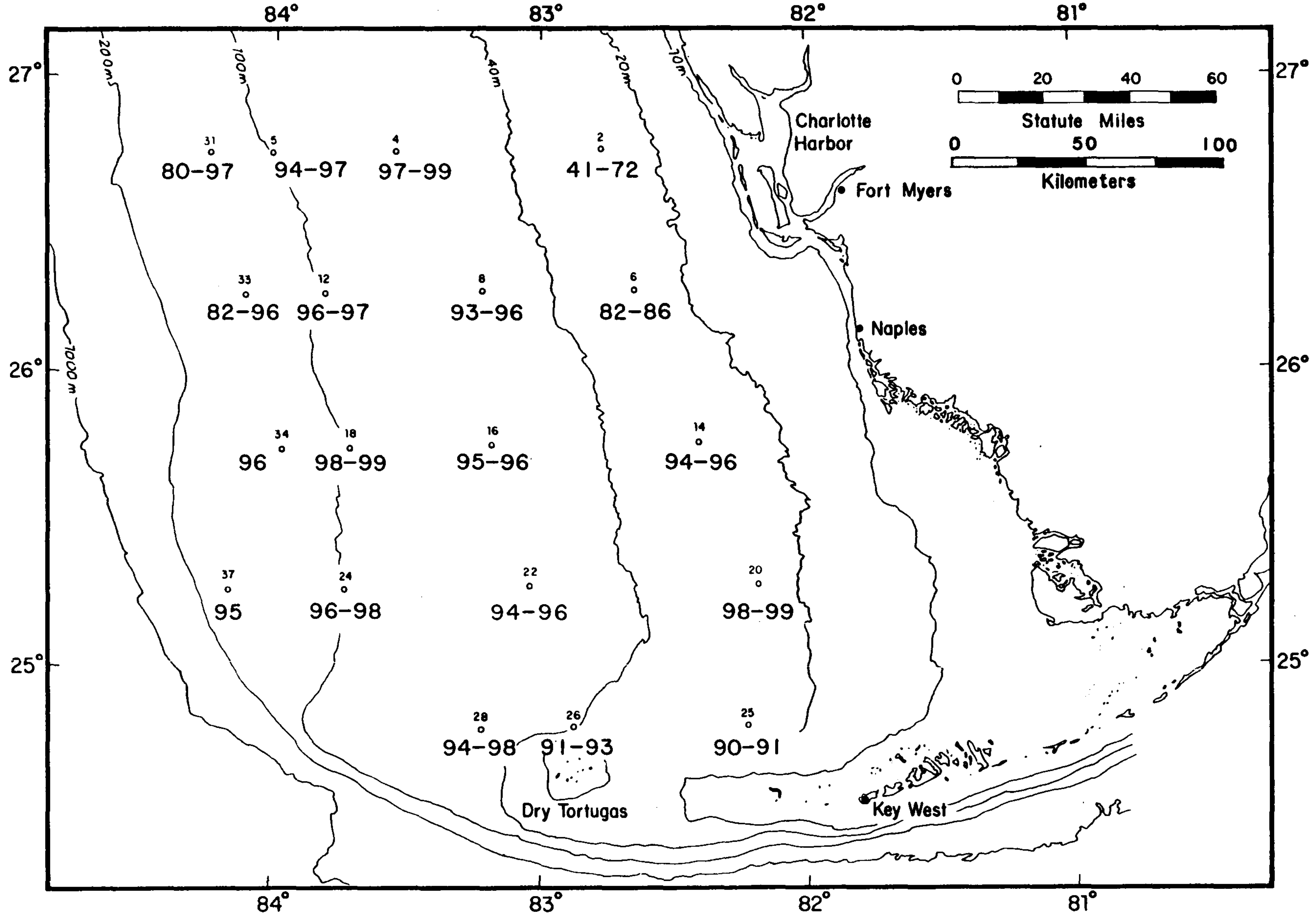

Figure 5-26. Range of mean percentages of $CaCO_3$ in southwest Florida shelf surficial sediment samples collected during Years One and Two.

5.3.3.2 Still Camera Photograph Data

Seasonal variations in visual sediment characteristics, as noted from still samera photographs, were apparent at only five locations (Stations 12, 16, 20, 22 and 24; Figures 5-16 through 5-18). These changes were slight and no general patterns were discernible from the data.

5.3.3.3 Surficial Sediment Samples

Seasonal variations among sediment grain size data were moderate and again no general trends were clearly indicated by the data. Mean grain sizes fluctuated noticeably at only seven locations (Stations 2, 4, 6, 12, 16, 20 and 22). At Stations 2, 4, 6 and 16, a shift to coarser grain sizes was observed during the Fall and/or Winter Cruises. Coarser sediments were also noted at Station 20 during the Summer and Fall Cruises, at Station 12 during the Spring Cruise, and at Station 22 during the Spring and Fall Cruises. Only very minor temporal changes were observed in the percentages of silt/clay in the sediments and no clear patterns were discernible for these. On the whole, the degree of sorting of the sediments varied only slightly with season, and then only in nearshore areas (Stations 2, 14 and 20).

Marked temporal changes were noted in the sediment carbonate content at three locations (Stations 2, 31 and 33). However, conclusions with regard to these variations are limited, since carbonates were only measured at each station during two of the seasonal cruises (see Section 3.2.2).

5.3.4 Station Descriptions

5.3.4.1 Station 2

Location -- 26°45.84'N, 82°45.18'W; 43.4km (27mi) from shore.

Depth & Relief -- Depth at station center: 25m; depth range across station: 24 to 26.5m; general slope: downward from ESE to WNW; physical features: series of ridges and troughs (NNE-SSW axis) crossing the block from ESE to WNW.

Substrate Composition -- Substrates ranged from moderately well-sorted fine sand (Spring Cruise) to poorly sorted medium sand (Fall Cruise). Grain size frequency distributions indicated near-symmetry and leptokurtic kurtosis. Carbonate composition was relatively low, as compared to other stations (41% to 72%).

Sedimentary Structures -- Sand ripple marks were observed only during the Spring Cruise. Axes were oriented in a north-south direction. Ripple heights ranged from 8 to 18cm and lengths, from 15 to 46cm. Bioturbation was moderate, with a small number of mounds and tracks evident across the station.

5.3.4.2 Station 4

Location -- 26°45.81'N, 83°32.12'W; 113.4km (70.5mi) from shore.

Depth & Relief -- Depth at station center: 55.5m; depth range across station: 55 to 56.5m; general slope: slight downward slope from east to west; physical features: none significant.

Substrate Composition -- Substrates ranged from poorly sorted, medium (Spring and Summer Cruises) to coarse (Fall and Winter Cruises) sands. Grain size frequency distributions were fine-skewed and leptokurtic. Calcium carbonate composition was very high at this station, ranging from 97 to 99%. A photographic example of a soft bottom substrate at Station 4 is presented in Figure 5-27.

Sedimentary Structures -- Sand ripple marks were observed only during the Winter Cruise, when they covered approximately 53% of the station television tow track. In size, they were slightly shorter and narrower than average (height: 5 to 8cm; length: 15 to 46cm). All axes were oriented in a north-south direction. Bioturbation was observed, with mounds, tracks and burrows evident across the station.

5.3.4.3 Station 5

Location -- 26°45.70'N, 84°00.13'W; 159.3km (99mi) from shore.

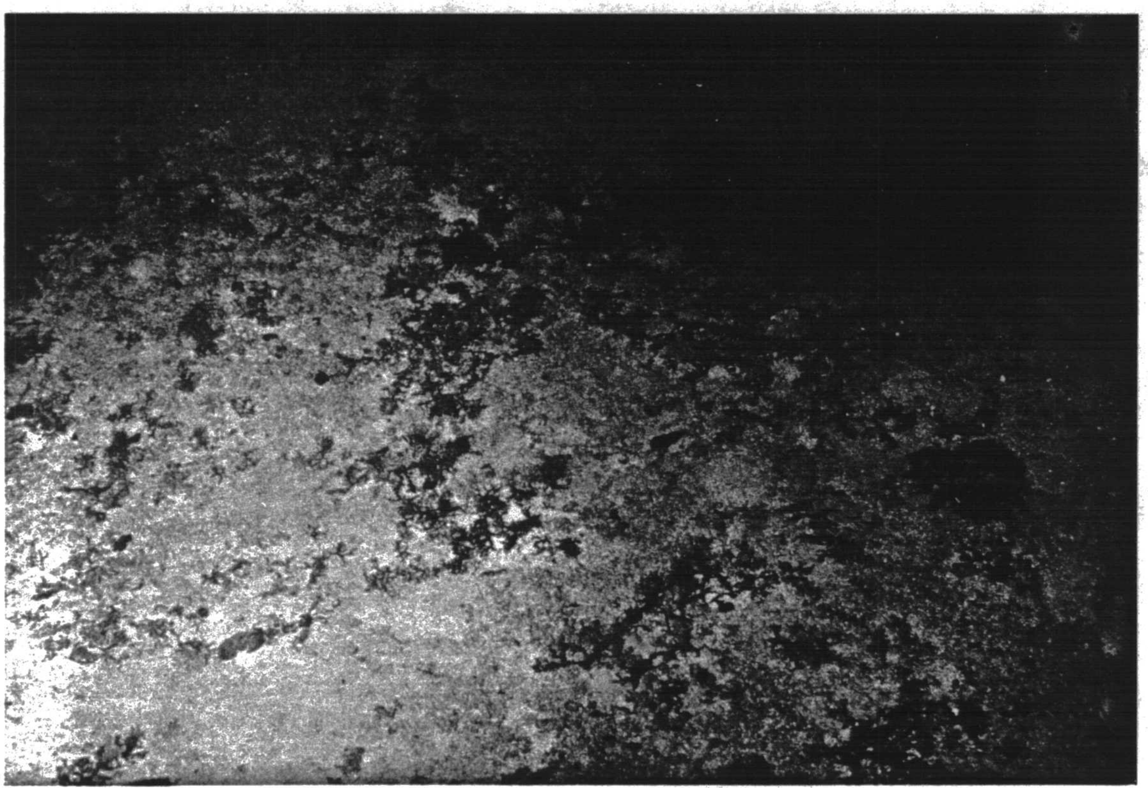

Figure 5-27. Photographic example of soft bottom substrate at Station 4. Shown here is a coarse sand bottom area with fairly dense algal cover (primarily the green alga <u>Halimeda gracilis</u>).

Depth & Relief -- Depth at station center: 90.5m; depth range across station: 88 to 92.5m; general slope: downward from NE to SW; physical features: none significant.

Substrate Composition -- Bottom substrate consisted of poorly sorted, coarse sands during each season. Grain size frequency distributions were fine-skewed and mesokurtic. Sediments consistently had a high calcium carbonate content (94-97%).

Sedimentary Structures -- No sand ripple marks were observed at this location. Bioturbation was extensive, with large numbers of mounds, burrows and tracks evident across the site.

5.3.4.4 Station 6

Location -- 26°16.79'N, 82°38.35'W; 60.3km (37.5mi) from shore.

Depth & Relief -- Depth at station center: 26.5m; depth range across station: 26 to 27.5m; general slope: downward from east to west; physical features: none significant.

Substrate Composition -- Bottom substrate consisted of poorly sorted, fine to very fine sands. Grain size frequency distributions were generally near-symmetrical and leptokurtic. Sediment carbonate content was only moderately high (83-86%).

Sedimentary Structures -- Sand ripple marks were only observed during the Spring Cruise. All axes were oriented in a north-south direction. Ripple marks were about average in size (height: 10-15cm, length: 25-36cm). Bioturbation was widespread, with mounds, burrows and tracks evident across the site.

5.3.4.5 Station 8

Location -- 26°16.72'N, 83°12.81'W; 111.0km (69mi) from shore.

Depth & relief -- Depth at station center: 48.5m; depth range across station: 48.5 to 50m; general slope: downward from east to west; physical features: none significant.

Substrate Composition -- Bottom substrate was composed of poorly sorted, fine sands. Grain size frequency distributions ranged from fine-skewed to near-symmetrical; all were mesokurtic. Sediments always exhibited high carbonate content (93-96%) at Station 8.

Sedimentary Structures -- Sand ripple marks were only observed during the spring. In size, they were about average (height: 10 to 18cm, length: 25 to 36cm). All axes were oriented in a north-south direction. Bioturbation appeared to be extensive, with large numbers of burrows and tracks evident across the station.

5.3.4.6 Station 12

Location -- 26°16.72'N, 83°47.67'W; 161.7km (100mi) from shore.

Depth & Relief -- Depth at station center: 90m; depth range across station: 88 to 91.5m; general slope: downward from ENE to WSW; physical features: none significant.

Substrate Composition -- Poorly sorted, fine sands predominated throughout most of the year. During spring, however, poorly sorted medium sands were noted. Occasional rock outcrops were also observed during the Winter Cruise, when they composed approximately 1% of the bottom area viewed at Station 12. Grain size frequency distributions ranged from fine- to coarse-skewed. All were mesokurtic. Calcium carbonate content in the sediments was found to be consistently high (96-97%).

Sedimentary Structures -- No sand ripple marks were observed at Station 12. Bioturbation was extensive, with abundant mounds, burrows, and tracks evident across the station.

5.3.4.7 Station 14

Location -- 25°46.01'N, 82°23.82'W; 72.4km (45mi) from shore.

Depth & Relief -- Depth at station center: 26m; depth range across station: 25.5 to 27m; general slope: none indicated; physical features: minor bathymetric variation with occasional 0.3 to 0.9m depressions.

Substrate Composition -- Bottom substrates at this site consisted of generally poorly sorted, fine sands. Grain size frequency distributions were near-symmetrical in spring, summer and fall, but strongly fine-skewed in winter. All were leptokurtic. Sediment carbonate content was always high (94-96%).

Sedimentary Structures -- Sand ripple marks were only observed during spring. In size, they were larger than average (height: 15 to 20cm, length: 38 to 46cm). All ripple marks were oriented with their axes in a north-south direction. Bioturbation was extensive, with mounds, burrows and tracks generally spread across the station block.

5.3.4.8 Station 16

Location -- 25°45.70'N, 83°11.07'W; 144.8km (90mi) from shore.

Depth & Relief -- Depth at station center: 54.5m; depth range across station: 54 to 55m; general slope: none indicated; physical features: minor bathymetric variation with occasional 0.3 to 0.6m depressions.

Substrate Composition -- Bottom substrates consisted of poorly sorted medium (fall and winter) to fine (spring and summer) sands. Grain size frequency distribution characteristics varied widely (skewness: fine- to strong coarse-skewed, kurtosis: meso- to leptokurtic). Calcium carbonate content of Station 16 sediments was consistently high (95-96%). A photographic example of a soft bottom substrate at Station 16 is presented in Figure 5-28.

Sedimentary Structures -- No sand ripple marks were observed at Station 16. Bioturbation was widespread, with mounds, burrows and tracks evident.

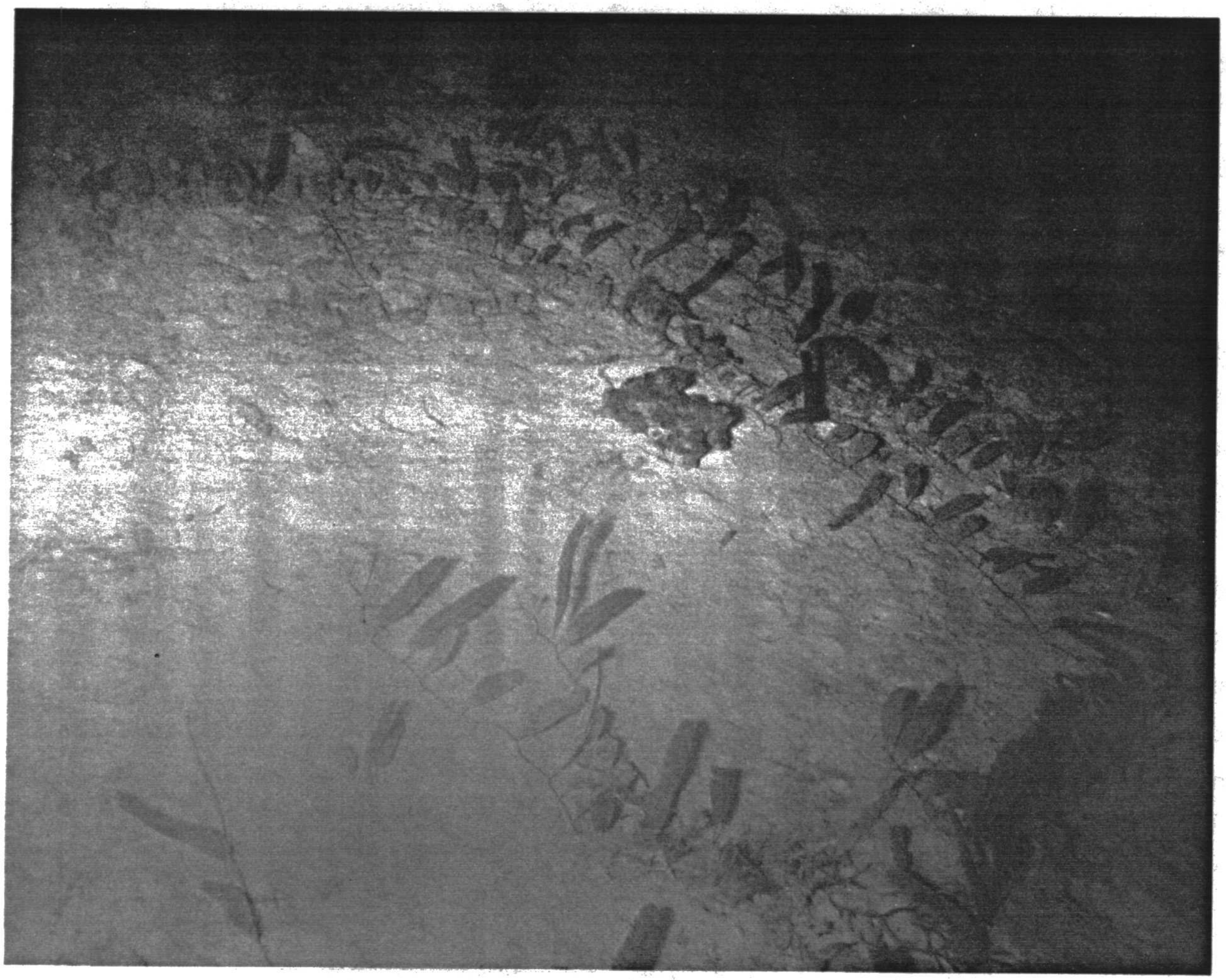

Figure 5-28. Photographic example of soft bottom substrate at Station 16. Shown here is a sand bottom area covered with the green alga Caulerpa sp. The sponge Geodia sp. is located in the center of the photo.

5.3.4.9 Station 18

Location -- 25°45.37'N, 83°42.22'W; 183.4km (114mi) from shore.

Depth & Relief -- Depth at station center: 87m; depth range across station: 84 to 90m; general slope: downward from east to west; physical features: gradual downward slope from east to west in the northern portion of the station block, becoming more abrupt in the southern areas (maximum slopes occur along the southeast border of the station).

Substrate Composition -- Bottom substrates were composed entirely of poorly sorted, medium sand. Grain size frequency distributions were fine- or coarse-skewed, but mesokurtic. Calcium carbonate content in the sediment ranged from 98 to 99%.

Sedimentary Structures -- No ripple marks were observed at this location. Bioturbation was widespread across the station block and mounds, burrows and tracks were numerous.

5.3.4.10 Station 20

Location -- 25°17.34'N, 82°09.73'W; 38.6km (24mi) from shore.

Depth & Relief -- Depth at station center: 22.5m; depth range across station: 22 to 23m; general slope: no slope indicated; physical features: minor bathymetric variation with occasional 0.3 to 0.6m depressions.

Substrate Composition -- In general, substrates were composed of moderately sorted, medium to coarse sands. Grain size frequency distributions were near-symmetrical and mesokurtic. Carbonate content of the sediments was always high (98-99%). A photographic example of a soft bottom substrate at Station 20 is presented in Figure 5-29.

Sedimentary Structures -- Ripple marks were observed during all seasons except fall. As always, axes were oriented in a north-south direction. Ripple mark heights ranged from 5 to 30cm and lengths, from 30 to 61cm. Bioturbation was moderate at this station. Mounds, burrows and tracks were observed.

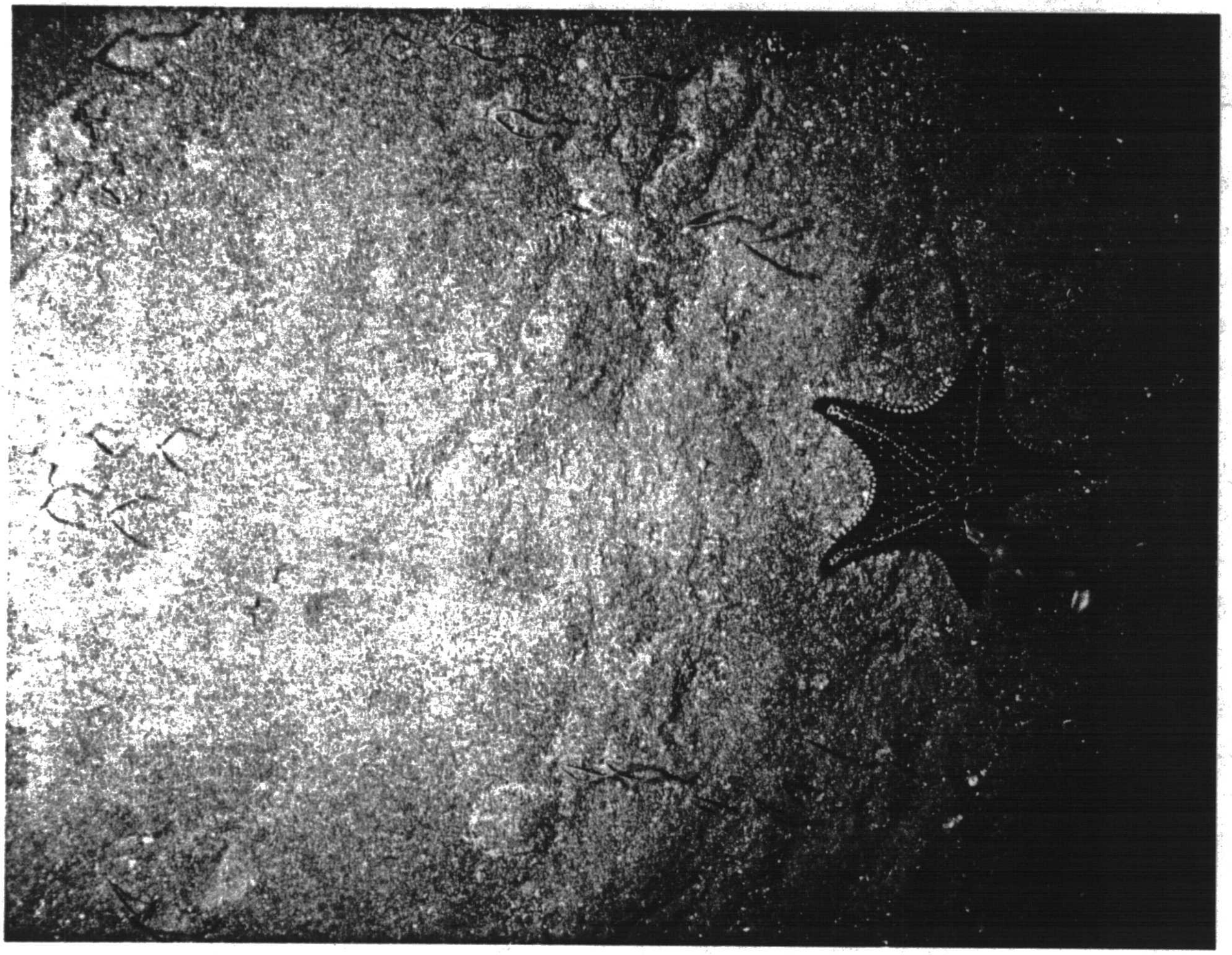

Figure 5-29. Photographic example of soft bottom substrate at Station 20. Shown here is a coarse sand bottom with the asteroid <u>Oreaster reticulatus</u>.

5.3.4.11 Station 22

Location -- 25°17.18'N, 83°02.07'W; 154.5km (96mi) from shore.

Depth & Relief -- Depth at station center: 52.5m; depth range across station: 52 to 53.5m; general slope: none indicated; physical features: none significant.

Substrate Composition -- Bottom substrates were composed of poorly sorted medium (fall and spring) to fine (summer and winter) sand. Grain size distributions varied from fine- to strongly coarse-skewed; all were mesokurtic. Surficial sediment carbonate content was consistently high (94-96%).

Sedimentary Structures -- Sand ripple marks were only observed during the Spring Cruise. They were of average heights (8 to 12cm), but greater than average wavelengths (51 to 61cm). Axes were all oriented in a north-south direction. Evidence of bioturbation was extensive. Mounds, burrows and tracks were noted throughout the site.

5.3.4.12 Station 24

Location -- 25°16.90'N, 83°43.18'W; 217.2km (135mi) from shore.

Depth & Relief -- Depth at station center: 88.5m; depth range across station: 87 to 90m; general slope: downward from east to west; physical features: none significant.

Substrate Composition -- Bottom substrates were composed of poorly sorted, medium sand. Grain size frequency distributions were generally near-symmetrical and leptokurtic (except during winter, when they were strongly coarse-skewed). Carbonate content in the sediments was high, ranging from 96 to 98%.

Sedimentary Structures -- No ripple marks were observed on the bottom at Station 24. Bioturbation was widespread and mounds, tracks and burrows were abundant across the station block.

5.3.4.13 Station 25

Location -- 24°47.95'N, 82°13.26'W; 118.3km (73.5mi) from shore.

Depth & Relief -- Depth at station center: 23.5m; depth range across station: 23 to 24m; general slope: downward from south to north; physical features: none significant.

Substrate Composition -- Bottom substrates consisted of moderately sorted, silt/clays. Grain size frequency distributions were strongly coarse-skewed and leptokurtic. Carbonate content was always high (90-91%) in sediments at Station 25.

Sedimentary Structures -- No ripple marks were observed on the sea floor at this station. Bioturbation in the form of mounds, burrows and tracks was evident across the station.

5.3.4.14 Station 26

Location -- 24°47.82'N, 82°52.07'W; 176.2km (109.5mi) from shore.

Depth & Relief -- Depth at station center: 38.5m; depth range across station: 37.5 to 38.5m; general slope: slight, downward from east to west; physical features: none significant.

Substrate Composition -- Station substrates were characterized by poorly sorted, silt/clay sediments. Grain size frequency distributions were strongly coarse-skewed and very leptokurtic. High calcium carbonate content was indicated for the sediments (91 to 93%).

Sedimentary Structures -- No ripple marks were observed on the bottom at this location. Evidence of bioturbation was widespread; mounds, burrows and tracks were noted throughout the station block.

5.3.4.15 Station 28

Location -- 24°47.11'N, 83°13.08'W; 200.3km (124.5mi) from shore.

Depth & Relief -- Depth at station center: 58.5m; depth range across station: 58.5 to 59m; general slope: none indicated; physical features: none significant.

Substrate Composition -- Bottom substrates at Station 28 were composed of poorly to very poorly sorted fine sands. Occasional rock outcrops (<1% total bottom area viewed) were also observed during the Summer Cruise. Grain size frequency distributions were near-symmetrical and leptokurtic. Sediment carbonate content was consistently high (94 to 98%). A photographic example of a soft bottom substrate at Station 28 is presented in Figure 5-30.

Sedimentary Structures -- No ripple marks were observed on the bottom at this location. Bioturbation appeared to be widespread. Mounds, burrows and tracks were noted throughout the station block.

5.3.4.16 Station 31

Location -- 26°45.61'N, 84°14.81'W; 183.4km (114mi) from shore.

Depth & Relief -- Depth at station center: 141.5m; depth range across station: 139 to 143m; general slope: downward from ENE to WSW; physical features: none significant.

Substrate Composition -- Poorly sorted, fine sands were the characteristic bottom substrate at this station. Grain size frequency distributions were coarse-skewed and meso- or leptokurtic. Calcium carbonate content in the sediment ranged from 80 to 97%. A photographic example of a soft bottom substrate at Station 31 is presented in Figure 5-31.

Figure 5-30. Photographic example of soft bottom substrate at Station 28. Shown here is a fine sand bottom covered with the green alga *Caulerpa* (?) *taxifolia*.

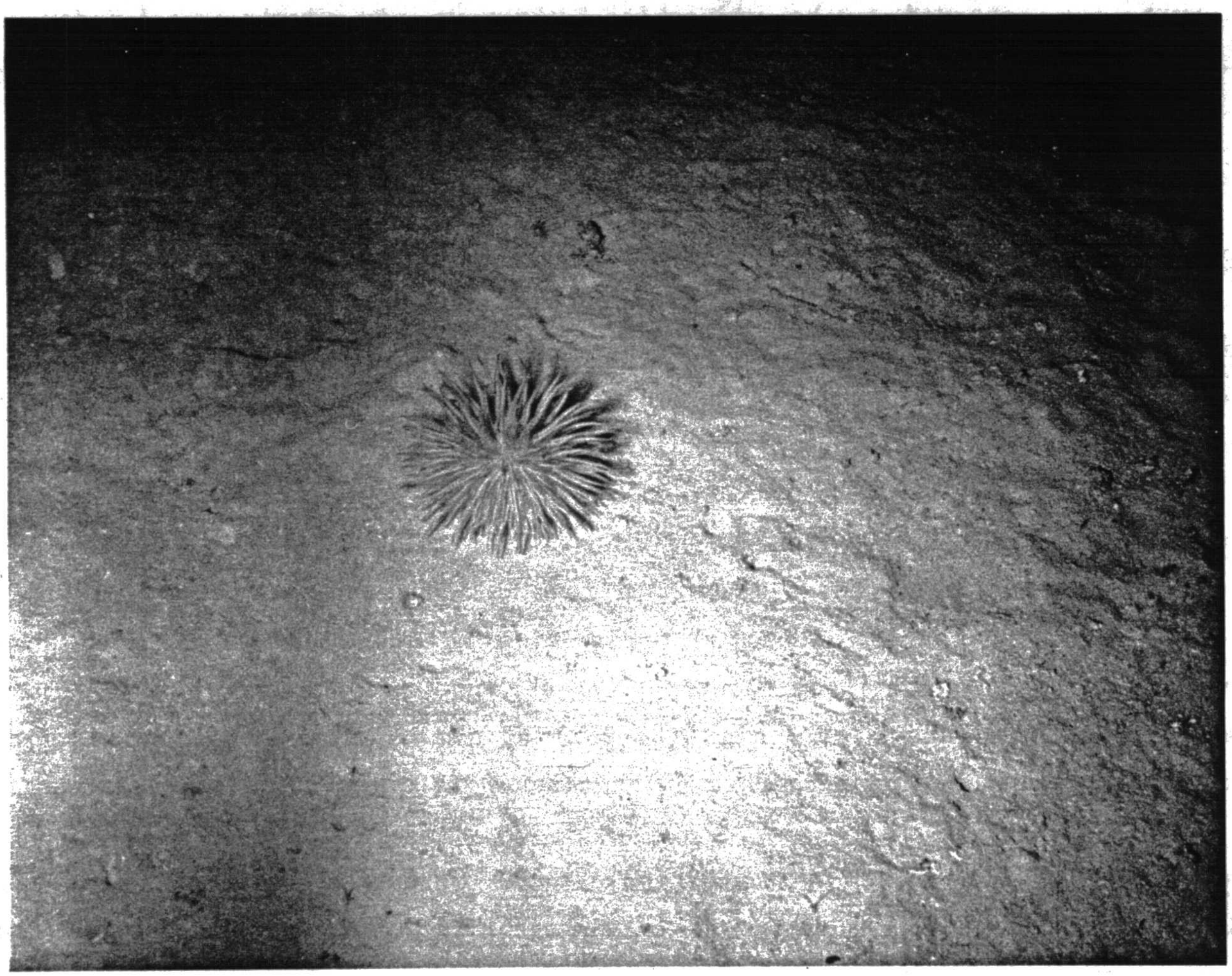

Figure 5-31. Photographic example of soft bottom substrate at Station 31. Shown here is a fine sand bottom. An unidentified anemone appears in the center of the photo.

Sedimentary Structures -- No sand ripple marks were observed at Station 31. Bioturbation appeared to be widespread. Burrows and tracks were numerous throughout the station block.

5.3.4.17 Station 33

Location -- 26°16.53'N, 84°05.97'W; 188.3km (117mi) from shore.

Depth & Relief -- Depth at station center: 146m; depth range across station: 146 to 149m; general slope: downward from east to west; physical features: none significant.

Substrate Composition -- Sea floor substrates were composed primarily of poorly sorted, fine sand sediments. A few rock outcrops were also recorded (<1% total bottom area viewed). Grain size frequency distributions were mesokurtic and ranged from coarse- to strongly coarse-skewed. Sediment carbonate content was always high (82-96%) at this station. A photographic example of a soft bottom substrate at Station 33 is presented in Figure 5-32.

Sedimentary Structures -- No sand ripple marks were observed at Station 33. Bioturbation was evident over most of the station, with mounds, burrows and tracks common throughout.

5.3.4.18 Station 34

Location -- 25°45.31'N, 83°57.63'W; 207.6km (129mi) from shore.

Depth & Relief -- Depth at station center: 135m; depth range across station: 133 to 135m; general slope: downward from the NW to the center of the station and then back upward to the SE; physical features: none significant.

Substrate Composition -- Bottom substrates at Station 34 were composed of poorly sorted, medium sand sediments. Grain size frequency distributions were strongly fine-skewed and mesokurtic during summer and strongly coarse-skewed and leptokurtic during winter. Calcium carbonate levels were high (96%). A

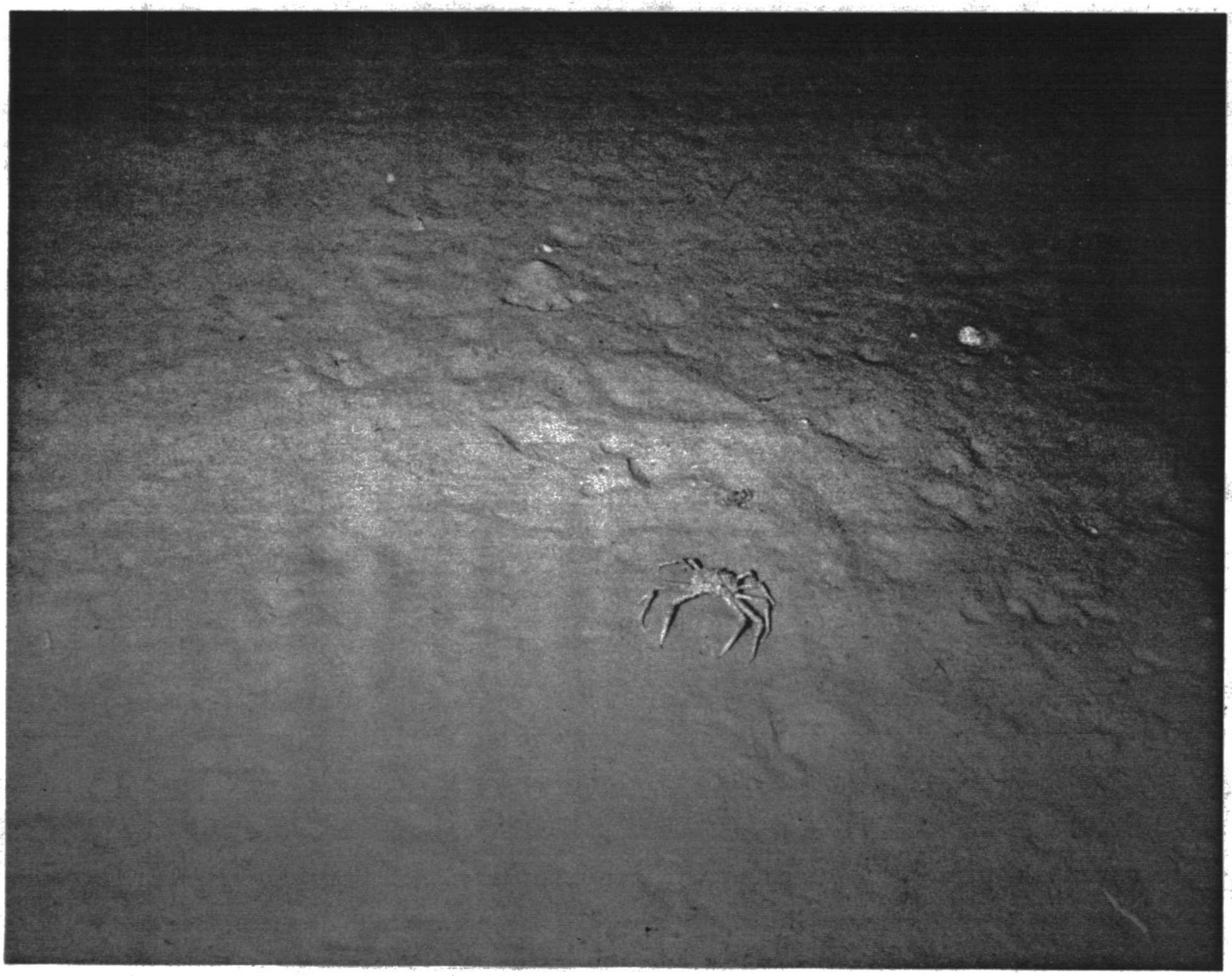

Figure 5-32. Photographic example of soft bottom substrate at Station 33. Shown here is a soft, bioturbated bottom. A large spider crab (? *Stenocionops sp.*) appears in the center of the photo.

photographic example of a soft bottom substrate at Station 34 is presented in Figure 5-33.

Sedimentary Structures -- No sand ripple marks were evident at this site. Mounds, burrows and tracks were characteristic of the sea floor surface at Station 34, indicating widespread bioturbation.

5.3.4.19 Station 37

Location -- 25°16.64'N, 84°09.39'W; 258.2km (160.5mi) from shore.

Depth & Relief -- Depth at station center: 148m; depth range across station: 147 to 149m; general slope: downward from east to west; physical features: none significant.

Substrate Composition -- Substrates at this site were poorly sorted, medium sand sediments. Grain size distributions were fine-skewed and mesokurtic. Carbonate content in the sediments was high (95%).

Sedimentary Structures -- No sand ripple marks were recorded at this location. Bioturbation was indicated by the presence of mounds, burrows and tracks across the station block.

5.4 SURFICIAL SEDIMENT HYDROCARBONS

5.4.1 Introduction

Hydrocarbon analyses were performed on surficial sediment samples collected during the Year One and Year Two study programs. Year One samples were collected from 15 soft bottom sites on the southwest Florida shelf, ranging in depth from approximately 20 to 100m: Year Two samples were taken from four sites at depths greater than 100m (Figure 5-34). This section presents a brief summary and synthesis of the results of analyses from both studies.

Figure 5-33. Photographic example of soft bottom substrate at Station 34. Shown here is a typical shallow sand depression in a soft bottom area. An unidentified fish hovers within the depression.

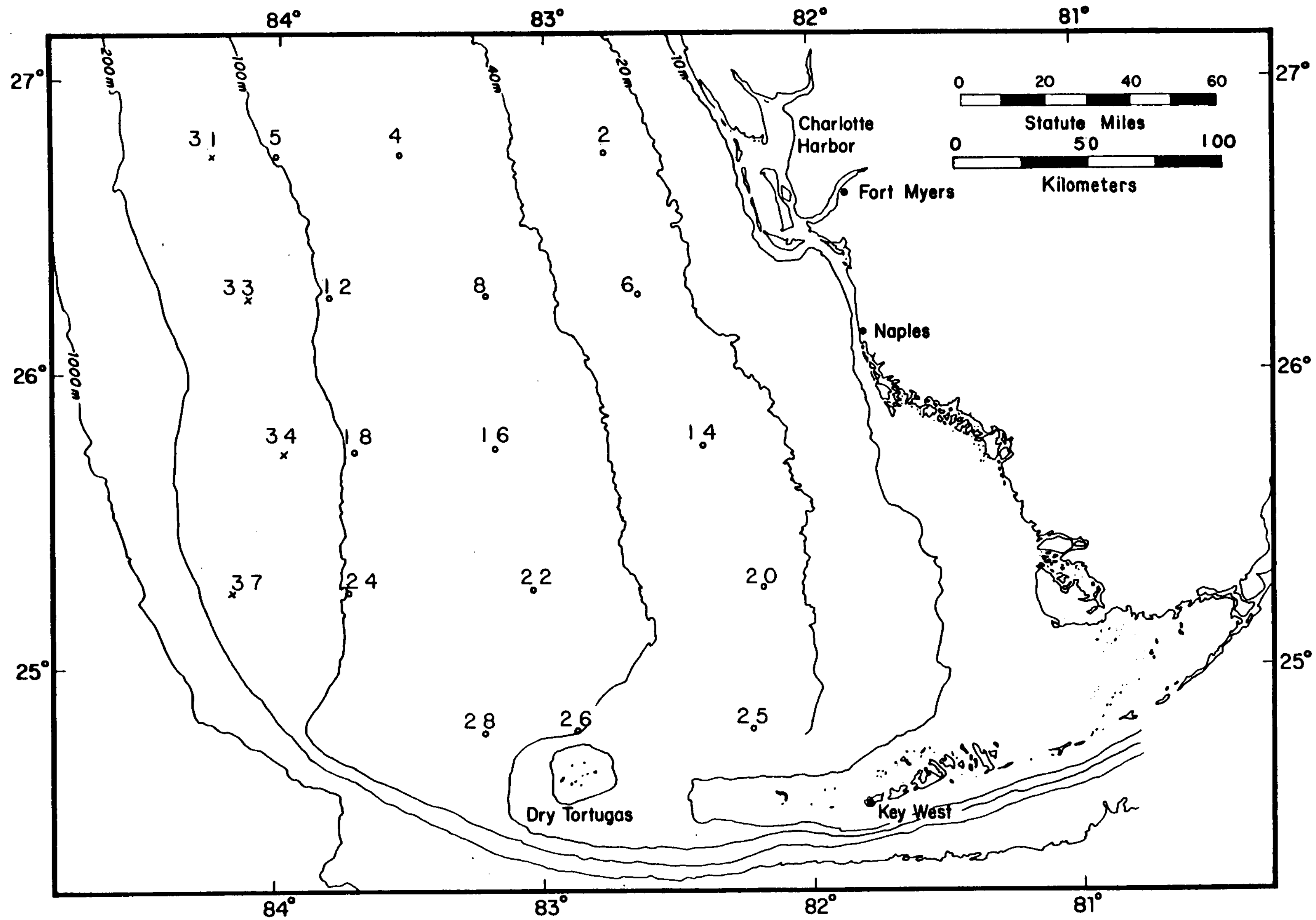

Figure 5-34. Surficial Sampling Sediment Sites: Hydrocarbon Analysis Year One (•), Year Two (X).

5.4.2 Methods

Year One samples were analyzed by Dr. R. Pierce at the Florida Institute of Technology (Melbourne, Florida). Detailed methodologies for all Year One field and laboratory procedures were presented in the Southwest Florida Shelf Ecosystems Study Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983).

Year Two samples were analyzed by Dr. P. Boehm of ERCO (Cambridge, Massachusetts). Collection procedures followed those utilized in the Year One program. Analytical procedures differed from Year One however, following instead those described by Brown et al. (1980).

Because different procedures were used for hydrocarbon extractions, and no interlaboratory calibration was performed between the two laboratories, some variability between the Year One and Year Two results can be expected. However, gas chromatographic analyses of both years' samples were performed with similar glass capillary columns using flame ionization (GC-FID) and mass spectrometric (GC-MS) detector systems. The use of standard key parameters for hydrocarbon characterization by both laboratories also affords a common means for comparison and data synthesis.

5.4.3 Results

Results of the Year One and Year Two hydrocarbon characterizations are presented in Table 5-4. The data reflect very low background hydrocarbon concentrations throughout the area. The key parameters used were obtained from GC analyses of surficial sediment samples. Comparing total aliphatic and aromatic hydrocarbon content of Year One deep water stations (5, 12, 18, and 24) with Year Two stations (31, 33, 34, and 37) shows a trend toward lower hydrocarbon concentrations in deeper areas, with no significant difference between the two data sets (Year One deep stations, mean ± std. dev. = 0.38 ± 0.24 μg/g dry weight sediment; Year Two stations, mean ± std. dev. = 0.25 ± 0.13 μg/g). Sediments collected nearshore during Year One (Stations 2, 6, 14, 20, and 25) contained significantly more total hydrocarbon material (mean ± std. dev. = 0.87 ± 0.26 μg/g). This may be due to enhanced productivity in

Table 5-4. Total hydrocarbon content and classification for surficial sediments of the southwest Florida shelf, Year One and Year Two.

	Total Hydrocarbons[1] (μg/g)		Individual Hydrocarbons[2] (μg/g)							
Station Number	Aliphatic	Aromatic/ Olefinic	1700	Pristane	1800	Phytane	2085	2900	CPI	Hydrocarbon[3] Classification
Year One[4]										
2	.60	.50	.03	.03	.02	.01	.10	.02	---	BM
4	.07	.03	<.01	<.01	<.01	<.01	.04	<.01	---	BM
5	.19	.06	.01	.01	.01	<.01	.01	<.01	2.3	BMT
6	.60	.24	.02	.06	<.01	<.01	.13	.07	1.1	BM
8	.50	.19	<.01	.01	<.01	<.01	.12	.06	---	BM
12	.05	.28	<.01	.01	<.01	<.01	.02	.03	---	BMTP
14	.45	.22	.02	.05	.02	.01	.10	.10	---	BM
16	.32	.32	<.01	.01	<.01	<.01	.10	.01	---	BM
18	.12	.06	<.01	<.01	<.01	<.01	.01	<.01	---	BM
20	.35	.14	.03	.03	<.01	<.01	.06	.02	---	BM
22	.38	.18	.01	.01	<.01	<.01	.16	.05	---	BM
24	.15	.08	<.01	<.01	<.01	<.01	.01	.01	---	BMT
25	.78	.43	<.01	<.01	<.01	<.01	.44	.11	3.5	BMT
26	.27	.20	.01	.02	<.01	.01	.10	.05	---	BMT
28	.42	.19	.02	.02	<.01	.01	.14	.06	---	BMT
Year Two										
31	.21	.26	.005	.0005	.002	.0004	.022	.010	2.6	BMT
33	.13	.15	.003	<.001	.001	<.001	.016	.007	3.1	BMT
34	.08	.10	.003	<.001	.001	<.001	.055	.004	2.7	BMT
37	.08	.06	.001	.0004	.001	<.001	.006	.005	2.6	BMT

[1] Total hydrocarbons (GC) were measured by summing the concentrations of all resolved peaks in each column fraction and are reported as micrograms per gram dry weight.

[2] Individual hydrocarbons were measured by the internal standard method of quantification. Numbers refer to retention indices of peaks on an SE30 column.

[3] Hydrocarbon classification: BM = Biogenic Marine; BMT = Biogenic Marine and Terrigenous; BMTP = Biogenic Marine, Terrigenous, and Petrogenic.

[4] Average of duplicate and triplicate analyses.

shallower waters and input from the very productive estuaries along the southwest Florida coastal zone. The remaining six mid-depth Year One sample sites exhibited intermediate hydrocarbon content (mean ± std. dev. = 0.53 ± 0.22 µg/g).

Although total hydrocarbon mass is important, additional parameters must be used to characterize the type of hydrocarbons present. These parameters (Table 5-4) help to distinguish hydrocarbons as predominantly biogenic, petrogenic, or a mixture of both. All of the Year Two samples contained hydrocarbons representative of marine benthic and terrestrial biota, with no evidence for petrogenic input. Year One deep water stations exhibited the same characteristics except for Station 12, which did contain some petroleum-like hydrocarbons.

An interesting aspect of these results is that the mid-depth stations from Year One did not contain as much terrigenous biogenic material (predominance of odd n-alkanes from C_{25} through C_{31}) as did the Year One and Year Two deep water stations. This could be a result of Gulf Loop Current transport of water and suspended particulate matter from the northern Gulf of Mexico (Mississippi River discharge) southward, along the western edge of the Southwest Florida Shelf. Most of the nearshore stations from Year One also contained primarily marine biogenic hydrocarbons with no overriding evidence of terrestrial or petrogenic input.

The hydrocarbon data obtained during this study are consistent with more recent analyses performed by Pierce et al. (1982) on sediments collected just offshore (~ 3m depth) from Captiva and Gasparilla Islands. The hydrocarbon content of these samples ranged from 1.26 to 1.37 µg/g with mixed marine and terrestrial biogenic composition. Previous sediment hydrocarbon analyses performed in the southwest Florida shelf area also reported similar hydrocarbon concentrations and characterizations (Alexander et al. 1977; Boehm, 1978).

Due to the use of improved data processing instrumentation, the Year Two study was able to quantify individual hydrocarbon concentrations an order of magnitude lower than was possible for the Year One study. Despite this, similar trends were observed from both data sets.

5.4.4 Conclusions

Results from the Year One and Year Two southwest Florida shelf surficial sediment hydrocarbon studies are consistent with each other and with other hydrocarbon studies in the area. Predominant hydrocarbons were characterized as marine biogenic, with some terrigenous input evident in the samples collected farthest offshore (100 to 200m water depths). None of the Year Two samples exhibited petrogenic hydrocarbons and only Station 12 from Year One contained any indicators of petroleum-like hydrocarbons.

The results clearly indicate that surficial sediments within the southwest Florida shelf study areas contain only very low levels of primarily marine biogenic hydrocarbons. These results provide essential information for assessing the impact of future oil drilling, production, and transport operations within the region. Any significant hydrocarbon input should be readily apparent and easily detectable.

5.5 SURFICIAL SEDIMENT TRACE METALS

5.5.1 Introduction

As part of the Year One study program, concentration levels of nine trace metals were investigated in surficial sediments of the southwest Florida shelf. Fifteen soft bottom stations were sampled during the Fall Cruise, 1980 (Table 3-1). The results of this study are summarized below. For a detailed presentation of methodology, results, and discussion, the reader should refer to the Year One Final Report (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983).

5.5.2 Summary of Findings

Analyses for Barium (Ba), Cadmium (Cd), Copper (Cu), Iron (Fe), Nickle (Ni), Lead (Pb), Vanadium (V), and Zinc (Zn) showed both low levels and uniform distributions across the southwest Florida shelf (Tables 5-5 and 5-6). The observed levels were directly related to the sediment mineralogy, which showed carbonate levels in excess of 90% at 13 of 15 sampled stations. Except for

Table 5-5. 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)	

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

Table 5-6. 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)

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[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].

copper and zinc, no significant correlations between trace metal concentrations and grain size were evident. Copper tended to be associated with medium clays and finer sediments; zinc, with very fine clay sediments.

Data obtained during the Year One investigation were compatible with previous data from the Florida shelf (Table 5-7). Trace metal levels were somewhat lower than those reported for typical carbonate rocks and only about 5% of those reported for Mississippi River suspended matter.

The generally low concentration levels of trace metals in the carbonate rich sediments of the southwest Florida shelf are indicative of "pristine" conditions. Any significant trace metal input from oil and gas development activities would be readily detected should it occur.

MARCH 3, 1849

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.